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- Comprised of the General and Technical Program Chairs plus Robert Buckley,
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Welcome to CIC16

On behalf of the Society for Imaging Science and Technology and the Society for Information Display, we are delighted to welcome you to the 16th IS&T/SID Color Imaging Conference. We hope first-time attendees and familiar faces find these six days of color imaging in Portland technically stimulating and a rewarding opportunity to network with industrial and academic colleagues from around the world. We have a full week planned—including many new and special events—and we invite you to take advantage of all the opportunities this meeting provides. An overview can be found on page 2.

The week begins with a comprehensive set of short courses that spans two days (Monday and Tuesday) and features the ever-popular Hunt Course. Short course chairs Fumio Nakaya and Stephen Westland have assembled a range of informative classes taught by experts in their fields, including many new offerings and four classes now offered on Monday. Monday also sees the return of ICC DevCon’08, which offers an opportunity to learn about the use and implementation of v4 ICC profiles.

2008 marks an expansion of the ever-popular Interactive Session. Interactive program chairs Francisco Imai and Peter Morovic created not one, but two, interactive sessions with corresponding spotlight previews. Interactive sessions provide direct access to authors, their results, and a rich environment for peer discussion. We hope that you enjoy the additional technical content and greater participation that the new schedule allows.

Please plan to join us on Friday afternoon and evening for The Hunt Symposium. Organized by Michael Kriss, the symposium will honor the varied and extensive contributions Robert W. G. Hunt has made to the field of color imaging. The symposium and Hunt reception are included in the registration fee; attendance at the banquet requires a separate ticket. The week concludes Saturday with “The Black and White Meeting,” an ISCC Special Topics hosted by IS&T and SID.

We look forward to seeing you at the ICC DevCon, Welcome, Conference, and Hunt receptions, as well as the special Thursday evening microbrew outing we’ve planned to enjoy the fine local Portland beer scene. Please take advantage of these gatherings to meet new people, give us feedback about the conference, and engage in detailed discussions of the day’s technical presentations.

Finally sincere thanks and appreciation to the entire conference committee, reviewers, session chairs, AV Chair Vien Cheung, and the dexterous and professional staff at IS&T. We hope you have a wonderful and productive time at the 16th Color Imaging Conference.

—Jim Larimer & Nathan Moroney, General Co-Chairs
Wednesday, November 12
Registration open 7:00 am to 4:00 pm
• Keynote: Large Display Research Overview
• IS&T Honors and Awards Presentations
• Technical Sessions
• Displaying Color
• Capturing Color
• Calculating Color
• Interactive Spotlight and Paper Session I
• Evening Microbrew Tour

Friday, November 14
Registration open 8:00 am to 3:30 pm
• Keynote: The Push-Me Pull-You of Color
• Cactus Award Presentation
• Technical Sessions
• Perceiving Color
• Achromatic Color
• The Hunt Symposium
• Hunt Reception
• Hunt Banquet*

Saturday, November 15
Registration open 8:00 to 10:00 am
• ISCC: The Black and White Meeting*

* separate ticket required

Venue: The Benson Hotel, Portland, Oregon
www.bensonhotel.com
309 SW Broadway, Portland, OR 97205 • 1-800/663-1144

CIC16 will take place at the lovely Benson Hotel in downtown Portland. Room rates for singles/doubles are $137/night, including Internet access in guest rooms. The hotel is 12 miles (21 minutes by car) from Portland International Airport (PDX) and is accessible by taxi ($35), shuttle ($14), or Max Train ($2.30, trains stop four blocks from the hotel).

Portland offers many exciting opportunities for cultural and dining experiences, including day trips to world famous wineries, the stunning Oregon Coast, and the beautiful Columbia Gorge Valley. To discover more about Portland, visit www.travelportland.com/visitors/.

There are numerous non-stop flights to Portland from many cities, including Atlanta (Delta); Boise (SW/Horizon); Boston (Alaska); Chicago (American/United); Frankfurt (Lufthansa); LA (Alaska/Delta/Horizon/United); Minneapolis (NW); Newark (Continental); San Francisco (Alaska/Horizon/United); and Tokyo (NW); visit www.flypdx.com/NonStop/Search.aspx for a complete list.

Technical Program

Wednesday November 12, 2008

8:30 – 9:30 AM
KEYNOTE SESSION
Session Chairs: James Larimer, ImageWetrix LLC, and Nathan Moroney, Hewlett-Packard Laboratories

Welcome
Physiologically-based Color Matching Functions, Andrew Stockman, University College London (UK)

9:30 – 10:30 AM
SEEING COLOR
Session Chair: R. Victor Klassen, Xerox Corporation

A Probabilistic Model of the Categorical Association Between Colors, Jason Chuang,¹ Maureen Stone,² and Pat Hanrahan³;¹Stanford University (USA) and ²StoneSoup Consulting (Canada)
Report on the Development of Improved Human Observer Functions, Christopher J. Edge, Eastman Kodak Co. (USA)
Retinal HDR Images: The Effects of Intraocular Glare and Object Size, John J. McCann, McCann Imaging (USA), and A. Rizzi, University of Milano (Italy)
CIETC1-71 Perspective: An Overview on Accurately Computing the Tristimulus Values (Wednesday Interactive), Changjun Li, University of Leeds (UK)
Report on the Optimization of Human Observer Functions and CIELAB (Thursday Interactive), Christopher J. Edge, Eastman Kodak Company (USA)
Minimizing Color Variation (Thursday Interactive), Gary Demos, Image Essence LLC (USA)

11:10 AM – 12:30 PM
EXTREME COLOR
Session Chair: Philipp Urban, Rochester Institute of Technology
Conjoint Analysis of Parametrized Gamut Mapping Algorithm, Zolta Baranczuk-Turska,

PLEASE NOTE
This year there will be two Interactive Paper Sessions. These Sessions will contain presentations from all the top areas, in no particular grouping order. To facilitate the location of papers related to the same subject, we have listed all papers by topic under the corresponding Session. Interactive papers are indicated and noted as to whether they will be given on Wednesday or Thursday. The exact order of the Spotlight Presentations will be handed out onsite.
Thursday November 13, 2008

8:30 – 9:30 AM
KEYNOTE SESSION
Session Chairs: James Larimer, ImageVetics LLC, and Nathan Moroney, Hewlett-Packard Laboratories

Large Display Research Overview,
Mary Czerwinski, Microsoft Research (USA)

Presentation of IS&T Honors and Awards

9:30 – 10:30 AM
DISPLAYING COLOR
Session Chair: Joshua Pines, Technicolor

Mapping Standard Image Content to Wide-Gamut Displays, Stacey E. Casella, Rodney L. Heckaman, and Mark D. Fairchild, Rochester Institute of Technology (USA); and Masato Sakurai, Sony Corporation (Japan)

Perceived Color Breakup In Spatio-Temporal Color Displays with Two and Three Color Fields, E. H. A. Langendijk, J. Cernini, and O. Belik, Philips Research Laboratories (The Netherlands)

Gamut Mapping in LCD Backlight Compensation (Wednesday Interactive), Louis Kerofsky, Jon Speigle, and Scott Daly, Sharp Labs of America (USA)

Image Quality Evaluation for Motion Picture Compressed by H.264/AVC (Wednesday Interactive), Naoya Matsumoto, Tokiya Abe, Masato Kogami, and Hideaki Haneishi, Kyung-pook National University (South Korea)

Color Breakup: Taxonomy, Measurement, and Remedy (Wednesday Interactive), Wei-Chung Cheng, National Chiao Tung University (Taiwan)

Testing Colour Appearance Models Using Complex Images (Wednesday Interactive), YungKyung Park, Changjun Li, and M. Ronnier Luo, University of Leeds (UK); and Youngshin Kwak, Du-Sik Park, and Changyeong Kim, Samsung Advanced Institute of Technology (South Korea)

11:10 AM – 12:30 PM
CAPTURING COLOR
Session Chair: Joseph Goldstone, Piliputian Pictures LLC

Colouring the Near-Infrared, Clement Fredembach and Sabine Süssrunk, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

Exploiting Color Filter Array Sensor NIR Spectral Sensitivity to Improve Color Accuracy: Spectral Reflectance Analysis, Shizhe Shen and Roy S. Berns, Rochester Institute of Technology (USA)

Evaluating Wide Gamut Color Capture of Multispectral Cameras, Yuki Murakami, Kenko Iwase, Masahiro Yamaguchi, and Nagaoeki Ohyama, Tokyo Institute of Technology (Japan)

PCA-based Reflectance Analysis/Synthesis of Cosmetic Foundation, Shoji Tominaga and Yuuke Morichi, Chiba University (Japan)

Evaluating of Light Sources Based on Visual Colour Rendering (Wednesday Interactive), Cheng Li, M. Ronnier Luo, and Changjun Li, University of Leeds (UK)

An Illumination Independent Descriptor Using Chromatic Moment Invariants (Wednesday Interactive), Bing Li and De Xu, Beijing Jiaotong University (China), and Weihua Xiong, Omnivision Technologies (USA)

Cluster Based Color Constancy (Wednesday Interactive), Weihua Xiong, Jiangtao Kuang, and Xiaoyong Wang, Omnivision Technologies (USA)

Maximum Entropy Spectral Models for Color Constancy in the Presence of Interreflections (Wednesday Interactive), Sandra Skaff and James J. Clark, McGill University (Canada)

Reflectance Prediction in Multi-Angle Measurement by Wiener Estimation Method (Wednesday Interactive), Pesal Koirala, Markku Hauta-Kasas, Juoni Hiltunen, and Jussi Parkkinen, University of Jyvaskyla (Finland)

Illuminant Retrieval for Fixed Location Cameras (Thursday Interactive), Joanna Marguier and Sabine Süssrunk, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

The trade-off Between Color Reproduction Accuracy and Image Sensor Noise (Thursday Interactive), Hideyasu Kinba, Nikon Corporation (Japan), and Roy S. Berns, Rochester Institute of Technology (USA)

Evaluation of Vehicular Camera Performance Through ISO-Based Image Quality Quantification (Thursday Interactive), Kyung-Woo Ko, Kee-Hyon Park, and Yeong-Ho Ha, Keung-pook National University (South Korea)
Sixteenth Color Imaging Conference

Estrada, and Sabine Süssstrunk, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

An Investigation into Perceptual Hue-Ordering (Thursday Interactive), David Connah,1 Alinea Blaj,2 and Graham D. Finlayson1; 1University of East Anglia and 2University of Bradford (UK)

A Solution to CIECAM02 Numerical and Range Issues (Thursday Interactive), Graeme W. Gill, Computer Graphics Technology Pl. (Australia)

Saliency Map for Human Gaze Prediction in Images (Thursday Interactive), Puneet Sharma, Faouzi Alaya Cheikh, and Jon Yngve Fradeberg, Ovijak University College (Norway)

11:10 AM – 12:30 PM

ACHROMATIC COLOR

Session Chair: Clement Fredembach, Ecole Polytechnique Fédérale de Lausanne (EPFL)

Quaturnion Color Curvature, Liling Shi, Brian Funt, and Ghassan Hamarneh, Simon Fraser University (Canada)

Fast Colour2Grey, Ali Alasm, National Gallery London (UK), and Mark Drew, Simon Fraser University (Canada)

Visual Equivalence: An Object-Based Approach to Image Quality, James A. Ferwerda, Munssel Color Science Lab (RIT), and Ganesh Ramanarayanan, Bruce Walter, and Kavita Bala, Cornell University (USA)

Alpha, Contrast, and the Perception of Visual Metadata, Maureen Stone, StoneSoup Consulting, and Lyn Bartram, Simon Fraser University (Canada)

2:00 – 5:00 PM

HUNT SYMPOSIUM

Session Chair: Michael Kriss, MAK Consulting


Nearly 40 years ago, Robert Hunt defined the following six color reproduction objectives: spectral, colorimetric, exact, equivalent, corresponding, and preferred. Since then, advances in color imaging have been astounding including hyperspectral and HDR capture, multi-primary, high luminance, and dynamic range display, and multirink output. This lecture will review Dr. Hunt’s color reproduction objectives and report on our progress in achieving these objectives, and perhaps, whether these objectives should be modified in light of our astounding advances in color reproduction.*

Color Vision and More Comprehensive Color Appearance Models, Hirohisa Yaguchi, Chiba University (Japan)

At the AIC 2nd Congress in 1973, the late Dr. Wyszecki said “methods of assessing the appearance of color stimuli are considered the ultimate goal of colorimetry.” Robert Hunt played a large role in achieving this goal. Today, CIECAM02—widely used as a tool of advanced colorimetry—was intended to be an empirical model; however, some aspects of the model are closely related to the human color vision mechanism. This lecture will discuss the relationship between color vision and color appearance models, and report on more comprehensive models including mesopic, dichromatic, and categorical color appearance. *

Holy Grail of Colour Appearance Research, M. Ronnier Luo, University of Leeds (UK)

A general review of Robert Hunt’s contribution to color science since his initial work in 1950 will be given, focusing on the topic with which he was most involved: color appearance. Starting with his initial research on adaptation—he investigated the role in achieving this goal. Today, CIECAM02—widely used as a tool of advanced colorimetry—was intended to be an empirical model; however, some aspects of the model are closely related to the human color vision mechanism. This lecture will discuss the relationship between color vision and color appearance models, and report on more comprehensive models including mesopic, dichromatic, and categorical color appearance. *

November 10–15, 2008 • Portland, Oregon

Friday November 14, 2008

8:30 – 9:30 AM

KEYNOTE SESSION

Session Chairs: James Laimer, ImageMetrics LLC, and Nathan Moroney, Hewlett-Packard Laboratories

The Push-Me Pull-You of Color, Robert W.V. Hunt, consultant (UK)

Presentation of Cactus Award for “Best Interactive Paper”

9:30 - 10:30 AM

PERCEIVING COLOR

Session Chair: Changjun Li, University of Leeds

Modelling Vividness Perception for Colour Laser Printer Evaluation, Youn Jin Kim, Yoonsun Bang, and Heuk-Keun Choh, Samsung Electronics (South Korea)

Preferred Color Imaging Algorithms and Psychophysical Evaluation, Shuxue Quan and Elaine Jin, Aptina Imaging (USA)

Subjective Rules on the Perception and Modeling of Image Contrast, Seo Young Choi, M. Ronnier Luo, Michael R. Pointer, and Gui Hua Cui, University of Leeds (UK)

Segmenting Memory Colours (Wednesday Interactive), Clement Fredembach, Francisco

3:00 – 3:40 PM

INTERACTIVE SPOTLIGHT SESSION II

and

3:40 – 5:40 PM

INTERACTIVE SESSION II

Session Chairs: Francisco Imat, Samsung R&D Center, and Peter Morovic, Hewlett-Packard España

Two-minute previews of papers noted as “Thursday Interactive” will be presented during the spotlight session followed by discussions with authors during Interactive Session II

EVENING MICROBREW TOUR

Join other attendees for this informal tour of local microbreweries. Tour gratis; associated costs are the responsibility of participants.
Special Pre- and Post-Conference Events

ICC DevCon ’08
For Users and Product Developers Working with ICC-based Color Management
Monday, November 10, 9:00 am to 7:30 pm • The Benson Hotel

Digital information today includes color. How should color be encoded? How should it be processed for application? ICC DevCon 2008 is your opportunity to learn from the experts—experienced developers and users in the imaging, printing, and publishing color community. Join in the development of color management technologies for today and the future.

Below is the program schedule; for speaker information and other details visit www.color.org. You may register directly for DevCon when you register for CIC16—see page 24 for rates and details.

Morning presentations will deal with various aspects of the following: Consider an application developer working in the consumer application domain. The application developer would like to enable the use of camera raw images in an application that:
• enables a user to compose images into documents which include vector graphics,
• provides a print-look preview on a wide-gamut LCD display
• and then generates a print via a home printer, achieving color fidelity with the on-screen preview.

What are the operating system supports [CMM supports] and enablements for this application and how should the application developer best use them? What are the application platform portability factors that can affect the solution?

Morning Abstract: Problem Statement, ICC Chair, William Li, Kodak Graphic Communications
Discussion of Intelligent CMM—X-Rite CMM, Moshe Kedar, X-Rite

ISC/IS&T/SID Special Topics Meeting
The Black and White Meeting
Saturday, November 15, 8:30 am to 3:20 pm

A one-day meeting devoted to the special challenges and solutions for black and white, two of the most important properties of a colored image. Registration includes lunch.

8:30 – 10:15 am
WHITE

Fluorescent Excitation from White LEDs, Dave Wyble (RIT)
Indoor Daylight: Illuminant C with UV Extrapolation, Byron Jordon (National Resource Council of Canada)
Estimating the Spectral Reflectance of Fluorescent Offset Papers for Varying Illuminants, Eva-Maria Löffler (Abteilung PrePress-Reproduktion)
Gärtner-Griesser Coefficients for UV Calibration for CIE Illuminant D50 Simulators, Veronika Lovell & Danny Rich (Sun Chemical)

10:45 am – 12:00 pm
BLACK

Perceived and Device Black and White as Reference Colours in Image Technology, Klaus Richter (Berlin University of Technology)
Perceptual Assessment of Blackness, Renzo Shamey and Reid Clouts (North Carolina State University)
Designing the Neutral Scale—Noise and Perception, Jack Holm (Hewlett Packard)

12:00 – 1:15 pm
Hosted Lunch with colleagues and speakers

1:15 – 3:20 pm
MEASUREMENT, CALIBRATION, AND STANDARDS

The Characteristics of Optical Brightening Agent Fluorescence Emission and How they Relate to Methods for UV-cut Measurement, Brian Gamm (RIT)
AATCC UV Calibration Textile Standard, Roland Connelly (X-Rite Inc.)
Evaluation of UV Calibration and Whiteness Formulæ, Ye (David) Chen (University of Leeds)
The Evolution of ISO 2469 for International Agreement on Optical Properties for Pulp and Paper, Joanne Zwinkels (National Resource Council of Canada)
ISO TC6/WG3 and the Role of Authorized Labs: Transferring Calibrations to Users and Consumers, Pat Robertson (Technidyne Corp.)

Registration
Register when you register for CIC or via the ISCC website at www.iscc.org.

For the latest information on the ISCC one-day conference, go to www.iscc.org
This comprehensive two-day course covers the principles of color perception, measurement, and reproduction, as applied to photography, television, printing, desktop publishing, and electronic imaging. Each day consists of six one-hour lectures with discussion.

Prerequisites
A minimum of one year of college chemistry, physics, and math is recommended and some experience with color systems is helpful, but not mandatory.

Benefits
Attendees will be able to:
- Describe normal color vision in terms of system components and their functions, trichromacy, adaptation, and luminance
- Discuss light sources including incandescent and fluorescent lamps, daylight, color temperature, and standard illuminants
- Understand the principles of spectrophotometry, including the geometry of illumination, and viewing and dealing with fluorescent samples
- Explain the experimental basis of colorimetry, and the reason why some colors cannot be matched by RGB additive mixtures
- Explain primaries, chromaticity, the effects of changing primaries, and color matching functions
- Describe the CIE system of colorimetry, including the XYZ, u', v', CIELUV, and CIELAB systems, and understand the concepts of whiteness, advanced color difference formulae, observer and illuminant metamerism indices, color inconstancy index, chromatic adaptation transform, and color appearance models
- Describe color reproduction in terms of both additive and subtractive trichromatic principles and become familiar with television display devices and color film and its processing
- Learn about densitometry and describe the factors affecting tone reproduction
- Understand the principles involved in broadcast television and digital cameras
- Discuss the application of color science to lithographic printing
- Appreciate what factors affect quality in digital imaging and desktop publishing
- Understand the essential requisites of successful color imaging

Robert Hunt worked for 36 years at the Kodak Research Laboratories in Harrow, England, taking early retirement as Assistant Director of Research in 1982. Since then he has been an independent color consultant. Hunt has had two published books: The Reproduction of Colour, now in its sixth edition, and Measuring Colour, now in its third. He has attended all the previous Color Imaging Conferences and is a regular contributor of keynote papers.

Cost before October 13th:
$650 IS&T/SID members
$825 non-members
$250 students
add $50 to all fees after Oct. 13, 2008

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Cost before October 13th:
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$825 non-members
$250 students
add $50 to all fees after Oct. 13, 2008

This course is divided into two parts: color difference evaluation for color patches and images, respectively. The former covers the fundamentals in understanding color difference assessments such as visual assessment methods, reference viewing condition, and evaluation and development of color difference formulas using visual results. The latter introduces the way and theory to extend the formulae based on patches for evaluating images such as conventional formula with add-on spatial filters, color appearance model based formula, and image appearance model. Furthermore, some experiments conducted and associated with CIE TC8-02 Colour Difference Evaluation for Images will be introduced. The visual results were used to evaluate the performance of various types of formulae.

Benefits:
Attendees will be able to:
- Explain the techniques for visually assessing color difference
- Understand different types of color difference formulae and evaluate their performances
- Apply color difference formula in the imaging industry.

Intended Audience:
color engineers and research scientists involved with color reproduction, imaging device developers, computer software developers. Knowledge of the fundamental colorimetry is assumed.

M. Ronnier Luo is a Professor of Colour and Imaging Science at the Department of Colour Science, University of Leeds, and the Director of CIE Division 1 (Vision and Colour). He has more than 300 publications in color and imaging science and
manufacturing of color imaging algorithms and devices. Participants should be familiar with the function and basic properties of digital cameras. A rudimentary knowledge of color science and image processing would be helpful.

Professor Sabine Süsstrunk leads the Images and Visual Representation Group (IVRG) at the École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, where she has taught since 1999. Her main research areas are in computational photography, color imaging, image quality metrics, image indexing, and archiving. Süsstrunk is an Associate Editor for IEEE Transactions on Image Processing and has served as chair or committee member for many international conferences on color imaging, digital photography, and image systems engineering. She is currently Director of CIE Division 8 (Imaging Technology). She is a senior member of IS&;T and a member of IEEE, ACM, and OSA.

M3: Color Optimization for Displays
1:30–3:30 pm (2 hours)
Instructor: Gabriel Marcu, Apple, Inc.

This tutorial introduces color optimization techniques for various display types, covering LCD (transmissive, reflective and transfactive), plasma, OLED, and projection systems (DLP, LCD, LcoS) and ranging from mobile devices to large LCD TV screens. Factors such as technology, luminance level, dynamic/static contrast ratio, gamma correction, color gamut, viewing angle, white point, gray tracking, response time, color model, calibration, and characterization are discussed and color optimization methods for displays are presented.

Benefits: Attendees will be able to:
• Identify the critical color parameters for various displays from mobile devices to LCD TV
• Understand the color performances and limitations for various LCD modes (TN, IPS, MVA, FFS and OCB) used in different devices (mobile, monitor, LCD TV and projector)

3:45 – 5:45 pm (2 hours)
Instructor: J. A. Stephen Viggiano, Rochester Institute of Technology (RIT)

Learn how to use human observations to assess image quality and get hands-on experience doing it. After a brief introduction/review of psychometric image quality assessment, the modern analysis method of rank order experiments is introduced. A hands-on experience is the focus of the course and a rank order image quality experiment is conducted and analyzed using ordinary spreadsheet software. Error bars are computed and multiple range tests run, so that the stimuli may be placed into groups not statistically significantly different from each other.

Benefits: Attendees will be able to:
• Construct a scale of image preference from a rank-order experiment
• Establish statistical significance between different alternatives in a rank-order experiment
• Understand results of rank-order experiments presented by others
• Recognize the advantages of rank-order experiments over other methods
• Avoid pitfalls in older analysis methods

Intended Audience: engineers, scientists, managers, prepress professionals, and others confronting display related color issues.

J. A. Stephen Viggiano is Senior Scientist in the ColorSync group, at Apple, Inc. His achievements are in color reproduction on displays and desktop printing (characterization/calibration, halftoning, gamut mapping, ICC profiling, HDR imaging, RAW color conversion). Marcus is responsible for color calibration and characterization of Apple displays and for RAW color for digital camera in MacOS X. He has taught seminars and short courses on color topics for UC Berkeley, IMI London (UK), and various IS&;T, SPIE, and SID conferences. He was co-chair of the 2006 SPIE/IS&;T Electronic Imaging Symposium and the 11th IS&;T/SID Color Imaging Conference. He is co-chair of the EI Color Imaging Conference: Display, Hardcopy, Processing, and Applications. Marcus is a Fellow of SPIE.

This course describes the context, structure, and applications of spatio-chromatic vision models for imaging. After a brief review of the important characteristics of the visual system and the basic concepts of color science, a general framework for spatio-chromatic vision models based on trichromacy, color opponency, and the limited spatial frequency response of the vision system is developed. Next applications of these models to color image quantization and digital color halftoning are discussed. During the last part of the course, a more complex group of models that account for the multi-channel nature of the visual system, the dependence of percept on contrast, and the role of the psychometric function in describing detection and discrimination is introduced. Finally, potential applications of these models to image quality assessment are discussed.

Benefits: Attendees will be able to:
• Understand the fundamental spatio-chromatic aspects of the visual system and how they can be captured in models
• Know how spatio-chromatic models for the human visual system can be used in the development of color image quantization and halftoning algorithms, and also for image quality assessment

Intended Audience: scientists, engineers, analysts, and managers involved in the design,
engineering, manufacturing, marketing, or evaluation of imaging products, algorithms, or systems. Participants should be familiar with the function and basic properties of color imaging systems. A rudimentary knowledge of color science, linear systems, and image processing would be helpful, but is not essential.

Jan P. Allebach is Hewlett-Packard Professor of Electrical and Computer Engineering at Purdue University. His work on digital halftoning and image rendering algorithms has been licensed by major vendors in the printing industry and is used in products, some of which have sold 100s of millions of units world-wide. His current research interests include image rendering, image quality, color imaging, and digital publishing. Allebach is a Fellow of IEEE, IS&T, and SPIE. He has been Distinguished Visiting Lecturer for IS&T and the IEEE Signal Processing Society, and has received four teaching awards while at Purdue. He received the Bowman Award from IS&T in 1998, and was named 2004 Electronic Imaging Scientist of the Year by IS&T and SPIE. In 2007, he was named Honorary Member of IS&T—the Society’s highest honor. In 2008, he received the Purdue College of Engineering Mentoring Excellence Award and the Purdue Sigma Xi Faculty Research Award.

Kevin Spaulding received a BS in Imaging Science from Rochester Institute of Technology (1983), and MS and PhD in Optical Engineering from the University of Rochester (1988 and 1992). He has been with Eastman Kodak Company since 1983 where he is currently a senior principal scientist in the Inkjet Systems Division. Spaulding serves on several international standards committees that are working on standards pertaining to the unambiguous communication of digital color image data in digital imaging systems. His research interests include color reproduction, digital halftoning, image processing algorithms for digital camera and printers, and image quality metrics.

T1B: Color Management Concepts for Digital Imaging Systems
8:00 – 10:00 am (2 hours)
Instructor: Kevin Spaulding, Eastman Kodak Company

Color management technology enables predictable and desirable color reproduction to be achieved in digital imaging systems. This tutorial discusses color management concepts in the context of an image state architecture that has been developed to describe the relationship between various types of digital images, image capture and display devices, image processing workflows, and digital color encodings. Color management is presented as five connected classes of operations including input, rendering, un-rendering, effects, and output. The characteristics and properties of color management transforms used for each of these basic operations are described together with a discussion of how these transforms can be implemented in the framework of the ICC Color Management System.

Benefits: Attendees will be able to:
• Describe common digital imaging workflows within the context of an image state architecture model
• Understand the characteristics and uses of commonly encountered color encodings (e.g., sRGB, sYCC, ICC PCS, RIMM/ROMM RGB, etc.)
• Distinguish between the different types of color management transformations used in digital imaging systems
• Understand the relationship between color management systems and the image state architecture model

Intended Audience: scientists, engineers, analysts, and managers involved in the design, engineering, manufacturing, marketing, or evaluation of digital imaging systems.

Kevin Moroney is a principal scientist at Hewlett-Packard Laboratories. He holds a BS in color science from Philadelphia University and an MS in color science from the Munsell Color Science Laboratory of the Rochester Institute of Technology. He served as chair of technical committee 8-01, which developed the CIECAM02 model. Moroney has published papers, been granted patents, and given invited presentations on color appearance modeling, non-photo realistic rendering, and color naming algorithms, and is the author of the reference magazine Color Thesaurus. He is an IS&T Fellow and a member of ISCC.

Sixteenth Color Imaging Conference

T1C: Color Appearance Modeling and CIECAM02
8:00 – 10:00 am (2 hours)
Instructor: Nathan Moroney, Hewlett-Packard Laboratories

This short course begins with a review of color appearance phenomena and the basics of color appearance modeling, including chromatic adaptation, color attribute correlates, and other topics, such as gamut mapping or device modeling. The class focuses on the CIECAM02 color appearance model and its applications. The majority of the course considers the forward model or the calculation of color appearance attributes given stimulus tristimulus values and information about the viewing conditions. The inverse model is briefly covered, as are the publicly available CIECAM02 tools and the advantages and trade-offs of using this model for specification applications. Finally, in-class demonstrations and worked examples are used to show the model and its application to displays.

Benefits: Attendees will be able to:
• Understand the basic components of a color appearance model
• Acquire working familiarity with the CIECAM02 color appearance model
• Gain exposure to available tools and resources for CIECAM02
• Participate in a hands-on demonstration of the model

Intended Audience: researchers and developers working in the area of color appearance and color reproduction. The course includes examples and a detailed technical discussion of the model so attendees will benefit from previous familiarity with colorimetry and the basics of color science.

Nathan Moroney has published papers, been granted patents, and given invited presentations on color appearance modeling, non-photo realistic rendering, and color naming algorithms, and is the author of the reference magazine Color Thesaurus. He is an IS&T Fellow and a member of ISCC.

T1D: System Interactions in Digital Color Imaging
8:00 – 12:15 pm (4 hours)
Instructors: Raja Bala, Xerox Corporation, and Gaurav Sharma, University of Rochester

This short course underscores the system aspect of color imaging by providing insight into the common interactions among different functions within a digital imaging system. It begins with a brief overview of the basic color processing functions, including color halftoning, device calibration, characterization, gamut-mapping, quantization, and compression. The course then highlights common system interactions among these functions, and illustrates through specific case studies how knowledge of these interactions may be beneficially exploited for improving overall system performance and/or image quality.

Benefits: Attendees will be able to:
• List basic processing functions in a digital color imaging system, and schematically represent a system from input to output
• Describe unintended interactions between input and output characterization profiles and ways to mitigate these
• Comprehend and exploit the interactions between color and spatial dimensions in optimizing a color imaging system
• Explain how media characteristics influence the performance of color imaging devices
• Understand the interactions between halftones and color in output devices and some techniques for co-optimization of these
• Appreciate how system design and
Color image using a printer quickly runs into issues of not being able to match some of the original's colors. The role of gamut mapping is to make the role of gamut mapping explicit in its context, discusses how it is implemented in actual color management systems, and focuses on sketching out the variety of gamut mapping solutions proposed over the last 30 years. Understanding the nature of gamut mapping provides a basis for making informed choices about it when setting up color reproduction solutions.

**Benefits:** Attendees will be able to:
- Understand the theory of color reproduction
- Identify the role and position of color gamut mapping within color reproduction
- Evaluate the performance of a color gamut mapping solution
- Choose from among the multitude of existing gamut mapping approaches
- Trace a color's progress through a color reproduction workflow, with particular emphasis on the gamut mapping stage
- Consider future trends in color gamut mapping

**Intended Audience:** engineers, scientists, students, and managers interested in acquiring a broad, system-wide view of digital color imaging systems. Practitioners and experts who are familiar with specific components also stand to gain a better perspective for the remainder of the system. Case studies on system optimization presented in this course will be of interest to technologists looking for ways to improve their digital color imaging systems and will hopefully serve as inspiration for additional research in this area. Attendees are expected to be familiar with basic image processing and colorimetry.

Raja Bala is a principal color scientist at Xerox Innovation Group, where he has performed research and development in color imaging for the last 15 years. He has been an adjunct faculty member in the School of Electrical Engineering at Rochester Institute of Technology.

Gaurav Sharma is an associate professor in the Electrical and Computer Engineering Department at the University of Rochester, where he has been since Fall 2003. Prior to that, he was with the Xerox Innovation Group. He has worked on research in color imaging for the past 15 years and is editor of the Digital Color Imaging Handbook, published by CRC press in 2003.

### 10:15 AM – 12:15 PM

**T2A: Color Gamut Mapping**

**10:15 – 12:15 pm (2 hours)**

**Instructor:** Ján Morovic, Hewlett-Packard Español

Attempting the reproduction of a displayed color image using a printer quickly runs into issues of not being able to match some of the original's colors. The underlying cause of this, and many other color reproduction scenarios, is the fact that different color reproduction media are capable of reproducing different ranges (gamuts) of colors. When addressing color gamut differences it is necessary to assign reproducible colors to all the original ones, called gamut mapping.

This short course, based on the instructor's recently published *Color Gamut Mapping* book, provides an introduction to color reproduction, makes the role of gamut mapping explicit in its context, discusses how it is implemented in actual color management systems, and focuses on sketching out the variety of gamut mapping solutions proposed over the last 30 years. Understanding the nature of gamut mapping provides a basis for making informed choices about it when setting up color reproduction solutions.

**Benefits:** Attendees will be able to:
- Understand the applications of spectral imaging compared with trichromatic imaging
- List and compare different techniques of spectral imaging
- Become familiar with the foundations of estimating spectral reflectance from multi-channel images
- Learn about separation techniques for spectral reproduction
- Comprehend the applications of spectral imaging for multi-ink printing, spectral color management

**Intended Audience:** those wishing to become more familiar with the opportunities and challenges within the emerging field of spectral color reproduction, which may include color and imaging scientists, camera and printer designers, and image processing specialists.

Ján Morovic is a senior color scientist and Master Technologist at Hewlett-Packard’s Large Format Printing division in Barcelona, Spain. He has a BA in Print Management from the London College of Printing and a PhD in Color Science from the University of Derby. Between 1998 and 2003, Morovic was Lecturer in Digital Color Reproduction at the University of Derby's Colour and Imaging Institute.
More recently, he has been involved with Dolby Canada’s HDR display developments, which employ dual modulators to show colors 30 times as bright and ten times as dark as conventional monitors. Working in the computer graphics research community for more than 20 years, Ward has developed rendering algorithms, reflectance models and measurement systems, tone reproduction operators, HDR image processing techniques, and photo printer calibration methods. His past employers include Lawrence Berkeley National Laboratory, EPFL, SGI, Shutterfly, and Exponent. Ward holds a BS in Physics from UC Berkeley and MS in Computer Science from San Francisco State University. He is currently a consultant in Albany, California (www.anyhere.com).

When the right color matching functions (CMFs) are used, vector methods demystify camera sensors, lighting, and other topics. In Jozef Cohen’s invariant formulation, the vectors of spectral lights at unit power define the “locus of unit monochromats” (LUM). Orthornormal opponent CMFs map lights into Cohen’s color space and establish intuitive axes: whiteness, red-green, and blue-yellow. If a camera’s LUM matches the eye’s, it meets Luther’s criterion. The instructor presented details at CIC12 and CIC 14. The course emphasizes the practical use of color vectors and the orthornormal CMFs. If you plan to bring a computer to the course, please install a VRML viewer prior to attending. For background, see www.jimworthey.com.

Mark Fairchild is a professor at the Munsell Color Science Laboratory in RIT’s Chester F. Carlson Center for Imaging Science. He received his BS and MS degrees in Imaging Science from RIT and PhD in Vision Science from the University of Rochester. He is author of the book, Color Appearance Models, 2nd Ed. that serves as a reference to the fundamentals of colorimetry and color appearance.

Greg Ward is a leader in the HDR space, having developed the first widely-used HDR image file format in 1986 as part of the RADIANCE lighting simulation system. Since then, he has developed the LogLuv TIFF HDR image format, the JPEG-HDR format, and authored the application Photosphere, an HDR image builder and browsing program.

### T3B: Vectorial Color

**1:30 – 3:30 pm (2 hours)**

**Instructor: James Worthey, consultant**

When the right color matching functions (CMFs) are used, vector methods demystify camera sensors, lighting, and other topics. In Jozef Cohen’s invariant formulation, the vectors of spectral lights at unit power define the “locus of unit monochromats” (LUM). Orthornormal opponent CMFs map lights into Cohen’s color space and establish intuitive axes: whiteness, red-green, and blue-yellow. If a camera’s LUM matches the eye’s, it meets Luther’s criterion. The instructor presented details at CIC12 and CIC 14. The course emphasizes the practical use of color vectors and the orthornormal CMFs. If you plan to bring a computer to the course, please install a VRML viewer prior to attending. For background, see www.jimworthey.com.

**Benefits:** Attendees will be able to:
- Use the orthornormal CMFs and calculate color vectors
- Understand LUMs as an invariant summary of matching
- Work with 3D plots of such data as color chips under a lighting change
- Compare light sources on the basis of vectorial composition

**Intended Audience:** Scientists and engineers involved in either designing or working with systems that produce or reproduce images/video in various media and/or are observed under varying viewing conditions. Knowledge of the fundamentals of colorimetry and color appearance is assumed.

### T3C: Medical Imaging Applications of Spectral Imaging

**1:30 – 3:30 pm (2 hours)**

**Instructor: Yoichi Miyake, Chiba University**

This course contains an introduction of multi-spectral imaging and its applications to medical imaging. Most imaging devices such as CCD cameras, scanners, LCDs, and film are three channel devices generating RGB signals or CIE-XYZ tristimulus values, which are dependent on the characteristics of imaging devices and illuminant conditions. For a true record of an object, it is necessary to capture the reflectance spectra of every sample point independent of both the spectral characteristics of imaging systems and the spectral radiant distribution of the illumination. In this course, fundamentals and applications of spectral imaging, particularly medical imaging, are introduced and described. The course is designed for graduate students and engineers in printing, camera, and electronics.
1:30 – 5:45 PM

T3D: Digital Camera Image Capture and Processing — From Pixels to Picture
1:30 – 5:45 pm (4 hours)
Instructor: Matt Whalen, Applied Color Science, Inc.

This course presents an overview of the image capture and processing elements in a digital camera that transform raw pixel output from an electronic image sensor into full color video or still images. The course examines the differences between CCD and CMOS image sensors that affect image quality and describes a generic image processing pipeline (exposure control, Bayer de-mosaic, color matrix, gamma, white balance, and sharpening, etc.). The function of each processing element is discussed including the variations for specific implementations and tradeoffs between image quality and available camera resources.

Intended audience: color scientists and engineers for image quality, cameras, and printers, as well as engineers for medical image processing

Yoichi Miyake has been a professor at Chiba University since 1989. He received his PhD from Tokyo Institute of Technology (1978). In 1978 and 1979, he was a post doctoral fellow at the Swiss Federal Institute of Technology (ETHZ). In 1997, he was a guest professor of University of Rochester. He received the Charles E Ives Award (for best paper) from IS&T in 1991, 2001, and 2005. He was named ISE-T Fellow in 1995 and Honorary Member in 2003. In 2000 he was given the Electronic Imaging Scientist of the Year award by IS&T and SPIE. Miyake has published many books and original papers on image processing, color science, and image evaluations and he is a pioneer of spectral image processing. He served as a president of SPSTJ (The Society of Photographic Science and Technology of Japan) from 2000 to 2002 and as vice president of IS&T from 2000 to 2004. He also served as a president of The Japanese Association of Forensic Science and Technology from 1998 to 1999. He is currently professor and director of Research Center for Frontier Medical Engineering at Chiba University.

Benefits: Attendees will be able to:
• Understand the differences between CCD and CMOS sensors and the relative merits/limitations of each
• Know the basic elements of a digital camera image processing pipeline
• Understand the differences between video and still image processing
• Appreciate the tradeoffs among image processing algorithms
• Identify image processing problems from evaluation of output images

Intended Audience: digital camera designers, image processing engineers and managers engaged or interested in developing new digital imaging devices or improving existing image processing workflows.

Matt Whalen, founder and chief imaging scientist for Applied Color Science, Inc. (www.appliedcolor-science.com) has been actively involved in CMOS image sensor applications and digital image processing for more than 10 years. Whalen’s work in image sensor evaluation and image processing development has ranged from consumer products to medical (Smith and Nephew HD endoscopy camera) to professional (RED digital cinema camera). Whalen has held senior technical positions with Lucent/ Bell Labs, Comaxant, and SiliconFilm Technologies. He currently holds more than 10 patents in the areas of lightwave and digital camera technology and has published numerous technical articles and conference papers in these areas. He has a BS and MS in Physics from Rutgers University and is a member of IS&T.

3:45 – 5:45 PM

T4A: Wide Gamut Color Capture and Reproduction
3:45 – 5:45 pm (2 hours)
Instructor: Charles Poynton, consultant

The color gamut of digital imaging systems, in both the professional and consumer domains, has historically been limited by CRT technology and by the BT.709 and sRGB standards. Emergent display technologies (such as LED-backlit LCDs and laser- and LED-illuminated DLPs) are poised to enable wide-gamut color, and D-SLR cameras are already capable of wide-gamut capture. The emergence of these display technologies brings new challenges in how to capture wide-gamut color, and how to transform between wide gamut and moderate gamut representations at origination equipment, and at display equipment. Deployment of wide-gamut color in consumer electronics is particularly challenging; there is a huge distribution infrastructure, and there are trillions of “legacy” images. How is the existing infrastructure to be adapted? How are legacy images to be treated? And how are new, wide-gamut images to be displayed on legacy devices?

The course outlines the color science and color image coding issues behind wide gamut capture and reproduction. It describes why cameras are inherently wide-gamut. The course also outlines the color transforms necessary to optimize classical colorimetry, and explains how color transforms interact with the picture rendering transforms that are a part of all commercial imaging systems. A discussion of several wide-gamut standards including Adobe RGB 1998 (IEC “opRGB,” for graphics arts), SMPTE/DCI P3 R’G’B’ and X’Y’Z’ (for digital cinema), and xvYCC (for broadcast television) is included.

Benefits: Attendees will be able to:
• Summarize various deployed and proposed wide-gamut encoding systems
• Estimate gamut coverage of various capture and display technologies
• Explain the signal processing required to capture, encode, and reproduce wide-gamut scenes
• Evaluate wide-gamut color encoding systems

Intended Audience: appropriate for technical professionals who are experienced in the engineering of color imaging systems. Many graphs, equations, and diagrams will be presented.

Charles Poynton is an independent contractor specializing in the physics, mathematics, and engineering of digital color imaging systems, including digital still cameras, digital video, HDTV, and digital cinema (D-cinema). He does technology forecasting, systems modeling, algorithm development (including digital filter design), video signal processing architecture, color characterization and calibration, and image quality assessment. He is involved in engineering wide color gamut systems, including xvYCC.

T4B: Color Management in Apple ColorSync
3:45 – 5:45 pm (2 hours)

This course provides an overview of ColorSync, which is the foundation block of Color Management in Mac OS X. The course describes the architecture of color management in the system, along with the principles of using ColorSync. It then addresses details of acquiring color data from input color devices like cameras and scanners, and managing the color data for display, printing, and storing. The class also...
demonstrates how to automate a color management workflow in Mac OS X.

Benefits: Attendees will be able to:
• Get an overview of the color management architecture in Mac OS X
• Become familiar with the principles of color management in ColorSync
• Understand the role of drivers for color devices in Mac OS X color management
• Understand different mechanisms of color management in the applications running on Mac OS X
• Apply the knowledge from the course to solve practical problems of color processing on Mac OS X

Intended Audience: engineers, scientists, project managers, prepress professionals, and others confronting color management issues.

Lake Walls is a senior scientist in ColorSync group at Apple Computer. His responsibilities include color color management in Mac OS X and ColorSync framework.

T4C: Color Vision and Color Appearance
3:45 – 5:45 pm (2 hours)
Instructor: David H. Foster, University of Manchester

This course introduces the physiology, physics, and psychology of human color vision and color appearance. The first part concentrates on the spectral sensitivities of the receptors of the eye, the luminosity function, light adaptation and von Kries scaling, and post-receptoral coding. The second part identifies some of the factors complicating color-vision models, including selective absorption in the ocular media, retinal inhomogeneity, rod intrusion, and color deficiency. The third part introduces sensory, perceptual, and cognitive cues influencing color appearance and color constancy, including mean chromaticity, spatial chromatic contrast, and highlights. The last part deals with the experimental measurement of color appearance, particu-
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Name ____________________________
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Conference registration includes admission to all technical sessions, the Hunt Symposium, full-color conference proceedings with CD, coffee breaks, and four receptions (DevcOn, Welcome, Conference, and Hunt). Separate registration fees are required for short courses, ICC DevCon, the Hunt Symposium Banquet, and The Black and White Meeting. You may also register online at www.imaging.org/conferences/CIC16.

Conference Registration (CHECK ONE)

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Extra copy of Proceedings (special pre-conference/onsite rate)

| Extra copy | $85 | $85 | $85 |

Hunt Short Course Registration

Hunt Short Course Registration (be sure to multiply number of classes by per course fee and place on total line)

| 2-day Hunt Course | $650 | $825 | $825 |
| 2-hour Hunt Course Student | $250 | $250 | $250 |

After October 13th, add $50 to the appropriate fee below. Students add $5.

| 4-hour tutorial | $225 | $255 | $255 |
| 4-hour tutorial Student | $50 | $50 | $50 |
| 2-hour tutorial | $150 | $180 | $180 |
| 2-hour tutorial Student | $50 | $50 | $50 |

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| Extra copy | $85 | $85 | $85 |

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- Banquet ticket | $75 | $75 | $75 |

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| Speaker/Session Chair | $495 | $605 | $605 |
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| Admission to CIC16 Welcome, Conference, and Hunt Receptions | $200 | $250 | $250 |
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Name/Affiliation of Guest for badge:

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- vegetarian
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