Nineteenth Color and Imaging Conference

13th International Symposium on Multispectral Color Science

and

ISCC/IS&T/SID Special Topics Meeting: Revisiting Color Spaces

November 7-11, 2011
San Jose, California

Sponsored by
Society for Imaging Science and Technology and
Society for Information Display

Cooperating Societies
Inter-Society Color Council (ISCC)
Imaging Society of Japan (ISJ)
Royal Photographic Society of Great Britain (RPS)
Society of Motion Picture and Television Engineers (SMPTE)
Society of Photographic Science and Technology of Japan (SPSTJ)
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Search Facebook or LinkedIn groups for "color imaging conference"

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Welcome to CIC19—
featuring the 13th International Symposium on
Multispectral Color Science and the
ISCC Special Topics Meeting on Color Spaces!

The 19th IS&T/SID Color and Imaging Conference (CIC19) takes place in the heart of Silicon Valley in downtown San Jose, this year. Its location in the stately and historic Sainte Claire Hotel provides an outstanding opportunity for leading color and graphics professions from the nearby high-tech companies to interact with visiting industry colleagues and world-class academics, involved in color science, vision science, materials appearance, and visual perception research.

The technical program this year features 37 oral and 30 short papers covering a broad range of color topics. We also have keynote presentations by three distinguished speakers:

- **Kathy Mullen**, professor in the Dept. of Ophthalmology at McGill University has an impressive record of achievement in the field of color vision research. She will speak on her current research, which aims to understand the encoding and analysis of scene color content in the human visual system in a talk titled “Color Responses of the Human Brain Explored with fMRI.”

- **David Brainard**, professor in the Dept. of Psychology at the University of Pennsylvania is a renowned researcher in the fields of visual neuroscience and computational modeling of visual processing. His current research involves understanding how the visual system estimates object properties. He will discuss this in his talk “Human Demosaicing Algorithm.”

- **Robert W.G. Hunt and Michael Pointer** are well known to regular CIC attendees. At CIC19 they will complete a series of three thought provoking keynotes started in 2009 by Dr. Hunt. In this year’s topic—“The Challenge of our Known Knowns”—they discuss higher order visual phenomena affecting color and material appearance.

Wednesday evening will feature a lecture by acclaimed oceanographer David Gallo from Woods Hole Oceanographic Institute on “Exploring the Fascinating World of Color Beneath the Sea.”
This year we are trying an innovative and exciting new approach, eliminating the traditional interactive paper session in favor of a Short Papers program. The new approach provides these authors the opportunity to give two back-to-back less formal 15-minute presentations of their work to a subset of the conference audience. Each attendee can choose to attend 10 of these presentations. The goal is to make this session more engaging, informative, and valuable to both the presenters and the audience.

There are two special sessions at this year’s conference. Wednesday afternoon is devoted to a series of invited talks and a panel discussion involving world-class leading experts on the Color Rendering Index. This important session is particularly relevant given the breakthrough technological development in the lighting industry over the past several years. A special High Dynamic Range Imaging session has been scheduled for Thursday afternoon. This session features invited papers from some of the leading experts in the field.

Additionally, the 13th International Symposium on Multispectral Color Science is being held Friday afternoon and Saturday features the Inter-Society Color Council (ISCC) Special Topics Meeting celebrating the 15th anniversary of the publication of RGB color encoding.

As usual, we have included an extensive short course program including several new ones. Michael Pointer will present a comprehensive course based on the new edition of “Measuring Colour,” which he co-authored with Bob Hunt. Keynote speaker Kathy Mullen will present a course on color vision: how we see color and why. Rod Bogart from Pixar and Stefan Luka from Walt Disney Feature Animation team up to give us an insider’s look at the color pipeline used in recent animated features; and Françoise Viénot, Muséum National d’Histoire Naturelle, provides an overview on LED lighting technology and its many applications. The short course program is rounded out with a broad selection of topics including imaging, multispectral imaging, color management, high dynamic range imaging, and printing.

—Jim Ferwerda and Geoff Woolfe, CIC19 General Chairs
Conference At-a-Glance

**Monday, November 7**
Registration open 7:00 am to 5:45 pm
- Color Science and Imaging Course: Day 1
- Short Course Program: Three two-hour classes offered (see page 6 for details)

**Tuesday, November 8**
Registration open 7:00 am – 6:00 pm
- Color Science and Imaging Course: Day 2
- Short Course Program: 18 two-hour classes offered (see page 6 for details)
- Welcome Reception at the Sainte Claire

**Wednesday, November 9**
Registration open 7:00 am to 6:00 pm
- Keynote: Kathy Mullen—Color Responses of the Human Brain Explored with fMRI
- Technical Sessions
  - Color and Perception
  - Image Quality
  - CRI Special Session
- Short Paper Sessions 1 and 2
- CRI Panel Discussion
- Evening Lecture: David Gallo—Exploring the Fascinating World of Color Beneath the Sea

**Thursday, November 10**
Registration open 8:00 am – 5:00 pm
- Keynote: David Brainard—Human Demosaicing Algorithm
- IS&T Honors and Awards Presentations
- Technical Sessions
  - Computational Imaging
  - Color in Displays
  - HDR Special Session
  - Color Printing
  - Short Paper Sessions 3 and 4
  - Conference Reception

**Friday, November 11**
Registration open 8:00 am to 2:00 pm
- Keynote: Robert G.W. Hunt and Michael Pointer—The Challenge of our Known Knowns
- Cactus Award Presentation
- Technical Sessions
  - Aesthetics Color
  - Miscellaneous Color Curiosities
- MCS Technical Sessions
  - MCS Short Papers
  - Spectral Acquisition
  - Spectral Illumination and Visualization

**Saturday, November 12**
Registration open 8:00 – 10:00 am
- ISCC/IS&T/SID Special Topics Meeting: Revisiting Color Spaces (see page 4 for details)
- **Separate registration fees are required for the Short Courses and Special Topics Meeting.**

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**Venue: The Sainte Claire, San Jose, California**

CIC19 will take place at the architecturally-charming, historic Sainte Claire hotel, which is on the prestigious list of Historic Hotels of America. The hotel is located in the heart of downtown San Jose, just steps from local transportation and the city’s sights.

San Jose is the tenth largest city in the US, and “epicenter of internationally renowned Silicon Valley.”* It has its own version of New York’s SoHo, SoFA: San Jose’s South of First Avenue, which is filled with galleries featuring a unique blend of art and technology. There are dining options for every taste with many restaurants focusing on locally sourced food and wine. In fact, the wines of the San Jose area have been noted as, “the most underappreciated appellation in the world,” by Wine Spectator magazine. The average weather in November is a cool but bright 65°F/18°C. To discover more about San Jose, visit [http://www.sanjose.org/](http://www.sanjose.org/).

*The Business Journals, March 16, 2011*
Special Post-conference Event

ISCC/IS&T/SID Special Topics Meeting

Revisiting Color Spaces

Saturday, November 12

This one-day meeting will honor the 15th anniversary of the publication of sRGB and create an opportunity to discuss currently used color spaces from the perspective of the scientific and technological advances of the past 15 years. The meeting will also consider industrial needs for color specifications and standards for interchange in light of the emergence of new imaging technologies such as HDR imaging and multi-primary displays.

Registration includes lunch.

9:00 – 10:00 AM
sRGB—Work in Progress
Ricardo Motta, NVIDIA Corp. (USA)
OSA-UCS System: Color-Signal Processing from Psychophysical To Psychometric Color
Claudio Oleari, University of Parma (Italy)

10:00 – 10:20 AM
Coffee Break

10:30 – 11:30 AM
Design and Optimization of the ProPhoto RGB Color Encodings
Geoff Woolfe, Canon Information Systems Research Australia Pty. Ltd. (Australia)
Adobe RGB: Happy Accidents
Chris Cox, Adobe Systems, Inc. (USA)

11:30 AM – 1:00 PM
Inter-Society Color Council 80th Annual Meeting and Luncheon

1:00 – 2:30 PM
Recent Work on Archival Color Spaces
Rob Buckley, University of Rochester/ NewMarket Imaging (USA)
Modern Display Technologies: Is sRGB Still Relevant?
Tom Lianza, X-Rite, Inc. (USA)
Is There Really Such a Thing as Color Space? Foundation of Unidimensional Appearance Spaces
Mark Fairchild, Munsell Color Science Lab/RIT (USA)

3:00 – 4:00 PM
HDR and UCS: Do HDR Techniques Require A New UCS Space?
Alessandro Rizzi, Universita degli Studi di Milano (Italy)
Digital HDR Color Separation Images
John McCann, McCann Imaging (USA)

4:00 – 4:30 PM
Speaker Panel and Closing

Registration Details
Registration fee includes lunch, two coffee breaks, full technical program, and handouts. Non-member registration includes ISCC membership through December 2012.

Fee before/after October 9th:
$250/$300 IS&T/SID members
$325/$375 non-members
$100/$100 students
Special Two-Day Short Course

Color Science and Imaging

Mon/Tues November 7-8, 2011 • 8:30 am to 4:30 pm

Instructor: Michael R. Pointer, University of Leeds and University of the Arts, London

This comprehensive two-day course covers the principles of the color perception, measurement, and reproduction, as applied to current digital imaging systems. Each day consists of six one-hour lectures with opportunities for questions and discussion.

Prerequisites

A basic education in college physics and maths is useful and some experience with color systems is helpful, but not by any means 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, fluorescent, and LED lamps; daylight; color temperature; standard illuminants; and color rendering.
- Understand the principles of color measurement, including the geometry of illumination and viewing.
- 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 color-difference formulae, observer and illuminant metamerism indices and color appearance models.
- Describe color reproduction in terms of both additive and subtractive trichromatic principles.
- Understand the principles involved in devices to capture and display digital images.
- Discuss the principles of color management in color reproduction systems.
- Appreciate the factors that affect the quality of images including aspects of tone and color reproduction.

Michael R. Pointer received his PhD from Imperial College, London and then worked for 28 years in the Research Division of Kodak Limited, followed by a period at the National Physical Laboratory. He is now a visiting professor at the University of Leeds and the University of the Arts, London. In 1997, Pointer received the Fenton Medal from The Royal Photographic Society (RPS); in 2004, he received a Silver Medal from the Society of Dyers and Colourists for ‘contributions to colour science.’ He has authored more than 100 scientific papers, is a Fellow of RPS and the Institute of Physics, has been active in the Colour Group of Great Britain since 1971, where he is now an Honorary Member; and since 1974 has been active in the Technical Committees of CIE Division 1 Vision & Colour, where from 1995 to 2007, he was responsible for all technical aspects of color science.

Fee before/after October 9th:

- $675/$725 IS&T/SID members
- $850/$900 non-members
- $265/$290 student member/non-member
CIC19 Short Course Program

MONDAY NOVEMBER 7, 2011

Special Two-Day Class: Color Science and Imaging
8:30 am – 4:30 pm
Instructor: Michael R. Pointer, University of Leeds and University of the Arts, London
See page 5 for details.

M1B: Color Pipelines for Computer Animated Features
10:15 am – 12:15 pm (2 hours)
Instructors: Rod Bogart, Pixar, and Stefan Luka, Walt Disney Feature Animation

This course examines the color pipelines used in animated feature production, from preproduction through final mastering and exhibition. Case studies follow recent productions at Pixar and Disney Animation Studios as well as offer a look into future developments considering industry trends. An examination of the impact of authoring color spaces, desktop displays, and audience presentation environments is discussed. The colorimetry of each is covered along with methods, both scientific and artistic, that we use to reconcile the differences.

Benefits: Attendees will be able to:
- List the stages in feature production and mastering.
- Associate color spaces with displays and image formats.
- Identify and build color conversions.
- Follow color grading operations.
- Appreciate the many options in establishing an end-to-end pipeline.

Intended Audience: engineers, software developers, and technical directors involved or interested in motion picture production. A basic understanding of colorimetry and image processing is expected.

Rod Bogart, whose initials are RGB, joined Pixar in 2005 after spending ten years as a software engineer at Industrial Light & Magic. He has a MS from the University of Utah, where he specialized in computer graphics. At Pixar, he is in charge of color science at the studio, overseeing the technology for creating the final distributed masters of the movies.

Stefan Luka is a senior software engineer and color scientist at Walt Disney Feature Animation, where he oversees the production and mastering color pipelines. His work in the motion picture industry has also included film restoration, digital cinema systems, and display development. He received a BS in engineering and applied science from Caltech and a MS in color science from RIT.

M1C: LED Lighting: Characterization and Visual Quality
1:30 – 3:30 pm (2 hours)
Instructor: Françoise Viénot, Muséum National d’Histoire Naturelle

This course covers an overview of LED technology including the operating principles. Additionally, scientific findings related to quality and the value added to users of LED lighting is discussed. The ways of producing white light and the resultant spectral power distributions are also given.

The necessary elements of photometry, colorimetry, and radiometry are reviewed in order to describe how to characterize and control LED illumination, with examples given. Luminous efficiency and correlated colour temperature will be defined.

Color quality is introduced with respect to the Color Rendering Index recommended by the CIE. Other approaches that support colour quality are also presented, with indices and experimental validation when they exist. Many applications of the technology are presented, including: display, indoor, and outdoor uses.
Benefits: Attendees will be able to:
- Identify the major lighting technologies and explain the production of white light using LEDs.
- Use photometry, colorimetry and radiometry tools to characterize and control LED illumination.
- Grasp the concept of correlated color temperature (CCT) and binning.
- Implement the Color Rendering Index calculation as defined by the CIE in 1995.
- Appreciate the various aspects of color quality and discriminate between fidelity and colorfulness magnification.

Intended Audience: scientists, engineers, technologists, designers, photographers, and students who are interested in acquiring knowledge about lighting technology, who might question color rendering and/or who are interested in emerging LED technology. The course assumes a basic level in colorimetry.

Françoise Viénot is a senior scientist at the Muséum National d’Histoire Naturelle, Paris, France. She is conducting research in colorimetry, photometry, gloss metrics, LEDs illumination, colour vision and the measurement of appearance.

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<th>8:00–10:00 am</th>
<th>10:15 am–12:15 pm</th>
<th>1:30–3:30 pm</th>
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<td>MONDAY SHORT COURSE</td>
<td>M1B: Color Pipelines for Computer Animated Features</td>
<td>M1C: LED lighting: Characterization and Visual Quality</td>
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<td>T1B: Fundamentals of Spectral Measurements for Color Science</td>
<td>T1C: Understanding and Handling the Quality of Experience (QoE) for Multimedia Applications</td>
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<td>T2A: The Digital Camera Image Processing Pipeline – From Pixels to Picture</td>
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<td>T2C: Color Difference</td>
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<td>T3A: A Unified Paradigm for Color Management</td>
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<td>T3C: Display Technologies</td>
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<td>T4A: Introduction to Multi-spectral Color Imaging</td>
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<td>T4C: Color in High Dynamic Range Imaging</td>
<td>T4D: HDR Imaging in Cameras, Displays and Human Vision</td>
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<td>T5A: Psychophysics 101 - How to Design Perception Experiments</td>
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at the Centre de Recherche sur la Conservation des Collections. She is the French representative in the CIE Division 1 (Vision) and the chair of CIE TC 1-36 on the “Chromaticity diagram with physiologically significant axes,” and Vice-President of CIE-France.

**M1D: The Role of Color in Human Vision**
3:45 – 5:45 pm (2 hours)
Instructor: Kathy Mullen, McGill University

This course presents an introduction to two fundamental and linked factors of color vision: the neural systems of the brain that undertake the computation of color, and the function of color for human vision. The first part of the course covers an overview of the aspects of the physical world our color vision informs us about. It discusses how we are able to see color, the basic neural mechanisms of our color vision from the cones in the retina to the cone opponent processes, and the visual cortex of the brain. The second addresses the question “why have color vision” by defining what color vision is good at, and what it is bad at. Experimental approaches are discussed that have allowed the measurement of the spatial contrast-sensitivity function for color and color resolution, and that have revealed the role of color in defining shape and forms in the visual scene and in disambiguating shape and shading. The type of information that human color vision filters out, the temporal contrast-sensitivity function, and the sensitivity of color vision to motion is also be discussed.

**Benefits:** Attendees will be able to:
- Understand the neural mechanisms of color vision.
- Design psychophysical experiments in color vision.
- Understand the limitations of color vision: the modulation transfer functions of human vision compared for color and luminance information.
- Understand the role of color vision for the analysis of shape and form in an image.

**Intended Audience:** color engineers, scientists and designers. Those who wish to understand techniques for measuring vision thresholds of contrast sensitivity. Those interested in understanding perceptual metrics or the design of image analyses for chromatic and achromatic components.

Kathy Mullen received her Bachelor degree in physiology from Oxford University and a PhD in neuroscience from the University of Cambridge. Her PhD supervisor, Horace Barlow, was the great grandson of Charles Darwin. She remained at the University, where she received a Royal Society University Research Fellowship and a College Fellowship from New Hall, Cambridge. She moved to McGill University in 1990 and is currently a professor of neuroscience, and a world authority on human color vision.

**TUESDAY NOVEMBER 8, 2011**

**Special Two-Day Class:**
**Color Science and Imaging**
8:30 am – 4:30 pm
Instructor: Michael R. Pointer, University of Leeds and University of the Arts, London
See page 5 for details.

**8:00 – 10:00 AM**
**T1A: Human Color Perception:**
**Aesthetic Preference and Emotional Response**
8:00 – 10:00 am (2 hours)
Instructor: Stephen E. Palmer, University of California, Berkeley

This course covers aesthetic and emotional responses to color. Preferences for single colors are higher for cool (blue/green) than warm colors (yellow/orange), with a minimum at dark-yellow (olive), but differ with gender, culture, training, object, season, and individuals. Average preferences
are explained by ecological valence: people like colors to the extent that they like the objects that are those colors. Preferences for color pairs depend on perceived harmony, preferences for individual colors, and preferences for figural colors against colored backgrounds. Large individual differences exist in preference for harmony—the extent to which people prefer harmonious combinations—which generalizes to music and other visual domains. Colors also evoke emotional responses that link them cross-modally with music, facial expressions, and gestures.

Benefits: Attendees will be able to:

- Learn the strengths and weaknesses of different psychophysical measurement techniques for assessing aesthetic and emotional responses to colors.
- Use the results of color preference experiments to aid in designing more aesthetically pleasing graphic designs and websites.
- Understand the ecological reasons underlying color preferences.
- Learn about differences in color preference that arise in different object contexts, cultures, genders, and individuals, and understand ecological explanations for them.
- Use knowledge of differences in preference-for-harmony to inform more appropriate choices about color compositions for different types of audiences.
- Associate color with other perceptual domains through knowledge of the meditational role that emotion plays in people’s response to colors.

Intended Audience: color scientists, website designers, graphic designers, photographers, artists, marketing specialists, software engineers, and anyone who is interested in understanding what colors people like and why they like them. No special knowledge of the topics covered will be presupposed.

Stephen E. Palmer (PhD, UCSD, 1975) is professor in the Graduate School in Psychology and Cognitive Science at UC Berkeley. He wrote Vision Science: Photons to Phenomenology (1999, MIT Press) and co-edited Aesthetic Science: Connecting mind, brain, and experience (forthcoming, Oxford University Press). He has authored more than 100 publications on visual perception and is currently writing a new, interdisciplinary book about color, Reversing the Rainbow: Reflections on Color and Consciousness.

T2A: The Digital Camera Image Processing Pipeline – From Pixels to Picture

8:00 – 10:00 (2 hours)
Instructor: Matt Whalen, Applied Color Science, Inc.

This short course describes the collection of image processing elements (Bayer De-mosaic, Color Matrix, Exposure Control, Gamma, White Balance, Sharpening, Hue/Saturation Control etc.) in digital cameras and image sensors that transform raw pixel output from an image sensor into full color video or still images. The course explains the function of each processing element and discusses various implementations and tradeoffs for each with examples.

Benefits: Attendees will be able to:

- Understand the elements of a digital camera image processing pipeline (IPP).
- See the relationship between imaging system design and the IPP.
- Appreciate the system tradeoffs among image processing algorithms.
- Analyze image processing problems from evaluation of output images.
- Learn how new 3D and High Dynamic Range cameras affect the IPP.

Intended Audience: digital camera designers, imaging engineers, and managers involved or interested in developing or improving an image processing pipeline.

Matt Whalen is the founder and chief imaging scientist for Applied Color Science, Inc. He has been actively involved in CMOS image sensor
applications and digital image processing for more than 15 years. His work in image sensor evaluation and image processing development has ranged from consumer products (Kodak CMOS sensors, Cisco Telepresence) to medical (True-Vision 3D surgery camera) and professional (RED digital cinema). 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. He has a BS/MS in physics from Rutgers University and is a member of IS&T.

**T3A: A Unified Paradigm for Color Management**

8:00 – 10:00 am (2 hours)
Instructor: Thomas E. Madden, Eastman Kodak Company

The principal objective of color management is to represent, control, and communicate color within and among color-imaging systems. Numerous methods claiming to provide “device-independent” color have not proven in practice to be completely successful. This course sets forth the underlying principles required to understand the successful management of color in imaging systems.

Two fundamentally different methods of representing color images are explored: scene-based and rendered-image-based color encoding. Three basic color-management paradigms describing the different behaviours of various types of color-imaging systems are presented. A unified color-management paradigm is then described which, together with its unique appearance-based color encoding, offers a comprehensive solution to the difficult problem of managing color in today’s complex color-imaging systems.

**Benefits:** Attendees will be able to:
- List and compare the capabilities and limitations in the technologies used in various types of color-managed systems.
- Recognize how the relationship between colorimetry and color appearance can be handled in color-managed systems.
- Describe the properties of a unified color-management paradigm.
- Differentiate the unified paradigm’s appearance-based representation from other color-encoding methods.
- Explain how the unified paradigm can be translated to practical systems.

**Intended Audience:** scientists, engineers, and others interested in and involved with color imaging or color-management products, devices, or systems will benefit from this class. Participants should have some familiarity with basic colorimetry and color-imaging systems.

Thomas Madden is a senior principal scientist and group leader in the Image Science Platform Center at Eastman Kodak Company. He is co-author of Digital Color Management: Encoding Solutions, now in its second edition, a contributing author to other color-imaging texts, and holds numerous patents. Madden is an award-winning instructor at Kodak and a former adjunct instructor at the Rochester Institute of Technology. He is a contributor to numerous publications, and a frequent lecturer at technical symposia, universities, and industries in the US, Canada, and Europe.

**T4A: Introduction to Multispectral Color Imaging**

8:00 – 10:00 am (2 hours)
Instructor: Jon Y. Hardeberg, Gjøvik University College

Conventional color imaging science and technology is based on the paradigm that three variables are sufficient to characterize a color. However, in particular due to the effect of metamerism, three color channels are often insufficient for high quality imaging e.g., for museums and dig-
ital archives. This course introduces the concept of multispectral color imaging, and shows how increasing the number of color channels beyond three can resolve limitations of conventional image capture and reproduction systems. Several practical systems for multispectral color image capture and reproduction are described, along with their strengths and weaknesses. It discusses the calibration and characterization of multispectral color imaging systems, and briefly introduces some of the current research topics in the field.

Benefits: Attendees will be able to:
- Understand the basics of color science, in particular metamerism.
- Decide between 3-color and multispectral approaches.
- Understand the issues and tradeoffs involved in the design and practical realization of multispectral color imaging systems.
- Learn methods to evaluate the performance of multispectral acquisition systems.
- Know where to find more information about this subject, equipment, and tools.

Intended Audience: image scientists, archivists, quality engineers, and others charged with choosing, developing, and managing imaging systems that may require multispectral color image capture and reproduction.

Jon Y. Hardeberg received his PhD from Ecole Nationale Supérieure des Télécommunications, Paris (1999). After a short, but extremely valuable industry career near Seattle, Washington, where he designed, implemented, and evaluated color imaging system solutions for multifunction peripherals and other imaging devices and systems, he joined Gjøvik University College (GUC) in 2001. He is professor of color imaging in the Faculty of Computer Science and Media Technology, and director of the Norwegian Color Research Laboratory. His current research interests include multispectral color imaging, print and image quality, colorimetric device characterization, and color management. His book, Acquisition and Reproduction of Color Images: Colorimetric and Multispectral Approaches is considered a reference title in the area of multispectral color imaging.

T5A: Psychophysics 101 — How to Design Perception Experiments
8:00 – 10:00 am (2 hours)
Instructor: James A. Ferwerda, Rochester Institute of Technology

Psychophysical methods from experimental psychology can be used to quantify the relationships between the properties of images and the attributes people perceive. The results of psychophysical experiments can be used to create predictive models of human perception that can guide the development of effective and efficient color imaging algorithms and enabling interfaces. The course provides an introduction to the use of psychophysical methods in color science and engineering and will teach attendees how to develop experiments that can be used to advance color imaging research and applications. Throughout the presentation, relevant examples are used so that attendees understand how to design and run their own experiments; analyze the results; and develop perceptually-based algorithms and applications.

Benefits: Attendees will be able to:
- Identify the major techniques for measuring perceptual thresholds and scales

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2-hour Short Course Fees
Separate registration is required.

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<th>If you register:</th>
<th>by Oct. 9</th>
<th>after Oct. 9</th>
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<tr>
<td>2-hour Member</td>
<td>$155</td>
<td>$190</td>
</tr>
<tr>
<td>2-hour Non-member</td>
<td>$185</td>
<td>$220</td>
</tr>
<tr>
<td>2-hour Student</td>
<td>$50</td>
<td>$85</td>
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</table>

SPECIAL OFFER: Take 3 or more 2-hour classes and get 20% off the total fee (does not apply to student rates); see page 28 for details.

IS&T/SID reserves the right to cancel classes in the event of insufficient advance registration. Please indicate your interest early.
• Design psychophysical experiments using these techniques.
• Analyze the data from these experiments to derive perceptual metrics.
• Apply this knowledge to practical problems in color and imaging science and engineering.

**Intended Audience:** those who want to be able to interpret the results of perception psychology experiments and develop their own user perception studies. The course assumes a basic level understanding of issues in color imaging science and engineering. Familiarity with freshman-level college math is helpful. No specific knowledge of perception psychology or statistical methods is required. All relevant concepts are introduced in the class.

James A. Ferwerda is an associate professor in the RIT Munsell Color Science Laboratory. He received a BA in psychology, MS in computer graphics, and a PhD in experimental psychology from Cornell University. The focus of his research is on building computational models of human vision from psychophysical experiments, and developing advanced graphics algorithms based on these models. Current research interests include: high dynamic range imaging; perceptually-based rendering; perception of material properties; and low-vision and assistive technologies. In 1992 he received the IEEE Computer Society Paper of the Year Award, and in 2003 he was selected for the National Academy of Engineering Frontiers of Engineering Program. He is an associate editor of ACM Transactions on Applied Perception, was guest editor for a special edition of IEEE Computer Graphics and Applications on Applied Perception, and serves as a member of CIE Technical Committee TC8-08 on High Dynamic Range Imaging.

**10:15 AM – 12:15 PM**

**T1B: Fundamentals of Spectral Measurements for Color Science**

10:15 am – 12:15 pm (2 hours)
Instructor: David R. Wyble,
Rochester Institute of Technology

This short course begins by defining the basic terms surrounding the instruments and quantities used in spectral measurements in the color field. It covers the operation and construction of spectrophotometers and spectroradiometers by discussing the function of each of the various subsystems present in the devices. Instrument standardization and the application of CIE geometries for reflectance and transmittance will be covered. To evaluate instruments, the concepts of precision and accuracy of measurement devices is introduced along with practical suggestions for the analysis of instrument performance. The overall goal is to fully understand the procedures and concepts that lead to proper spectral measurements that are the basis for colorimetric calculations.

**Benefits:** Attendees will be able to:
• Identify the components of spectrophotometers and spectroradiometers and the functions of each.
• Define the standardization process of spectrophotometers and understand the implications of standardization upon the measurement process.
• Interpret measurement requirements and select appropriate measurement parameters and geometries for various applications.
• Understand the point of “hand-off” from spectral measurements to colorimetric calculations.

**Intended Audience:** color engineers and technologists responsible for making and interpreting color measurements of any type. A technical background is not required, although an understanding of basic scientific principles will be very helpful.

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**SHORT COURSE MONITORS NEEDED**

Monitors help with classes and take them for free.

Interested? Contact Diana Gonzalez at CIC@imaging.org
Priority is given to students.
David R. Wyble is a color scientist within the Munsell Color Science Laboratory, part of the Center for Imaging Science at the Rochester Institute of Technology. He holds a BS in computer science and MS and PhD in color science from RIT and Chiba University, respectively. Wyble currently teaches graduate color measurement within MCSL. He has published in the areas of device characterization and color instrumentation. Wyble is active in ISCC and CORM.

T2B: Color Image Compression
10:15 am – 12:15 pm (2 hours)
Instructor: Robert Buckley,
University of Rochester/NewMarket Imaging

Compression is an essential technology in almost all digital image media and applications. This course describes the origins of image compression, many of which can be traced to the 1950’s, and its principles, which are based on information theory and on the properties of images and the human visual system. It shows how those principles apply to the different compression methods and formats in use today, including standard approaches such as JPEG, JPEG 2000, PNG, GIF and MRC. Besides explaining the image types and applications for which each is appropriate, the course also explains the options and features each offers, how they apply to color images and how they may affect color accuracy. The short course uses numerous examples to illustrate the principles and application of color image compression.

Benefits: Attendees will be able to:
- Understand the differences between lossless, visually lossless, and lossy compression and why lossless compression is an oxymoron.
- List the three basic principles of image compression and how they apply to color.
- Understand why a color image that is three times larger than a grayscale image when uncompressed is less than three times larger when compressed.
- Recommend compression methods and parameters to get the desired results with different image types and applications.

Intended Audience: anyone who uses or wants to understand image compression for storing images and wants to know what their options are and what to look for in image compression. Attendees should have some familiarity with the basics of RGB color images.

Robert Buckley is a scientist in the department of Electrical and Computer Engineering at the University of Rochester and the founder of NewMarket Imaging, which works with clients on the capture, preservation, and interchange of digital color images. Formerly a Research Fellow with Xerox Corp., he was a member of the JPEG committee and the editor for Part 6 of the JPEG 2000 standard. He currently chairs the CIE Committee on Archival Color Imaging and is on the Advisory Board of the US Federal Agencies Digitization Guidelines Initiative. He is an IS&T Fellow and its current President.

T3B: Color Gamut Mapping
10:15 am – 12:15 pm (2 hours)
Instructor: Ján Morovic, Hewlett-Packard Española

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. To address color gamut differences, it is necessary to assign reproducible colors to all original ones, which is called gamut mapping. This short course, based on the instructor’s Color Gamut Mapping book, provides an introduction to color reproduction, making the role of gamut mapping explicit in its context, discusses how it is implemented in actual color management systems, and focus on sketching out
the variety of gamut mapping solutions proposed over the last thirty 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.
• Choosing from among the multitude of existing gamut mapping approaches.
• Trace 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: scientists, engineers and creative content creators either designing or working with systems that reproduce color image content in various media; students on courses involving color and imaging components. Knowledge of the fundamentals of colorimetry, color appearance, and color management is assumed, but a brief introduction will be given.

Ján Morovič is a senior color scientist and master technologist at Hewlett-Packard’s Large Format Printing division in Barcelona, Spain. He has a BA (Hons) in print management from the London College of Printing and a PhD in color science from the University of Derby. From 1998-2003 he was lecturer in digital color reproduction at the University of Derby’s Colour and Imaging Institute; he also chaired the CIE’s technical committee on gamut mapping during this period. Since 2003, he has worked at HP on a variety of color reproduction technologies used in current products across their printer portfolio, including HP Professional PANTONE Emulation, HP CMYK Plu, and the color separations and ICC profiling solutions for HP’s 12-ink Z-series Designjet printers. He is the director of CIE Division 8 on Image Technology and is the recipient of the RPS 2003 Selwyn Award.

T4B: Spectral Printing
10:15 am – 12:15 pm (2 hours)
Instructor: Philipp Urban,
Technische Universität Darmstadt

Conventional hardcopy reproduction (e.g., ICC) can have a wide range of colorimetric accuracy and is always constrained by metamerism. For color-critical, scientific, and archival applications, metameric reproduction is often insufficient. Spectral reproduction alleviates these limitations. This short course overviews spectral printer modeling, spectral separation, and spectral gamut mapping.

Benefits: Attendees will be able to:
• Understand the advantages and disadvantages of spectral reproduction compared to metameric reproduction.
• List and compare different spectral printer halftone models.
• Learn about separation techniques for spectral reproduction.
• Become familiar with the foundations of spectral gamut mapping.
• Comprehend the applications of spectral printing and spectral color management.

Intended Audience: for 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, printer designers, and image processing specialists.

Philipp Urban has been the head of the Color Research Group, Institute of Printing Science and Technology, Technische Universität Darmstadt, Darmstadt, Germany, since 2009. His research focuses on spectral-based acquisition, processing, and reproduction of color images considering the limited metameric and spectral gamut and low dynamic range of output devices. From 2006-2008 he...
was a visiting scientist at RIT Munsell Color Science Laboratory, where he developed the first spectral-based copying system especially designed for artwork reproduction. He holds an MS in mathematics from the University of Hamburg and a PhD from the Hamburg University of Technology.

**T5B: Psychophysics Lab: In-Depth and Step-by-Step**

10:15 am – 12:15 pm (2 hours)
Instructor: J.A. Stephen Viggiano, Acolyte Color Research

Learn how to use human observations to assess image quality and get hands-on experience doing it. After an introduction/review of psychometric image preference assessment, complete step-by-step instructions will be given for two different types of experiments. A hands-on experience is the focus of the course. A rank-order and graphical scaling image preference experiment is conducted and analyzed using ordinary spreadsheet software. Error bars are computed and range tests run so that the stimuli may be placed in groups not statistically significantly different from each other.

**Benefits:** Attendees will be able to:
- Construct an image preference scale from a rank-order and graphical scaling experiments.
- Establish statistical significance between different alternatives.
- Understand results of these type of experiments presented by others.
- Recognize the advantages (and disadvantages) of these experiment types over other methods.
- Avoid pitfalls in older analysis methods.

**Intended Audience:** this course assumes no prior experience with psychometric-based image preference/quality assessment; all that’s assumed is a passing familiarity with basic statistics. However, because the focus is hands-on activities, those familiar with psychometrics who wish to bring their knowledge up to date are encouraged to attend. If you’re using paired comparison and want to learn a faster, more efficient way, or if you’ve tried rank-order in the past, but are unfamiliar with modern analysis techniques, or have been wary of unreasonable assumptions (which are avoided in this modern analysis protocol), you should attend this course. Scientific, engineering, and marketing personnel will all benefit from this hands-on experience.

J. A. Stephen Viggiano, PhD, is principal and founder of Acolyte Color Research, a consulting and research firm specializing in solutions to problems in color science and technology, and is also an instructor of data analysis at the School of Mathematical Sciences, Rochester (NY) Institute of Technology. Between 1991 and 2001, Viggiano was a member of the faculty of RIT’s College of Imaging Arts and Sciences. He was also employed by RIT Research Corporation until its closing in 2001, where he had risen to the position of principal imaging scientist. He has presented this workshop as part of graduate-level courses at RIT, as well as for corporate and government clients.

**1:30 – 3:30 PM**

**T1C: Understanding and Handling the Quality of Experience (QoE) for Multimedia Applications**

1:30 – 3:30 pm (2 hours)
Instructor: Chaker Larabi, University of Poitiers

Quality assessment has become a very important issue in the framework of image and video processing, first because of the large availability of multimedia applications and contents, and then because many scientists/engineers need to make a selection of algorithms and tools. For several decades, systems were characterized in terms of quality of service (QoS). The latter is measured using metrics that are specific to the targeted application from a system point of view. However, QoS does not tell anything about the end-user. To cope with this problem, QoE (Quality of Experi-
ence) metrics have been used in the last years because they focus on the end-user/customer experience.

This course is designed to cover several aspects of the field of quality assessment and more specifically the QoE. After a brief introduction about the needs of quality assessment for multimedia applications, a review of the main approaches is made by giving a description of the most used metrics and subjective paradigms and their limitation. The focus of the course is on how to answer these questions: What is QoE for a multimedia application and how to measure it? Which quality procedure for which application and which content? Also, how to guarantee the quality of a system from the end-user point of view? Several practical examples will allow better handling of the quality assessment problem.

Benefits: Attendees will be able to:
- Understand the quality assessment problematic for image and video.
- Understand the difference between QoS and QoE.
- Learn how to integrate QoE in multimedia applications.
- Define a quality assessment procedure based on the targeted application for QoE modeling.
- Study the performance of a multimedia system.

Intended Audience: this course assumes no prior experience with quality assessment (subjective or objective). It is recommended for anyone (scientific, engineering and marketing personnel) looking for a concentrated and precise knowledge on how to assess the quality of a material, an algorithm, an application. Students will benefit from the many examples used to illustrate the different topics of this course.

Chaker Larabi received his PhD from the University of Poitiers (2002). He is currently associate professor, in charge of the perception, color, and quality activity at the same university. He is president of the French National Color Imaging Group (GFINC) founded in 2002. His scientific interests deal with image and video coding and optimization, and more specifically 2D and 3D image and video quality assessment. He works on the Human Visual System modeling (spatial, temporal and spatio-temporal) for the enhancement of several tools such as compression, digital cinema, etc. Larabi is a member of the French National Body for the ISO JPEG committee (since 2000) and chair of the Advanced Image Coding group. He serves as a member of Divisions 1 and 8 of CIE, is a member of IS&T, and a senior member of IEEE.

**T2C: Color Difference**

1:30 – 3:30 pm (2 hours)

Instructor: M. Ronnier Luo, University of Leeds

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 fundamental colorimetry is assumed.

M. Ronnier Luo is a professor of colour and imaging science in 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 is a Fellow of IS&T and the Society of Dyers and Colourists. He is also the recipient of the 2009 and 2004 Gold Medal and Centenary Medal from the Society of Dyers, the 2003 Davies Medal from the Royal Photographic Society of Great Britain, and a 1994 Bartleson Research Award.

T3C: Display Technologies
1:30 – 3:30 pm (2 hours)
Instructor: Erno Langendijk, Philips CL - BG TV Innovation Site Eindhoven

In the last decade, a revolution took place in the display industry. After more than 50 years of CRT domination, PDP and LCD took over as the main display technologies in consumer applications. Yet again, a number of other promising display technologies have seen the light and are ready to enter the consumer market. This short course explains the principles of various new display technologies and elaborates on some more advanced display system solutions improving their performance. It also compares the technologies with each other on a number of aspects, such as front-of-screen performance and power consumption.

Benefits: Attendees will be able to:

- Explain the principles of a number of new display technologies (LCD, PDP, OLED, Electro-Phoretic, Electro Wetting, DLP).
- List the pros and cons of each technology.
- Describe a number of advanced display system solutions (local dimming & boosting, multi-primary, color sequential) and understand how to apply them to the various new display technologies.

Intended Audience: scientists, engineers, managers, and others involved in the design, engineering, manufacturing, marketing, or evaluation of displays. Knowledge of the fundamentals of color perception and color reproduction is assumed.

Erno Langendijk is program manager of the Display Research Program and head of the Department of the Display Partnerships & Research Group in the Philips CL - BG TV Innovation Site Eindhoven. He joined Philips in 2000, first as senior scientist on visual perception, and later as a project leader and principal scientist on architectures of display systems. He holds more than 40 display related patents. Langendijk received his MS in physics from Nijmegen University and his PhD in physics from Delft University. He was General Co-chair of CIC18 and he teaches a display course at Delft University.

T4C: Color in High Dynamic Range Imaging
1:30 – 3:30 pm (2 hours)
Instructor: Greg Ward, Dolby Laboratories

The short course describes the techniques and technologies behind high dynamic range imaging, covering methods for HDR capture, representation, editing, and display. Live demonstrations of HDR image capture using a standard digital camera, and image-based lighting techniques for rendering synthetic objects into a real environment are featured. The course also addresses tone-mapping and gamut-mapping issues for low dynamic range output and printing.
Benefits: Attendees will be able to:

- Compare low dynamic range to high dynamic range imaging.
- Outline basic methods for HDR image capture.
- List major HDR image formats, their strengths and weaknesses.
- Describe the dual-modulation method for HDR image display.
- Summarize the tone-mapping problem as it applies to HDR image printing.
- Define image-based lighting and give examples from recent movies.

Intended Audience: color scientists, software and hardware engineers, photographers, cinematographers, production specialists, and students interested in the means and rewards of extending the dynamic range of their pipeline. By taking the audience from the basics of HDR to more advanced techniques such as image-based lighting, the course hopes to convey the simplicity and power of this exciting new trend in digital imaging.

Greg Ward, a leader in the HDR space, developed the first widely-used high dynamic range image file format in 1986 as part of the RADIANCE lighting simulation system. He developed the LogLuv TIFF HDR image format, the JPEG-HDR format, and authored the application Photosphere, an HDR image builder and browsing program. He’s been involved with Dolby Laboratories’ 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, he 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 the Lawrence Berkeley National Laboratory, EPFL Switzerland, SGI, Shutterfly, and Exponent. Ward holds a BS in physics from UC Berkeley and a MS in computer science from SF State University. He currently works at Dolby Laboratories, Inc. and consults for the Lawrence Berkeley National Laboratory.

3:45 – 5:45 PM
T1D: Spatio-Chromatic Vision Models for Imaging with Applications to the Development of Image Rendering Algorithms and Assessment of Image Quality
3:45 – 5:45 pm (2 hours)
Instructor: Jan Allebach, Purdue University

This course describes the context, structure, and applications of spatio-chromatic vision models for imaging. After a discussion of the framework within which spatio-chromatic vision models are used for the development of image rendering algorithms and as a component in metrics for the assessment of image quality, a brief review of the important characteristics of the visual system and the basic concepts of color science is provided. A general framework for spatio-chromatic vision models that is based on trichromacy, color opponency, and the limited spatial frequency response of the vision system is discussed. This is followed by a discussion on the applications of these models to the development of image rendering algorithms.

Digital color halftoning figures prominently in this part of the course, because this type of rendering algorithm can especially benefit from the application of spatio-chromatic vision models. During the second part of the course, consideration of quality assessment for color images and color imaging systems is discussed, as is examining two fundamentally different approaches to this problem. A more complex group of human vision 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 also introduced. This leads to discussing the potential applications of these models to image quality assessment. The course concludes with a discussion of the concept of similarity in image structure, and how this approach has led to the development of a metric for
image quality that is currently very popular.

Benefits: Attendees will be able to:
• Understand the relationship between image quality metrics and vision models.
• 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 rendering algorithms, and also for image quality assessment.
• Know how spatio-chromatic vision models are related to models for image structure, and can be accounted for in the development of image-structure-based quality measures.

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 Distinguished 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 color measurement, printer and sensor forensics, and digital publishing. Allebach is a Fellow of the IEEE, IS&T, and SPIE. He has served as Distinguished or Visiting Lecturer for both the IEEE Signal Processing Society and IS&T, and served as editor for the Journal of Electronic Imaging from 2000 to 2010. Allebach received the Senior (best paper) Award from the IEEE Signal Processing Society, the Bowman Award and the Itek Award from IS&T, was named 2004 Electronic Imaging Scientist of the Year, and in 2007, was named Honorary Member of IS&T, the highest award that IS&T bestows. From Purdue University, he is co-recipient of the College of Engineering Team Award in recognition of his long-term work with HP, and recipient of the College of Engineering Mentoring Excellence Award, the Sigma Xi Faculty Research Award, the Eaton Faculty Award, and five teaching awards.

T2D: Image Appearance
3:45 – 5:45 pm (2 hours)
Instructor: Mark Fairchild,
Rochester Institute of Technology

This course provides an introduction to image appearance specification and modeling, as well as describes some fundamental phenomena and techniques. Concepts for extending current color appearance models such as CIECAM02 into image appearance models dealing with complex spatial and temporal interactions are discussed, including an introduction of one image appearance framework called iCAM. Digital imaging systems can benefit from accurate and efficient image appearance models to allow rendering of image data on various displays and the specification of image differences and quality.
Benefits: Attendees will be able to:
- Describe the extension of color appearance to image appearance.
- Summarize the framework of image appearance models.
- Develop, implement, and use image difference/quality metrics.
- Understand HDR image/video rendering issues.
- Consider future directions in color and image appearance.
- Judge the utility of image appearance models in their application.

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.

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 color appearance and the formulation of specific models.

T3D: Color Optimization for Displays
3:45 – 5:45 pm (2 hours)
Instructor: Gabriel Marcu, Apple Inc.

This short course introduces color optimization techniques for various display types, covering LCD (transmissive, reflective, and transflective), 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, linearization and gamma correction, gray tracking, color gamut, white point, response time, viewing angle, uniformity, 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 color performances and limitations for various LCD modes (TN, IPS, MVA, FFS, and OCB).
- Select the optimal color model for a display and highlight its dependency on display technology.
- Follow a live calibration and characterization of an LCD screen and of the projector used in the class, using tools varying from visual calibrator to instrument based ones.
- Apply the knowledge from the course to practical problems of color optimization for displays.

Intended Audience: engineers, scientists, managers, pre-press professionals, and those confronting display related color issues.

Gabriel Marcu 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). Marcu is responsible for color calibration and characterization of Apple display products. He has taught seminars and short courses on color topics for UC Berkeley, IMI London, and various IS&T, SPIE, and SID conferences. He was co-chair of the 2006 SPIE/IS&T Electronic Imaging Symposium and of CIC11; he is co-chair of the EI Color Imaging Conference: Displaying, Hardcopy, Processing, and Applications. Marcu is a IS&T and SPIE Fellow.
High-dynamic range (HDR) imaging is a significant improvement over conventional imaging. After a description of the dynamic range problem in image acquisition, this course focuses on standard methods of creating and manipulating HDR images, replacing myths with measurements of scenes, camera images, and visual appearances. In particular, the course presents measurements about the limits of accurate camera acquisition and the usable range of light for displays of our vision system. Regarding our vision system, the course discusses the role of accurate vs. non-accurate luminance recording for the final appearance of a scene, presenting the quality and the characteristics of visual information actually available on the retina. It ends with a discussion of the principles of tone rendering and the role of spatial comparison.

Benefits: Attendees will be able to:
- Explore the history of HDR imaging.
- Understand dynamic range and quantization: the ‘salame’ metaphor.
- Compare single and multiple-exposure for scene capture.
- Measuring optical limits in acquisition and visualization.
- Discover relationship between HDR range and scene dependency; the effect of glare.
- Explore the limits of our vision system on HDR.
- Calculate retinal luminance.
- Put in relationship the HDR images and the visual appearance.
- Identify tone-rendering problems and spatial methods.
- Verify the changes in color spaces due to dynamic range expansion.

Intended Audience: color scientists, software and hardware engineers, photographers, cinematographers, production specialists, and students interested in using HDR images in real applications.

Since 1990, Alessandro Rizzi has been researching in the field of digital imaging and vision. His main topic is the use of color information in digital images with particular attention to color perception mechanisms. He is associate professor in the Department of Information Science and Communication at the University of Milano, teaching Fundamentals of Digital Imaging, Multimedia Video, and Human-Computer Interaction. He is one of the founders of the Italian Color Group and a member of several conferences program committees related to color and digital imaging.
Technical Program

Wednesday November 9, 2011

8:30 – 9:35 AM
WELCOME REMARKS AND KEYNOTE
Session Chairs: James A. Ferwerda, Munsell Color Science Lab/RIIT, and Geoff J. Woollfe, Canon Information Systems Research Australia Pty. Ltd.

Color Responses of the Human Brain Explored with fMRI, Kathy Mullen, McGill University (Canada)

9:35 – 10:35 AM
COLOR AND PERCEPTION
Session Chair: François Viénot, Muséum National D’Histoire Naturelle

(How) Do Observer Categories based on Color Matching Functions Affect the Perception of Small Color Differences?, Maria Fedutina¹, Abhijit Sarkar², Philipp Urban¹, and Patrick Morvan²; ¹Technische Universität Darmstadt (Germany) and ²Technicolor Research (France)
A Study on Spectral Response for Dichromatic Vision, Hiroaki Kotera, Kotera Imaging Laboratory (Japan)
Saliency as Compact Regions for Local Image Enhancement, Clement Fredembach, Canon Information Systems Research Australia (Australia)

11:15 AM – 12:10 PM
IMAGE QUALITY
Session Chair: Joyce Farrell, Stanford University

The Perception of Chromatic Noise on Different Colors, Hideyasu Kuniba, Nikon Corporation (Japan)
Predicting Image Differences based on Image-Difference Features, Ingmar Lissner, Jens Preiss, and Philipp Urban, Technische Universität Darmstadt (Germany)

Comparing a Pair of Paired Comparison Experiments: Examining the Validity of Web-based Psychophysics, Michael D. Harris, Jakkarin Singnoo, and Graham D. Finlayson, University of East Anglia (UK)

12:15 – 12:50 PM
SHORT PAPER SESSION 1
Session Chairs: Nicolas Bonnier, Océ Print Logic Technologies, and Yonghui Zhao, Xerox Corporation

Automatic Selection of Scanner Color Profiles, Miguel A. López-Álvarez, Johan Lammens, and Michel Encrenaz, Hewlett-Packard Corp. (Spain)
Evaluation of Incomplete Paired-Comparison Experiments, Yuan Li, Stephen Westland, and Vien Cheung, University of Leeds (UK)
The Significance Testing of a Skewed Color-Imaging Data Set, Mohsen Mohammadzadeh, Tarbiat Modares University (Iran); and Maryam Mohammadzadeh and Stephen Westland, University of Leeds (UK)
Removing Background Color from Blueprints, Martí María and Miguel A. López-Álvarez, Hewlett-Packard Corp. (Spain)
Using ICC Profiles for Determining Pigment Concentrations, Farhad Moghareh Abed and Ray S. Berns, Rochester Institute of Technology (USA)

2:15 – 3:35 PM
COLOR RENDERING INDEX SPECIAL SESSION
Session Chair: Lorne Whitehead, University of British Columbia

Recent Developments in Colour Rendering Indices and Their Impacts in Viewing Graphic Printed Materials, Yi-Fan Chou¹, Janos Schanda², and M. Ronnier Luo¹;
Color Quality of Light Sources with Narrow-band or Discontinuous Spectral Power Distribution, Wendy Davis and Yoshi Ohno, National Institute of Standards and Technology (USA)

Appearance Degradation and Chromatic Shift in Energy-Efficient Lighting Devices, Charles E. Hunt, University of California, Davis (USA), and Josep Carreras and Jesús Quintero, Catalonia Institute for Energy Research (Spain)

Consideration of Meta-Standards for Color Rendering Metrics, Lorne A. Whitehead, University of British Columbia (Canada)

A Control Operator for Perceptual Grouping based on the Gestalt Vision’s Theory, Jimmy Nagau¹, Anne-Sophie Capelle Laizié², Jean-Luc Henry², and Christine Fernandez-Maloigne¹; ¹Laboratory XUM-SIC (France) and ²Laboratory LAMIA (French West Indies)

Alternatives to the Third Dimension of Colour Appearance, Yoon-Ji Cho, Li-Chen Ou, and M. Ronnier Luo, University of Leeds (UK)

Locating Unique Hues under Mixed Illumination Conditions in CIECAM02, Kaida Xiao¹, Dimitris Mylonas¹, Chenyang Fu¹, Dimosthenis Karatzas², and Sophie Wuerger¹; ¹University of Liverpool (UK) and ²Computer Vision Centre (Spain)

Techniques to Enhance the Sense of Depth Using Visual Perception Characteristics, Ji-Young Hong, Samsung Advanced Institute of Technology (Korea)

Underwater Color Correction, Thor Olson, Electronics for Imaging (USA)

TangiPaint: A Tangible Digital Painting System, Anthony M. Blatner, Benjamin A. Darling, James A. Ferwerda, and Reynold J. Bailey, Rochester Institute of Technology (USA)

4:55 – 5:55 PM
COLOR RENDERING INDEX PANEL DISCUSSION

Moderator: Mike Brill, Datacolor

Panelists:
Gerard Harbers, Xicato
Steve Paolini, Lunera Lighting
Mark S. Rea, Lighting Research Center, Rensselaer Polytechnic Institute

8:00 – 9:00 PM
WEDNESDAY EVENING TALK

Session Chair: James A. Ferwerda, Munsell Color Science Lab/RIT

Exploring the Fascinating World of Color Beneath the Sea, David Gallo, Woods Hole Oceanographic Institute (USA)

Thursday November 10, 2011

8:30 – 9:35 AM
AWARDS AND KEYNOTE

Session Chair: James A. Ferwerda, Munsell Color Science Lab/RIT

Human Demosaicing Algorithm, David Brainard, University of Pennsylvania (USA)

9:35 – 10:35 AM
COMPUTATIONAL IMAGING

Session Chair: TBA

Image Fusion for Optimizing Gamut Mapping, Peter Zolliker and Zofia Baranczuk, Swiss Federal Laboratory for Materials Testing and Research, Empa (Switzerland); and
Joachim Giesen, Friedrich-Schiller-Universität Jena (Germany)
**Root-Polynomial Colour Correction**, Graham D. Finlayson and Michal Mackiewicz, University of East Anglia; and Anya Hurlbert, Newcastle University (UK)

**Image-Adaptive Color Super-Resolution**, Umamahesh Srinivas¹, Xuan Mo¹, Manu Parmar², and Vishal Monga¹; ¹Pennsylvania State University and ²Qualcomm MEMS Technologies (USA)

**11:15 AM – 12:10 PM**

**COLOR IN DISPLAYS**

Session Chair: Jennifer Gille, Qualcomm QMT

**Two-Field Colour-Sequential Display**, Martin Hammer¹, T. Baar¹,², Y. Zhang¹,³, Karel Hinnen¹, and Erno Langendijk¹; ¹Philips Consumer Lifestyle (the Netherlands), ²Delft University of Technology (the Netherlands), and ³Southeast University (China)

**Efficient Computation of Display Gamut Volumes in Perceptual Spaces**, Carlos Eduardo Rodriguez-Pardo¹, Gaurav Sharma¹, Jon Speigle², Xiao-Fan Feng², and Ibrahim Sezan²; ¹University of Rochester and ²Sharp Labs of America (USA)

**Appearance-based Primary Design for Displays**, Hao Li and Mark D. Fairchild, Rochester Institute of Technology (USA)

**12:15 – 12:50 PM**

**SHORT PAPER SESSION 3**

Session Chairs: Nicolas Bonnier, Océ Print Logic Technologies, and Yonghui Zhao, Xerox Corporation

**Fast Colour Vesselness**, Mark S. Drew¹, Ali Alsam², Ali Madooei¹, and Michael H. Brill³; ¹Simon Fraser University (Canada), ²Sor-Trondelag University College (Norway), and ³Datacolor (USA)

**Colorimetric Characterization of a Film Scanner Using an Extremely Reduced Training Data Set**, Jean-Baptiste Thomas, Université de Bourgogne, and Clotilde Boust, Centre de Recherche et de Restauration des Musées de France (France)

**Color QR Codes: Increased Capacity via Per-Channel Data Encoding and Interference Cancellation**, Orhan Bulan, Henryk Blasinski, and Gaurav Sharma, University of Rochester (USA)


**A 3D Interface for Selecting Household Paint Colors**, Seth Berrier, Gary Meyer, and Maximilian Montgomery, University of Minnesota (USA)

**Intersecting Color Manifolds**, Brian Funt and Hamid Mirzaei, Simon Fraser University (Canada)

**2:15 – 3:35 PM**

**HIGH DYNAMIC RANGE IMAGING SPECIAL SESSION**

Session Chairs: Anders Ballestad, Dolby Canada Corporation, and Madhi Nezamabadi, Dolby Laboratories, Inc.

**Tone Reproduction and Color Appearance Modeling: Two Sides of the Same Coin?**, Erik Reinhard, University of Bristol (UK)

**HDR Video: Capturing and Displaying Dynamic Real-world Lighting**, Alan Chalmers, University of Warwick (UK)

**High Dynamic Range Displays and Low Vision**, James A. Ferwerda, Munsell Color Science Laboratory (USA)

**Appearance at the Low-Radiance End of HDR Vision: Achromatic and Chromatic**, John McCann, McCann Imaging (USA)

**4:10 – 4:50 PM**

**SHORT PAPER SESSION 4**

Session Chairs: Nicolas Bonnier, Océ Print Logic Technologies, and Yonghui Zhao, Xerox Corporation

**Display Considerations for Improved Night Vision Performance**, Rafal Mantiuk¹,², Allan Rempel², and Wolfgang Heidrich²; ¹Bangor University (UK) and ²The University of British Columbia (Canada)

**Reconstruction of Super Resolution High**
Dynamic Range Image from Multiple-Exposure Images, Tae-Hyoung Lee, Ho-Gun Ha, and Yeong-Ho Ha, Kyungpook National University (Korea)

Dynamic Patch Optimization for Color Printer Characterization, Yonghui Zhao and Raja Bala, Xerox Corp. (USA)

Adaptively Selecting a Printer Profile, Kristyn Falkenstern¹,², Nicolas Bonnier¹, Hans Brettel³, and Françoise Viénot³,⁴; ¹Océ Print Logic Technologies S.A., ²Institut Telecom, Telecom ParisTech, LTCI CNRS, ³Muséum National d’Histoire Naturelle, and ⁴Centre de Recherche sur la Conservation des Collections (France)

Preferred Skin Colours of African, Caucasian, and Oriental, Huanzhao Zeng, Hewlett-Packard Company (USA), and M. Ronnier Luo, University of Leeds (UK)

Comparing Automated and Human Ratings of Photographic Aesthetics, Ramakrishna Kakarala, Todd S. Sachs, and Vittal Premachandran, Nanyang Technological University (Singapore)

**Friday November 11, 2011**

8:40 – 9:35 AM

**KEYNOTE**

Session Chairs: Geoff J. Woolfe, Canon Information Systems Research Australia Pty. Ltd., and James A. Ferwerda, Munsell Color Science Lab/RIT

The Challenge of our Known Knowns, Robert G. W. Hunt, consultant, and Michael Pointer, University of Leeds and the University of the Arts, London (UK)

9:35 – 10:35 AM

**AESTHETICS COLOR**

Session Chair: Jan Allebach, Purdue University

A Study on Perceptually Coherent Distance Measures for Color Schemes, Sandra Skaff¹, Luca Marchesotti², Gabriela Csurka², and Craig Saunders²; ¹Xerox Research Centre Webster (USA) and ²Xerox Research Centre Europe (France)

Effects of Skin Tone and Facial Characteristics on Perceived Attractiveness: A Cross-Cultural Study, Yinqiu Yuan, Li-Chen Ou, and M. Ronnier Luo, University of Leeds (UK)

Image Color Transfer with Naturalness Constraints, Xuemei Zhang, Apple Inc.; Hui Chao, Qualcomm; and Dan Tretter, Hewlett-Packard Laboratories (USA)

11:15 AM – 12:10 PM

**MISCELLANEOUS COLOR CURIOSITIES**

Session Chair: Michael Pointer, University of Leeds and the University of the Arts, London

The Influence of Speed and Amplitude on Visibility and Perceived Subtlety of Dynamic Light, Michael J. Murdoch, Pieter Seuntiens, and Dragan Sekulovski, Philips Research Europe (the Netherlands)

Blackness: Preference and Perception, L. Tao, Stephen Westland, and Vien Cheung, University of Leeds (UK)

Evaluating the Perceived Quality of Soft-copy Reproductions of Fine Art Images with and
A Portable Spectro-Photo/Radio-Metric Camera with Spatial Filtering for VIS-NIR Imaging, Fernando Fermi¹, Andrea Della Patria², Claudio Oleari¹, Angela Piegari³, and Anna Sytchkova²; ¹Parma University, ²CNR-Istituto Nazionale di Ottica, and ³ENEA-Optical Coatings Lab. [Italy]

Optimizing Spectral Color Reproduction in Multiprimary Digital Projection, David Long and Mark Fairchild, Rochester Institute of Technology [USA]

Color Signal Estimation in High Dynamic Range Scenes, Keita Hirai and Shoji Tominaga, Chiba University [Japan]

An Efficient Designing Method of Spectral Distribution of Illuminant for the Enhancement of Color Discrimination, Tohru Himeno, Ken Nishino, and Shigeki Nakauchi, Toyohashi University of Technology [Japan]

Hybrid Resolution Spectral Imaging by Class-based Regression Method, Yuni Murakami, Masahiro Yamaguchi, and Nagasaki Ohyama, Tokyo Institute of Technology [Japan]

Bidirectional Reflectance and Texture Database of Printed Special Effect Colors, Katharina Kehren, Philipp Urban, and Edgar Dörsam, Technische Universität Darmstadt [Germany]

Real-Time Multi-Spectral Rendering with Complex Illumination, Benjamin A. Darling, James A. Ferwerda, Roy S. Berns, and Tongbo Chen, Rochester Institute of Technology [USA]

Spectral Estimation of Fluorescent Objects Using Visible Lights and an Imaging Device, Shoji Tominaga, Takahiko Horiiuchi, and Toshiya Kamiyama, Chiba University [Japan]

Choosing Optimal Laser Scanner Wavelengths for Colour Image Accuracy, Lindsay MacDonald, University College London [UK]

Saliency-based Band Selection for Spectral Image Visualization, Steven Le Moan¹,², Alamin Mansouri¹, Jan Y. Hardeberg², and Yvon Voisin¹; ¹Université de Bourgogne (France) and ²Gjøvik University College (Norway)
**CIC19 Hotel Information**

**Reservations Deadline: October 15, 2011**

**The Sainte Claire**
www.larkspurhotels.com/collection/sainte-claire  
302 South Market Street, San Jose, CA  
Telephone 408/295-2000; toll free reservations 1-866-870-0726

Reservations may be made online by going to the hotel website and entering the Group Code: GCCOR2  
or clicking on the link at www.imagining.org/ist/Conferences/cic/index.cfm

A special block of rooms at a discounted rate ($135) is being held at the Sainte Claire hotel for the nights of November 4-12, 2011. The discounted rate will be honored for three days before and after these dates based on availability. To guarantee a room, make your reservation online as noted above; or call the hotel directly and identify yourself as part of the “IS&T Color and Imaging Conference” (Group Code: GCCOR2). Reservations made after October 15, 2011 will receive the group rate based on availability.

A credit card guarantee is required to secure each reservation and 72 hours advance notice is required to cancel a room without penalty of one night’s room and tax. An early departure fee of $50.00 applies for changes in the departure date made after arrival.

**Check in time: 3:00 pm  Checkout time: noon**

Room rates: $135 single/double + 14.075% occupancy tax + $2.00 per night  
Internet access is complimentary  
Valet parking is available for $21/day with unlimited in/out privileges

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**Transportation Information**

**Flying to San Jose:** Mineta San Jose International Airport (SJC) is conveniently located ~4 miles from the Sainte Claire hotel. There are direct flights from 22 US cities including Boston, Chicago, Los Angeles, New York, and Phoenix. You may also choose to fly into San Francisco International (SFO), which is ~1 hour drive (37 miles) north of San Jose.

Shuttles from SJC charge approximately $19 one way; taxis to downtown charge $15-$18. SuperShuttle (www.supershuttle.com) is one service that allows you to book online.

Shuttles from SFO are approximately $39 one way.

For more information on flights and transportation service to/from SJC, visit www.flysanjose.com.

For more information on flights and transportation service to/from SFO, visit www.flysfo.com.
**CIC19 Conference Registration**

Go to [www.imaging.org/ist/conferences/CIC](http://www.imaging.org/ist/conferences/CIC) to register online.

Name

Title/Position

Company

Mailing Address

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**Conference Registration (CHECK ONE)**

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☑️ Please check here if you you are an author on a paper.

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

After October 9, add $50 to the appropriate fee below.

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After October 9, add $35 to the appropriate fee below.

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Check all that apply:

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- T3A
- T3B
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- T4A
- T4B
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- T5A
- T5B

**Take three or more classes and receive 20% off the total price**

(enter three or more two-hour courses, fill in member or non-member fee next to each, add together, and multiply by .80 to get your price, representing 20% savings; add additional lines if needed; students may not take advantage of this offer)

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**Nineteenth Color and Imaging Conference**

**ISCC/IS&T/SID Special Topics Meeting**

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Note that registration includes lunch. Non-member registration includes membership through December 2012. After October 9, add $50 to the appropriate fee below; $50 fee does not apply to students.

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

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<td>Extra copy of CIC19 Proceedings</td>
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**Spouse/Guest Tickets**

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<td>Admission to CIC19 Welcome and Conference Receptions</td>
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Name/Affiliation of Guest for badge:

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<td>IS&amp;T new membership (join now; your membership is good until 12/12)</td>
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<td>IS&amp;T membership renewal (expires 12/31/12)</td>
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<tr>
<td>Student membership (expires 09/30/12)</td>
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Members receive one complementary online journal; you may purchase a hard copy or online subscription in addition to your complementary online journal. Please select one complementary online journal:

- [ ] JIST (Journal of Imaging Science and Technology)
- [ ] JEI (Journal of Electronic Imaging)

Indicate additional subscriptions here:

- [ ] hard copy JIST $55 $70 $ 
- [ ] hard copy JEI $55 $55 $ 
- [ ] Online subscription to JIST $55 $55 $ 
- [ ] Online subscription to JEI $55 $55 $ 

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or fax to 703/642-9094  

register online at www.imaging.org/ist/conferences/cic

Please note: To cover bank charges and processing fees, there is a cancellation fee of $75 until November 6, 2011. After that date, the cancellation fee is 50% of the total plus $75. All requests for refund must be made in writing. No refunds will be given after December 6, 2011.
Become part of the CIC online community!
Search Facebook or LinkedIn groups for "color imaging conference"