

A Week of Color in Paris

www.imaging.org/color

early reg deadline: 22 Sept 2019

CIC27

October 21–25, 2019

Paris, France

#CIC27



Material Appearance Workshop



MCS 2019: 20th International Symposium on
Multispectral Colour Science



imaging.org

Sponsored by Society for Imaging Science and Technology

PRELIMINARY PROGRAM

Twenty-seventh Color and Imaging Conference

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Cooperating Societies

- Comité del Color
- European Optical Society (EOS)
- The Finnish Color Association
- Forum Farge
- The French Color Imaging Group
- German Society for Color Science and Application (DfWG)
- GI Fachbereich Graphische Datenverarbeitung
- Gruppo del Colore-Associazione Italiana Colore
- IOP Printing and Graphics Science Group
- Imaging Society of Japan (ISJ)
- Inter-Society Color Council (ISCC)
- NOBIM (Norwegian Association for Image Processing and Pattern Recognition)

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Apple Inc. (US)

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CONFERENCE SPONSOR

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Reality Labs

CONFIRMED EXHIBITORS

as of June 27, 2019



- Swedish Colour Centre Foundation
- The Colour Group (Great Britain)
- The Royal Photographic Society of Great Britain/Imaging Science Group
- Society of Motion Picture and Television Engineers (SMPTE)

CIC27 JIST-first Associate Editors

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Rochester Institute of Technology (US)

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+ those with (*) above



Twenty-seventh Color and Imaging Conference

Color Science and Engineering Systems, Technologies, and Applications

A Week of Color in Paris

Join us in Paris, “the city of light”, for a week of color-related courses, workshops, paper presentations, exhibits, and interesting conversations around technical topics and application areas related to color and imaging!

I’ve attended every CIC since CIC13 in 2005. I first came to the conference as a young PhD student, monitored nearly every course CIC had to offer, and have learned so much throughout the years. I’m now truly humbled to serve as the general chair of this 27th year, and am very excited to welcome you to my hometown!

The conference begins with two days of extensive short courses on a wide range of topics, as well as an intensive one-day introduction to color science course and a workshop organized by GDR on material appearance. On Tuesday, we offer four participant-generated workshops designed to allow a deeper dive into specific color arenas.

The conference committee has put together a very strong technical program with 31 oral papers, 3 invited talks, and 41 interactive (poster) papers, providing a great opportunity to learn, discuss, and share knowledge. In addition, we are thrilled to host three outstanding keynote speakers:

- Dr. Marina Zannoli, vision scientist in the Display Systems Research group at Facebook Reality Labs, focusing on the perception-centered development of AR/VR displays.
- Dr. Beau Watson, chief vision scientist at Apple Inc., revealing the chromatic pyramid of visibility.
- Dr. Panagiotis-Alexandros Bokaris, augmented reality research engineer at L’Oréal, enlightening us with “Let there be light: An AR immersive experience”.

Long coffee breaks and lunches, plus the Welcome and Conference Receptions, provide the perfect time to meet new associates, reconnect with friends, and delve into the many exciting topics related to color and imaging.

Please help us get the word out about this amazing annual event and prepare yourself for a great week in Paris. We’re looking forward to seeing you and enjoying an excellent conference together!

—Nicolas Bonnier
General Chair CIC27

Conference At-a-Glance

Monday 21 October

Registration open 7:00 – 15:30

- Color and Imaging one-day short course (separate fee required), see page 10
- Short Courses Day 1 (separate fees required), see page 10
- Material Appearance Symposium, see page 3

Tuesday 22 October

Registration open 7:00 – 16:00

- Short Courses Day 2 (separate fee required), descriptions begin on page 10
- Workshop Program, see page 22
 - Future Directions in Image Quality
 - Lighting and Chromatic Adaptation
 - The Art and Science of High-End Digital Color Print-Making
 - Cultural Heritage Digitalization
- Welcome Reception, location TBA

Wednesday 23 October

Registration open 8:00 – 16:20

- Opening Keynote: Perception-Centered Development of Near-Eye Displays, Marina Zannoli (Facebook Reality Labs), see page 4
- Exhibition
- Technical Sessions
 - Lighting
 - Chromatic Adaptation
 - Material Appearance
 - Printing
 - Interactive Paper Previews I

EXHIBIT AT CIC27!

Interested in exhibiting or sponsoring an event at CIC? Contact Donna Smith to learn more: dsmith@imaging.org.

VENUE AND TRAVEL LOGISTICS

All CIC events take place at

Centre International de Conférences
Sorbonne Universités (CICSU)
4 place Jussieu, Patio 44–55
75005 Paris

unless otherwise noted. CICSU is in the Quartier Latin, 5e Arrondissement.

There is no conference hotel; attendees are asked to make their own travel and lodging arrangements. Please feel free to contact the IS&T office if you'd like any guidance or advice: info@imaging.org.

Thursday 24 October

Registration open 8:30 – 15:30

- Keynote: The Chromatic Pyramid of Visibility, Andrew “Beau” Watson (Apple Inc.), see page 6
- Exhibition
- Technical Sessions
 - Color Perception
 - Color Appearance
 - Interactive Paper Previews II
- Interactive (Poster) Paper Session
- Invited Focal on Imaging and Art: Scientific Imaging for Cultural Heritage, Clotilde Boust (Centre de recherche et de restauration des musées de France)
- Conference Reception, location TBA

Friday 25 October

Registration open 8:30 – 12:40

- Keynote: Let There Be Light: An AR Immersive Experience, Panagiotis-Alexandros Bokaris (L'Oréal), see page 9
- IS&T Honors and Awards Presentations
- Technical Sessions
 - Displays
 - Applications & Analysis
 - MCS 2019
- Best Student Paper Award Presentation



Conference Program

Monday 21 October 2019

8:00 – 17:45

SHORT COURSE PROGRAM

Featuring fundamental and advance-topic classes, see page 10 for details. Classes require an additional fee; you do not need to register for the conference to attend classes.

MATERIAL APPEARANCE WORKSHOP

Organized by GDR APPAMAT

This workshop looks at the different disciplinary fields around the appearance of materials, surfaces, and objects and how to measure, model, and reproduce them. More information at bit.ly/CIC27_MAWS.



Tuesday 22 October 2019

8:00 – 15:30

SHORT COURSE PROGRAM

Descriptions begin on page 10. Classes require an additional fee; you do not need to register for the conference to attend classes.

15:45 – 18:15

CIC27 WORKSHOPS

- W1: Future Directions in Image Quality
- W2: Lighting and Chromatic Adaptation
- W3: The Art and Science of High-End Digital Color Print-Making
- W4: Cultural Heritage Digitalization

See page 22 for details. A workshop is included with each full conference registration. You may also sign up for workshops and not attend the conference. See registration form for details.

18:15 – 19:45

WELCOME RECEPTION

Location TBA

Wednesday 23 October 2019

9:00 – 10:00

WELCOME AND OPENING KEYNOTE

Perception-Centered Development of Near-Eye Displays, Marina Zannoli, Facebook Reality Labs (US)

10:00 – 10:40

LIGHTING

CIC Best Paper Award Color Temperature

Tuning: Allowing Accurate Post-capture

White-balance Editing, Mahmoud Afifi, Abhijith Punnappurath, Abdelrahman Abdelhamed, Hakki Can Karaimera, Abdullah Abuolaim, and Michael S. Brown, York University (Canada)

Coupled Retinex, Javier Vazquez-Corral and Graham D. Finlayson, University of East Anglia (UK)

11:20 – 12:50

CHROMATIC ADAPTATION

Time Course of Chromatic Adaptation under

Dynamic Lighting, Rik Spieringhs¹, Michael Murdoch², and Ingrid Vogels¹; ¹Eindhoven University of Technology (the Netherlands) and ²Rochester Institute of Technology (US)

Degree of Chromatic Adaptation under

Adapting Conditions with Different Luminance and Chromaticities, Siyuan Chen and Minchen Wei, Hong Kong Polytechnic University (Hong Kong)

Evaluation and Modification of von Kries Chromatic Adaptation Transform,

Shining Ma¹, Peter Hanselaer¹, Kees Teunissen², and Kevin Smet¹; ¹KU Leuven (Belgium) and ²Signify (the Netherlands)

Colors and Emotions (Invited), Christine Fernandez-Maloigne, University of Poitiers (France)

12:50 – 14:00

LUNCH ON OWN

14:00 – 15:00

MATERIAL APPEARANCE

JIST-FIRST Detecting Wetness on Skin using RGB Camera, Mihiro Uchida and Norimichi Tsumura, Chiba University (Japan)

Perceived Glossiness: Beyond Surface

Properties, Davit Gigilashvili, Jean-Baptiste Thomas, Marius Pedersen, and Jon Yngve Hardeberg, Norwegian University of Science and Technology (Norway)

Appearance Perception of Textiles: A

Texture Study, Fereshteh Mirjalili and Jon Yngve Hardeberg, Norwegian University of Science and Technology (Norway)

15:00 – 15:40

TWO-MINUTE INTERACTIVE (POSTER) PAPER PREVIEWS I**The Importance of a Device Specific**

Calibration for Smartphone Colorimetry, Miranda Nixon, Felix Outlaw, Lindsay MacDonald, and Terence Leung, University College London (UK)

Jointly Design Plane-dependent FM Screens

Sets using DBS Algorithm, Yi Yang and Jan Allebach, Purdue University (US)

Color Processing and Management in Ghostscript, Michael Vrhel, Artifex Software (US)

An Evaluation of Colour-to-Greyscale Image Conversion by Linear Anisotropic Diffusion and Manual Colour Grading, Aldo Barba Ramirez, Marius Pedersen, and Ivar Farup, Norwegian University of Science and Technology (Norway)

Developing a Visual Method to Characterize Displays, Yu Hu, Ming Ronnier Luo, Baiyue Zhao, and Mingkai Cao, Zhejiang University (China)

A Testing Paradigm for Quantifying ICC Profilers, Pooshpanjan Roy Biswas, Alessandro Beltrami, and Joan Saez Gomez, HP Printing and Computing Solutions (Spain)

Beyond raw-RGB and sRGB: Advocating Access to the Colorimetric Image State, Hakki Karaimer and Michael Brown, York University (Canada)

Skin Balancing: Skin Color Based Calibration

OPENING KEYNOTE

Perception-Centered Development of Near-Eye Displays, Marina Zannoli, Facebook Reality Labs (US)

To create compelling mixed reality experiences, we need to better understand what it means to be an active observer in a complex environment. In this talk, I make the case that building mixed reality technology that seamlessly interfaces with our sensorimotor system allows for immersive and comfortable experiences. First, I present a theoretical framework that describes how mixed-reality technologies interface with our sensorimotor system. Then, I show how we can use knowledge about the human visual system to develop novel image quality metrics for near-eye displays. Finally, I describe how the Display Systems Research group at Facebook Reality Labs develops image quality metrics, testbeds, and prototypes to define requirements for future AR/VR displays. More specifically, I present a series of head-mounted prototypes, rendering techniques, and benchmark testbeds that explore various paths to support focus cues in near-eye displays.

for Portrait Images to Enhance the Affective Quality, Yuchun Yan and Hyeon-Jeong Suk, KAIST (South Korea)

On an Euler-Lagrange Equation for Color to Gray-scale Conversion, Hans Jakob Rivertz, Norwegian University of Science and Technology (Norway)

Conceptualization of Color Temperature Scenario Applied to Quality Lighting Design, Estelle Guerry, Céline Caumon, Georges Zissis, Elodie Bécheras, and Laurent Canale, Université de Toulouse (France)

Effects of Black Luminance Level on Image Quality, Ye Seul Baek and Youngshin Kwak, Ulsan National Institute of Science and



Technology, and Sehyeok Park, Samsung Electronics (South Korea)

Evaluating Colour Constancy on the New MIST Dataset of Multi-illuminant Scenes,

Xiangpeng Hao, Brian Funt, and Hanxiao Jiang, Simon Fraser University (Canada)

Styling of Refrigerator Lighting by Altering its Chromaticity and Placement,

Kyeong Ah Jeong and Hyeon-Jeong Suk, KAIST (South Korea)

Analysis of Relationship Between Wrinkle Distribution and Age based on the Components of Surface Reflection by Removing Luminance Unevenness on the Face,

Ikumi Nomura¹, Kaito Iuchi¹, Mihiro Uchida¹, Nobutoshi Ojima², Takeo Imai², and Norimichi Tsumura¹; ¹Chiba University and ²Kao Corporation (Japan)

Illuminance Impacts Opacity Perception of Textile Materials,

Davit Gigilashvili, Fereshteh Mirjalili, and Jon Yngve Hardeberg, Norwegian University of Science and Technology (Norway)

Impact of Shape on Apparent Translucency Differences,

Davit Gigilashvili¹, Philipp Urban^{1,2}, Jean-Baptiste Thomas¹, Jon Yngve Hardeberg¹, and Marius Pedersen¹; ¹Norwegian University of Science and Technology (Norway) and ²Fraunhofer Institute for Computer Graphics Research IGD (Germany)

Line Spread Function of Specular Reflection and Gloss Unevenness Analysis,

Shinichi Inoue and Norimichi Tsumura, Chiba University (Japan)

Removing Gloss using Deep Neural Network for 3D Reconstruction,

Futa Matsushita, Ryo Takahashi, Mari Tsunomura, and Norimichi Tsumura, Chiba University (Japan)

Estimating Concentrations of Pigments using Encoder-decoder Type of Neural Network,

Kensuke Fukumoto and Norimichi Tsumura, Chiba University (Japan), and Roy Berns, Rochester Institute of Technology (US)

Color Space Transformation using Neural Networks,

Lindsay MacDonald, University College London (UK), and Katarina Mayer, ESET (Slovakia)

CONVENE A CONVERSATION

Want to find others at CIC interested in a technical topic not covered at CIC that you'd like to discuss more? Convene a group during a coffee break. Contact color@imaging.org for details.

16:20 – 17:40

PRINTING

JIST-FIRST Angular Color Prediction Model for Anisotropic Halftone Prints on a Metallic Substrate,

Petar Pjanic, ESRI R&D (Switzerland); Li Yang and Anita Teleman, RISE (Sweden); and Roger D. Hersch, Ecole Polytechnique Federale de Lausanne (Switzerland)

Printing with Light: Daylight-fluorescent Inks for Large-gamut Multi-color Printing,

Peter Morovic¹, Jan Morovic², Peter Klammer³, Javier Maestro¹, Garry Hinch³, and James Stasiak³; ¹HP Inc. (Spain), ²HP Inc. (UK), and ³HP Inc. (US)

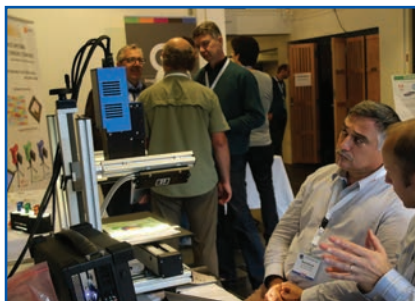
Estimation of Layered Ink Layout from Arbitrary Skin Color and Translucency in Inkjet

3D Printer, *Junki Yoshii¹, Shoji Yamamoto², Kazuki Nagasawa¹, Wataru Arai³, Satoshi Kaneko³, Keita Hira¹, and Norimichi Tsumura¹;*

¹Chiba University, ²Tokyo Metropolitan College of Industrial Technology, and ³Mimaki Engineering Corporation (Japan)

A Psychovisual Study of Print Smoothness

via Metameric Samples, *Sergio Etchebehere and Peter Morovic, HP Inc. (Spain), and Jan Morovic, HP Inc. (UK)*



Thursday 24 October 2019**9:00 – 10:00****THURSDAY KEYNOTE**

The Chromatic Pyramid of Visibility, Andrew B. Watson, Apple Inc. (US)

10:00 – 12:00**COLOR PERCEPTION**

Modelling the Simultaneous Colour Contrast Effect, Yuechen Zhu and Ming Ronnier Luo, Zhejiang University (China)

Perceptual Estimation of Diffuse White Level in HDR Images, Fu Jiang and Mark Fairchild, Rochester Institute of Technology (US), and Kenichiro Masaoka, NHK Science & Technology Research Laboratories (Japan)

Temporary Tritanopia: Effects of Cataract Surgery on Color, John McCann, McCann Imaging (US)

JIST-FIRST Color Vision Differences Following Refractive Detachment and Subsequent Cataract Surgery, Susan Farnand¹, Rajeev Ramchandran², and Mark Fairchild¹;

¹Rochester Institute of Technology and

²University of Rochester (US)

12:00 – 12:45**TWO-MINUTE INTERACTIVE (POSTER) PAPER PREVIEWS II**

Influence of Texture Structure on the Perception of Color Composition, Jing Wang, Bloomberg LP (US); Jana Zujovic, Google (US); June Choi, Accenture (US); Basabdutta Chakraborty, Amway (US); Rene van Egmond and Huib de Ridder, Delft University of Technology (the Netherlands); and Thrasyvoulos N. Pappas, Northwestern University (US)

Chromaticity Coordinates for Graphic Arts based on CIE 2006 LMS with Even Spacing of Munsell Colours, Richard A. Kirk, FilmLight Ltd. (UK)

Impact of Matching Primary Peak Wavelength on Color Matching Accuracy and Observer Variability, Jiaye Li, Kevin Smet, and Peter Hanselaer, KU Leuven (Belgium)

Comparing the Chromatic Contrast

THURSDAY KEYNOTE

The Chromatic Pyramid of Visibility,

Andrew “Beau” Watson, Apple Inc. (US)

The Pyramid of Visibility is a simplified model of the spatio-temporal luminance contrast sensitivity function (Watson and Ahumada 2016). It posits that log sensitivity is a linear function of spatial frequency, temporal frequency, and log luminance. It is valid only away from the spatiotemporal frequency origin. Though very useful in a range of applications, the pyramid would benefit from an extension to the chromatic domain. In this talk, I describe our efforts to develop this extension. Among the issues we address are the choice of color space, the definition of color contrast, and how to combine sensitivities among multiple pyramids.

Sensitivity in Vertical and Oblique

Orientations, Seyed Ali Amirshahi and Marius Pedersen, Norwegian University of Science and Technology (Norway)

Modelling Incomplete Chromatic Adaptation on a Display under Different Ambient Illuminations, Rui Peng¹ and Ming Ronnier Luo^{1,2};

¹Zhejiang University (China) and ²University of Leeds (UK)

Real-world Environment Affects the Color Appearance of Virtual Stimuli Produced by Augmented Reality, Siyuan Chen and Minchen Wei, Hong Kong Polytechnic University (Hong Kong)

Colour Image Enhancement using Perceptual Saturation and Vividness, Muhammad Safdar, Jon Yngve Hardeberg, and Noemie Pozzera, Norwegian University of Science and Technology (Norway)

New Metrics for Evaluating Whiteness of Fluorescent Samples, Xi Lv¹, Yuzhao Wang¹, Minchen Wei², and Ming Ronnier Luo¹;

¹Zhejiang University and ²The Hong Kong Polytechnic University (China)



IMAGING AND ART

Scientific Imaging for Cultural Heritage (Invited Focal), Clotilde Boust, Centre de recherche et de restauration des musées de France (France)

Scientific imaging is an important part of conservation sciences developed in museum laboratories. This is mainly because it is noninvasive, a decisive advantage to studying unique artworks. Various 2D and 3D optical techniques using several radiations (visible, UV, IR, X-rays) lead to a precise state report of the artwork, for color, shape, and surface on first intention. Depending on the object's conservation question, more investigation can be done to detect original or restauration materials or fabrication techniques. Several examples of imaging for art conservation are presented, with a focus on color collections and multimodal images.

No-Reference Image Quality Metric for Tone-Mapped Images, Muhammad Usman Khan, Imran Mehmood, Ming Ronnier Luo, and Muhammad Farhan Mughal, Zhejiang University (China)

Least Squares Optimal Contrast Limited Histogram Equalisation, Jake McVey and Graham Finlayson, University of East Anglia (UK)

Benchmark of Metrics for the Assessment of 360-degree Images Quality, Chaker Larabi, University of Poitiers (France)

Tone Mapping Operators Evaluation Based on High Quality Reference Images, Imran Mehmood, Muhammad Usman Khan, Ming Ronnier Luo, and Muhammad Farhan Mughal, Zhejiang University (China)

Colorimetric Determination of Vanadium in Water Samples, Asli Beyler Çigil, Amasya University, and Oya Aydin Urucu and Emine Arman Kandirmaz, Marmara University (Turkey)

DEMONSTRATION SESSION

Show the hardware, software, test charts, images, etc. that you are working on. Open to all, the Demonstration Session allows attendees to view and interact with "products" discussed during presentations or in the hallways. Demonstrations occur during the Friday morning coffee break. Interested in participating? Contact Donna Smith at dsmith@imaging.org.

New Design of pH-responsive Packaging Materials for Milk, Asli Beyler Çigil, Amasya University, and Memet Vezir Kahraman, Marmara University (Turkey)

Improvement of Blood Pressure Estimation from Face Video using RGB Camera, Ryo Takahashi¹, Kenta Masui¹, Keiko Ochiai-Ogawa², and Norimichi Tsumura¹; ¹Chiba University and ²Kanazawa University Hospital (Japan)

Measuring, Modeling, and Reproducing Material Appearance from Specular Profile, Shoji Tominaga, Norwegian University of Science and Technology (Norway)

MCS 2019 Exposure Invariance in Spectral Reconstruction from RGB Images, Yi-Tun Lin and Graham D. Finlayson, University of East Anglia (UK)

MCS 2019 Estimation of Blood Concentrations in Skin Layers with Different Depths, Kaito Iuchi¹, Rina Akaho¹, Takanori Igarashi², Nobutoshi Ojima², and Norimichi Tsumura¹; ¹Chiba University and ²Kao Corporation (Japan)

MCS 2019 Deep Learning for Dental Hyperspectral Image Analysis, Oleksandr Boiko, Joni Hyttinen, Pauli Fält, Heli Jäsberg, Arash Mirhashemi, Arja Kullaa, and Markku Hauta-Kasari, University of Eastern Finland (Finland)

MCS 2019 Spectral Image Recovery from Spectral Filter Array Cameras using LMMSE, Prakhar Amba and David Alleysson, LPNC, CNRS (France)

MCS 2019 Development of the Stool Color Card for Early Detection of Biliary Atresia using Multispectral Image, Masaru Tsuchida¹, Hideaki Gunji², Hideki Nakajima³, Takahito Kawanishi¹, Kunio Kashino¹, and Akira Matsui³;

¹NTT Corporation, ²Japan Association of Graphics Arts Technology, and ³National Center for Child Health and Development (Japan)

**12:45 – 14:00
LUNCH ON OWN**

**14:00 – 15:20
COLOR APPEARANCE**

Vividness as a Colour Appearance Attribute, Helene Midtjord, Phil Green, and Peter Nussbaum, Norwegian University of Science and Technology (Norway)

Consistent Colour Appearance—A Novel Measurement Approach, Marco Mattuschka, Andreas Kraushaar, and Philipp Tröster, Fogra Forschungsinstitut für Medientechnologien e.V. (Germany)

Change of Color Appearance Due to Extremely High Light Level: Corresponding Colors, Wenyu Bao and Minchen Wei, The Hong Kong Polytechnic University (Hong Kong)

Measurement of CIELAB Spatio-chromatic Contrast Sensitivity in Different Spatial and Chromatic Directions, Vlado Kitanovski¹, Alastair Reed², Kristyn Falkenstern², and Marius Pedersen¹; ¹Norwegian University of Science and Technology (Norway) and ²Digimarc Corporation (US)

**15:20 – 17:00
INTERACTIVE SESSION**

**17:00 – 17:30
IMAGING AND ART**

Scientific Imaging for Cultural Heritage (Invited Focal), Clotilde Boust, Centre de recherche et de restauration des musées de France (France)

**19:00 – 21:00
CONFERENCE RECEPTION**

Join colleagues for a wonderful evening of networking, food, and wine in a special Paris location TBA.

Friday 25 October 2019

**9:00 – 10:10
CLOSING KEYNOTE AND IS&T AND CIC AWARDS**

Let There Be Light: An AR Immersive Experience, Panagiotis-Alexandros Bokaris, L'Oréal (France)

**10:10 – 12:40
DISPLAYS**

Estimating OLED Display Device Lifetime from Pixel and Screen Brightness and its Application, Jeremie Gerhardt¹, Michael E. Miller², Hyunjin Yoo¹, and Tara Akhavan¹; ¹IRYStec Software Inc. (Canada) and ²LodeSterre Sciences, Ltd. (US)

Illuminant Estimation Through a Reverse Calibration of AWB Image That Contains Displays, Taesu Kim, Eunjin Kim, and HyeonJeong Suk, KAIST (South Korea)

Smartphone-based Measurement of the Melanopic Daylight Efficacy Ratio, Marcel Lucassen, Dragan Sekulovski, and Tobias Borra, Signify Research (the Netherlands)

Quantitative Assessment of Color Tracking and Gray Tracking in Color Medical Displays, Wei-Chung Cheng, Chih-Lei Wu, and Aldo Badano, US Food and Drug Administration (US)

Assessing Colour Differences under a Wide Range of Luminance Levels using Surface and Display Colours, Qiang Xu¹, Guihua Cui², Muhammad Safdar³, Ming Ronnier Luo¹, and Baiyue Zhao¹; ¹Zhejiang University (China), ²Wenzhou University (China), and ³COMSATS Institute of Information Technology (Palestine)



2019 Land Medal Winner Camera Optics: The CAOS Camera – Empowering Full Spectrum Extreme Linear Dynamic Range Imaging, Nabeel Riza, *University College Cork (Ireland)*

12:40 – 14:00
LUNCH ON OWN

14:00 – 15:00
APPLICATIONS & ANALYSIS
JIST-FIRST Deep Learning Approaches for Whiteboard Image Quality Enhancement, Mekides Assefa Abebe and Jon Yngve Hardeberg, *Norwegian University of Science and Technology (Norway)*

Analyzing Color Harmony of Food Images, Gianluigi Ciocca, Paolo Napoletano, and Raimondo Schettini, *University of Milano-Bicocca*, and Isabella Gagliardi and Maria Teresa Artese, *National Research Council of Italy (Italy)*

Physical Noise Propagation in Color Image Construction: A Geometrical Interpretation, Axel Clouet and Jérôme Vaillant, *CEA-LETI*, and David Alleysson, *Université Grenoble Alpes (France)*

15:40 – 17:00
20TH INTERNATIONAL SYMPOSIUM ON MULTISPECTRAL COLOUR SCIENCE (MCS 2019)



There are five Interactive (Poster) Papers that are also part of MCS 2019. See page 7.

Polarized Multispectral Imaging for the Diagnosis of Skin Cancer, Laura Rey Barroso¹, Francisco Javier Burgos Fernández¹, Fernando Díaz Douton¹, Sara Peña Gutiérrez¹, Santiago Royo Royo¹, Josep Malvehy Guilera², Susana Puig Sardá², Xana Delpueyo Espanyo¹, Giovanni Pellacani³, and Meritxell Vilaseca Ricart¹; ¹Universidad Politécnica de Cataluña (Spain), ²Clinic Hospital of Barcelona (Spain), and ³Università di Modena e Reggio Emilia (Italy)

CLOSING KEYNOTE

Let There Be Light: “An AR Immersive Experience”, Panagiotis-Alexandros Bokaris, *L’Oréal (France)*

Video-projected augmented reality offers unique immersive experiences while it changes the way we perceive and interact with the world. By projecting on real-world objects we can change their appearance and create numerous effects. Due to physical limitations and the complexity of such AR systems, color calibration, and processing for desired appearance changes require to be specifically addressed.

This talk focuses on the challenging aspects of video-projected AR systems composed of video projectors and cameras: geometric calibration, latency, color calibration, and characterization of desired effects. Such an AR solution developed at L’Oréal is presented to demonstrate applications in beauty industry.

Relative Spectral Difference Occurrence Matrix: A Metrological Spectral-spatial Feature for Hyperspectral Texture Analysis, Rui Jian Chu, Noël Richard, and Christine Fernandez-Maloigne, *Université de Poitiers (France)*, and Jon Yngve Hardeberg, *Norwegian University of Science and Technology (Norway)*

Appearance Reconstruction of Fluorescent Objects based on Reference Geometric Factors, Shoji Tominaga, *Norwegian University of Science and Technology (Norway)*, and Keita Hirai and Takahiko Horiuchi, *Chiba University (Japan)*

17:20 – 17:30
CLOSING REMARKS AND BEST STUDENT PAPER AWARD

CIC27 Short Course Program

MONDAY 21 OCTOBER 2019

EIGHT-HOUR CLASS

SC01: Color and Imaging

8:30 – 17:45 (8 hours)

Instructor: Gaurav Sharma, University of Rochester

Level: Introductory

This course provides a comprehensive introduction to the fundamentals of color perception, measurement, and representation. The course begins with the psychophysics of color, relating physical descriptions of color, through stages of the human visual system, to perceptual attributes of hue, saturation, and lightness. The anatomy and physiology of the visual system stages are briefly described. From there, basic colorimetric and perceptual color representations are developed, with a particular focus on CIE standards such as the CIEXYZ tristimulus space and the CIELAB and CIELUV perceptually uniform color spaces. Chromaticity representations are discussed as convenient 2D visualization tools.

Benefits: Attendees will be able to:

- Describe the basic findings from color matching experiments and the concept of trichromacy.
- Transform between commonly used color space representations.
- Describe how these color representations relate to the stages of the human visual system.
- Discuss chromatic adaptation and its critical role in color perception.
- Understand and differentiate among illuminant, observer, and device metamerism.
- Understand the utility of uniform color spaces and color appearance attributes.

Intended Audience: scientists, engineers, students, and managers involved in the design of color processing algorithms or color imaging systems.

Gaurav Sharma has more than two decades of experience in the design and optimization of color imaging systems and algorithms that spans employment at the Xerox Innovation Group and his current position as a professor at the University of Rochester in the departments of electrical and computer engineering and computer science. Additionally, he has consulted for several companies on the development of new imaging systems and algorithms. He holds 51 issued patents and has authored more than 200 peer-reviewed publications. He is the editor of the Digital Color Imaging Handbook (CRC Press) and served as the editor-in-chief for the IS&T/SPIE Journal of Electronic Imaging (2011-2015). Sharma is a Fellow of IS&T, IEEE, and SPIE.

TWO-HOUR CLASSES

NEW SC02: Solving Color Problems Using Vector Space Arithmetic

8:00 – 10:00 (2 hours)

Instructor: Michael Vrhel, Artifex Software, Inc.

Level: Intermediate

Matrices and vectors have been used for decades to model color technologies. Besides allowing the modeling of complex systems, this notation is readily implemented in vector-based languages like MATLAB. For some, this material can be overwhelming. The goal of the course is to make this approach to color science problems accessible to everyone. We will first review the basics of matrices and vectors including the conditions under which this notation can be used for color systems. Models in the area of color recording, reproduction, measurement, and transformation are covered. Optimization methods are reviewed, including the determi-



MONDAY COURSES / WORKSHOPS

Color Basics	8:30 – 17:45 (TBC) GDR APPAMAT Material Appearance Workshop (bit.ly/CIC27_MAWS)		
	8:30 – 17:45 SC01: Color and Imaging		
Advanced Topics	8:00 – 10:00	10:15 – 12:15	13:30 – 17:45
	NEW SC02: Solving Color Problems Using Vector . . .	SC03: The Art of Making Better Pixels . . .	EXPANDED FOR 2019 SC04: The Human Imaging Pipeline: Color Vision and Visual Processing . . .

TUESDAY COURSES / WORKSHOPS

Color Appearance Viewing & Processing Optimizing Color Color and Cameras	8:00 – 10:00	10:15 – 12:15	13:30 – 15:30	15:45 – 18:15
	SC05: Color and Appearance in 3D Printing	SC09: Characterizing Surface Appearance	REVISED FOR 2019 SC12: Adv. Colorimetry . . .	W1: Future Directions in Image Quality
	SC06: Fundamentals of Psychophysics	REVISED FOR 2019 SC10: Spatial Color Perception . . .	SC13: Color Fundamentals in LED Lighting	W2: Lighting and Chromatic Adaptation
	SC11: Color Optimization for Displays	NEW SC07: Digital Cinema Environment & IQ Evaluation	SC14: Using the New Colour Mgmt Technology, iccMAX . . .	W3: Art & Science of High-End Digital Color Print-Making
	SC08: Camera Color Characterization: Theory and Practice		NEW SC15: Color Imaging Challenges: Mobile Phone Optics	W4: Cultural Heritage Digitalization

nation of closed form solutions. For those problems that cannot be solved directly, numerical methods are required. In these cases, we turn to the use of MATLAB to model example systems. With the models in place, we demonstrate the use of MATLAB's optimization methods to determine a solution.

Benefits: Attendees will be able to:

- Understand the matrix-vector equations often seen at color conferences and in color journals.
- Express their own color systems in terms of vectors and matrices as well as know when it is appropriate to do so.
- Determine closed form solutions to optimization problems in color.
- Implement their models in MATLAB and apply numerical optimization methods.

Intended Audience: engineers, students, and those wishing to have a firmer understanding

of the mathematical modeling and optimization of color systems.

Michael Vrhel has more than 30 years' experience in color imaging. He received a PhD in electrical engineering from North Carolina State University. During his PhD studies he was a Kodak Fellow. He was a research associate with the National Research Council and has held positions at Color Savvy Systems, Conexant Systems, TAK Imaging, Pagemark Technology, and Artifex Software. He is the co-author of The Fundamental of Digital Imaging from Cambridge University Press.

SHORT COURSE MONITORS

Interested in taking a class, but lack funding? Volunteer to be a course monitor. Contact color@imaging.org. Preference given to students.

SC03: The Art of Making Better Pixels: High Dynamic Range Display Concepts and Technologies

10:15 – 12:15 (2 hours)

Instructor: Timo Kunkel, Dolby Laboratories, Inc.

Level: Introductory

The field of High Dynamic Range imaging or HDR was coined more than 20 years ago and has been evolving ever since. Over time, various building blocks have been designed that are suitable to form perceptually-correct, artistically-compelling, and technologically-efficient HDR imaging systems. Now, as those technologies are implemented into an increasing number of mainstream devices, it is important to keep track of several key perceptual and technological concepts in order to avoid pitfalls that can impact image fidelity when processing, transmitting, and displaying HDR imagery. This course is intended as an introduction into HDR display systems and its related imaging pipelines.

Benefits: Attendees will be able to:

- Understand how the human visual system perceives the physical world around us and how HDR display technologies cater to this.
- Assess how we can display a plausible depiction of the ‘real’ physical world and how we convey artistic intent.
- Identify the importance of a display’s white and black levels, its tone response curve, and quantization steps as well as its color volume.
- Explain the fundamentals of common HDR and Wide Color Gamut display technologies such as full array dual modulation, OLED, Quantum Dot, and Mini/MicroLED-based display.
- Differentiate the considerations for creating compelling content that lives up to the capabilities of HDR displays.

Intended Audience: anyone working in image display related fields such as display design, content creation, image transport and broad-

cast, and vision science. No direct previous knowledge is required, but a basic understanding of traditional display and imaging concepts is beneficial.

Timo Kunkel is a senior color and imaging researcher in the CTO office of Dolby Labs, Inc. He has been working with HDR imaging concepts for more than 15 years and his main areas of interest are advanced display and imaging technologies and how we can continue bringing them closer to human perception. He received his PhD in computer science from the University of Bristol (UK) and a MSc from the University of Freiburg (Germany).

FOUR-HOUR CLASS

SC04: The Human Imaging Pipeline: Color Vision and Visual Processing from Optics to Perception Expanded for 2019

13:30 – 17:45 (4 hours)

Instructor: Andrew Stockman, UCL Institute of Ophthalmology

Level: Intermediate

The course covers human color vision and visual processing from the optics of the eye to high-level color perception and cognition. Topics include physiological optics and light, the photoreceptor sensor array, univariance and the trichromacy of human color vision, photoreceptor spectral sensitivities and colour matching, melanopsin and intrinsically photosensitive retinal ganglion cells, color-opponent and non-opponent encoding and processing of color signals after the cone photoreceptors, neural processing of visual signals and parallel pathways from eye to brain, color in the cortex, color after-effects, color constancy, color contrast and assimilation, color categories, and color and cognition. Individual differences and color vision deficiencies, which can substantially affect the individual’s experience are described along with their underlying genetic causes. Best practices are reviewed for using the Stockman & Sharpe (2000) LMS cone fundamentals and XYZ color matching functions that form the new CIE 2006 and



2015 TC 1-36 colorimetry standards. Visual effects and illusions are demonstrated to illustrate many of phenomena discussed.

Benefits: Attendees will be able to:

- Have a fundamental understanding of human color vision and visual processing and its properties, limitations, and individual differences.
- Improve optimization choices amongst sensors, imaging pipelines, and displays.

Intended Audience: scientists and engineers interested in understanding human color vision and visual processing.

Andrew Stockman is the Steers Professor at the UCL Institute of Ophthalmology. His research areas include color vision, rod vision, visual adaptation, and temporal sensitivity. He may be best known for his work with Ted Sharpe on spectral sensitivities and luminous efficiency. He is the principal author of the widely-used colour database at <http://www.cvrl.org>. In 2016 he received the Colour Group Newton medal, and in 2018 the Inter-Society Color Council Macbeth Award.

TUESDAY 22 OCTOBER 2019

TWO-HOUR CLASSES

8:00 – 10:00

SC05: Color and Appearance in 3D Printing

8:00 – 10:00 (2 hours)

Instructor: Philipp Urban, Fraunhofer Institute for Computer Graphics Research IGD

Level: Intermediate

Novel 3D printers can combine multiple colorful materials in a single object enabling the reproduction of an object's color, texture, gloss, and translucency in addition to its shape. This short course provides an overview of the relevant 3D printing technologies and focuses on the color and appearance reproduction pipeline.

Short Course Fees

Separate registration is required. Fees in US\$.

If you register:	by 22 Sept	after 22 Sept
2-hour Member	\$185	\$235
2-hour Non-member	\$210	\$260
2-hour Student	\$65	\$90
4-hour Member	\$290	\$340
4-hour Non-member	\$315	\$365
4-hour Student	\$95	\$120
8-hour Member	\$510	\$560
8-hour Non-member	\$560	\$610
8-hour Student	\$195	\$220

IS&T reserves the right to cancel classes in the event of insufficient advance registration. Please register early.

Benefits: Attendees will be able to:

- Understand the basic concepts of 3D printing as they relate to color and appearance.
- Understand the differences between the existing color-capable 3D printing technologies.
- Describe ways to represent color and other appearance properties attached to 3D shapes.
- Learn the main principles of the 3D color reproduction pipeline.
- Have a basic understanding of 3D surface halftoning.

Intended Audience: attendees wishing to become more familiar with the opportunities and challenges of the emerging field of graphical 3D printing, which may include color and imaging specialists, 3D printer designers, and software developers.

Philipp Urban is head of the Competence Center 3D Printing Technology at the Fraunhofer IGD in Darmstadt, Germany, where he works on the appearance reproduction of objects using multimaterial 3D printers. He is also an adjunct professor at the Norwegian Colour and Visual Computing Laboratory, Department of Computer Science, Norwegian University of Science and Technology (NTNU), Gjøvik, Norway. During his career he has been a visiting scientist at the Munsell Color Science Laboratory at RIT and head of the color

research group at TU Darmstadt. He holds an MS in mathematics from University of Hamburg and a PhD from Hamburg University of Technology.

SC06: Fundamentals of Psychophysics

8:00 – 10:00 (2 hours)

Instructor: James A. Ferwerda, Rochester Institute of Technology

Level: Intermediate

Psychophysical methods from experimental psychology can be used to quantify the relationships between the physical properties of the world and the qualities people perceive. The results of psychophysical experiments can be used to create models of human perception that can guide the development of effective color imaging algorithms and enabling interfaces. This course provides an introduction to the theory and practice of psychophysics and teaches attendees how to develop experiments that can be used to advance color imaging research and applications. Hands-on examples are used throughout 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.
- Design perception experiments using these techniques.
- Analyze the data from these experiments to derive perceptual metrics.
- Apply these metrics to practical problems in color imaging.

Intended Audience: students and professionals who want to be able to interpret the results of perception psychology experiments and develop their own perception studies. The course assumes a basic level understanding of issues in color and imaging science, engineering, and statistics. No specific knowledge of perception psychology is required. All relevant concepts are introduced in the class.

James A. Ferwerda is an associate professor and the Xerox Chair in the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology. He received a BA in psychology, MS in computer graphics, and a PhD in experimental psychology, all from Cornell University. The focus of his research is on building computational models of human vision from psychophysical experiments and developing advanced imaging systems based on these models.

NEW SC07: Digital Cinema Environment and Image Quality Evaluation

10:15 – 12:15 (2 hours)

Instructors: Miloslav Novák, Silesian University and Antonín Charvát, EIZO Group

Level: Intermediate

The digital cinema environment—the umbrella of the projector, portal, screen, ambient light, and cinema architecture—is examined from the invention of cinematography to the present, in relation to the spectator's perception. Practical methods of measurement, calibration, and image quality evaluation of digital cinema projectors and displays using ISO and SMPTE international standards and test images are explained.

First, the course demonstrates new guidelines for faster, simpler, and more precise luminance and chrominance measurement using a photospectro radiometer, DCP player, and D-Cinema 4K display. Next, we describe the calibration principles of the D-Cinema projector using P7 color space correction. Finally, we provide an overview of techniques for the determination of measured photometric and colorimetric deviations from the ISO and SMPTE standards with several tools for advanced graphical analysis (ADA) using polarograms and CIEDE2000 formula to better understand specific cinema low level light conditions.

Benefits: Attendees will be able to:

- Understand the complexity and terminology of the digital cinema environment and learn



about its similarity to the analog 35mm film projection in cinema history context.

- Measure luminance and colorimetric coordinates deviation from the reference projector or display and evaluate quality of the measuring device.
- Apply digital cinema projector and display calibration process step-by-step.
- Learn the techniques for objective and subjective image quality evaluation of the projector or display using ISO and SMPTE standard image tests for digital cinema, including advanced graphical analysis of the measured data.
- Distinguish strengths and weaknesses of the digital cinema projectors and displays with different manufacturer's technologies.

Intended Audience: anyone interested in Digital Cinema projection or imaging on display in environments optimized for mesopic vision in low light-level conditions. Students, researchers, color grading artists, filmmakers, cinema operators, and other users who want to apply SMPTE and ISO standards and image tests for digital cinema measurement, calibration, and image evaluation for the production of superior imaging experiences.

Miloslav Novák graduated from Film Academy of Miroslav Ondříček where he received his Dipl Tech and continued his studies at the Faculty of Arts of Charles University in Prague. He received his MA (2008) in documentary filmmaking at the Academy of Performing Arts in Prague after graduating their editing department (2002). Since 2011, he has been teaching audiovisual technology and restoration at the Silesian University in Opava and at the Academy of Performing Arts where he is completing his PhD study. He has been cooperating with various film and photo archives, museums, and restoration labs as the researcher, technology supervisor, and/or restorer inland and abroad.

Antonín Charvát graduated the faculty of electrical engineering of the Czech Technical University with a MSc (1986) in cybernetic and computers. He dedicated his career to the field of

image technologies (displays, printing, photo, and video facilities, as well as digital cinema). Now he is director of the EIZO Group in the Czech Republic and Slovakia. He has given workshops focused on color management and image technologies in different higher educational programs at various Czech and Slovak schools. There he prepared and tested different image technology postproduction workplaces for students.

10:15 – 12:15

SC09: Characterizing Surface Appearance

10:15 – 12:15 (2 hours)

Instructor: James A. Ferwerda, Rochester Institute of Technology

Level: Intermediate

Surface appearance is of critical importance in a wide variety of fields including design, manufacturing, forensics, medicine, and cultural heritage preservation. This class first introduces a framework for characterizing surface appearance that includes the visual attributes of color, gloss, translucency, and texture. It then reviews efforts that have been made to measure these attributes, and describe the psychophysical methods that are used to relate the physical properties of surfaces to their visual appearances. Finally, the potential for using computer-graphics techniques to simulate the appearances of complex surfaces is discussed, and how new digital imaging technologies are being used to advance the measurement, modeling, visualization, and communication of surface appearance is described.

Benefits: Attendees will be able to:

- Identify the factors that contribute to the appearances of complex surfaces.
- Understand the physical bases of surface appearance and how these bases are measured.
- Learn about the psychophysical methods used to relate the physical and perceptual

aspects of surface appearance.

- Distinguish the different systems used to describe and communicate surface appearance.
- Comprehend how computer-graphics and digital imaging techniques are rapidly advancing the state-of-the-art in surface appearance characterization.

Intended Audience: students and professionals who want to understand the physics and psychophysics of surface appearance. The course assumes a basic level understanding of issues in color/imaging science and engineering. All specialized concepts will be introduced in class.

James A. Ferwerda is an associate professor and the Xerox Chair in the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology. He received a BA in psychology, MS in computer graphics, and a PhD in experimental psychology, all from Cornell University. The focus of his research is on building computational models of human vision from psychophysical experiments, and developing advanced imaging systems based on these models.

Revised for 2019 SC10: Spatial Color Perception and Image Processing

10:15 – 12:15 (2 hours)

Instructor: Edoardo Provenzi

Level: Intermediate

This short course is divided in two parts, focusing on spatial induction, *i.e.*, the modification of color perception of a point caused by a non-uniform surround, which plays an important role in image processing. To note just a few applications, it is used as a main ingredient to devise color enhancement algorithms and tone mapping operators in the high dynamic range imaging field. The first hour provides a detailed description of a psychophysical technique for measuring the relative strength of spatial induction focusing, at first, on a very simple geometrical configura-

tion and then extending it to more complex and realistic ones. During the following hour, we analyze a variational model that formalizes and extends the previous description to a more general framework that accounts also for cognitive phenomena.

Benefits: Attendees will be able to:

- Understand the important perceptual phenomenon of visual induction.
- Learn a simple mathematical model for color induction and how to implement it through psychophysical experiments.
- Be introduced to the very powerful concept of variational model, universally used in imaging.

Intended Audience: The course is intended for a very broad audience: master and PhD students, post-doc researchers, scientists, or engineers working in the following disciplines: color science, colorimetry, image processing (especially spatially-varying color enhancement and tone mapping of HDR images), psychophysics or cognitive, and perceptual psychology.

More generally, anyone who wishes to get acquainted about some very modern theories of color vision, based on the rediscovery of some profound and beautiful works of our ancestors. This modern vision puts in evidence the need of performing new and fascinating psychophysical experiments, which have the potential to lead to the future era of colorimetry. A general knowledge of calculus and linear algebra is required to fully grasp the concepts that are discussed. A basic knowledge of psychophysics is not necessary but it would be helpful for the sake of a better interaction.

Edoardo Provenzi obtained a master in theoretical physics at the University of Milan (2000) and a PhD in applied mathematics at the University of Genoa (2004). Since 2004, he has been studying color vision and image processing. He is currently working in these research fields: color science, geometry of color space, statistics of natural images, and variational techniques in imaging. He worked as



associate professor from 2014 to 2017 at the University Paris Descartes. He is Full Professor of Applied Mathematics in the Image Processing Group at the University of Bordeaux since 2017, where he is in charge of the Master program on mathematics for signals and images. He is the author of the book: Computational Color Science: Variational Retinex-like Methods, Wiley & Sons Eds. (2017).

SC11: Color Optimization for Displays

8:00 – 10:00 (2 hours)

Instructor: Gabriel Marcu, Apple Inc.

Level: Intermediate

This course introduces color optimization techniques for various display types (LCDs, plasma, OLED, QLED, and projection: DLP, LCD, LCoS), and ranging from mobile devices to large LCD TV screens. Factors such as technology, luminance level (including HDR), dynamic/static contrast ratio (including local dimming), linearization and gamma correction, gray tracking, color gamut (including wide 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 parameters and their impact on display color quality for smart phones, tablets, notebooks, desktops, LCD TVs, and projectors.
- Compare color performance and limitations for various LCD modes like IPS, MVA, FFS.
- Understand the critical factors for HDR displays and wide gamut displays.
- Understand the advantages of the LED backlight modulation and the principles of quantum dot gamut enhancement for QLED technology.
- Select the optimal color model for a display and highlight its dependency on display technology.
- Understand the use of the color model for

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the display ICC profile and the implication for the color management.

- Follow a live calibration and characterization of an LCD screen and 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 a senior scientist 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). He holds more than 80 issued patents in these areas. Marcu is responsible for color calibration and characterization of Apple desktop display products. He has taught seminars and courses on color topics at various IS&T, SPIE, and SID conferences and IMI Europe. He was co-chair of the 2006 IS&T/SPIE Electronic Imaging Symposium and CIC11; he is co-chair of the Electronic Imaging Symposium's Color Imaging Conference: Displaying, Hardcopy, Processing, and Applications. Marcu is an IS&T and SPIE Fellow.

13:30 – 15:30**Revised for 2019 SC12: Advanced Colorimetry and Color Appearance**

13:30 – 15:30 (2 hours)

Instructor: Gaurav Sharma, University of Rochester**Level:** Introductory

Building on a foundation in basic color science and colorimetry, this course provides attendees a broad understanding of color appearance phenomena and introduces them to color appearance modeling. The relationship of these important color appearance phenomena to the state of adaptation of the human visual system is explained. Students learn the perceptual color attributes of lightness, brightness, colorfulness, saturation, chroma, and hue. The course presents widely-used computational models for evaluating correlates of these attributes. Spatial aspects of color vision are discussed, as well as simple models for spatial color perception.

Benefits: Attendees will be able to:

- Understand how changes in the state of visual adaptation affect the perceived appearance of colors.
- Identify the main elements of a color appearance model and explain the critical role of chromatic adaptation in color appearance.
- Describe the Von Kries model for chromatic adaptation transformations, and perform computations using the model.
- List additional psycho-physical effects modeled by CIECAM02 and CAM16 color appearance models.
- Understand how models such as CIECAM02 and CAM16 are used in color management.
- Outline the basic characteristics spatial color perception.

Intended Audience: color engineers, research scientists, and software developers involved in design and optimization of color imaging

systems, algorithms, and devices. Prior knowledge of fundamental colorimetry is assumed.

Gaurav Sharma has more than two decades of experience in the design and optimization of color imaging systems and algorithms that spans employment at the Xerox Innovation Group and his current position as a professor at the University of Rochester in the departments of electrical and computer engineering and computer science. Additionally, he has consulted for several companies on the development of new imaging systems and algorithms. He holds 51 issued patents and has authored more than 200 peer-reviewed publications. He is the editor of the Digital Color Imaging Handbook (CRC Press) and served as the editor-in-chief for the IS&T/SPIE Journal of Electronic Imaging (2011-2015). Sharma is a Fellow of IS&T, IEEE, and SPIE.

SC13: Color Fundamentals in LED Lighting

13:30 – 15:30

Instructor: Michael Murdoch, Rochester Institute of Technology**Level:** Intermediate

Color is one of the most important attributes of lighting, whether for general illumination at home, commercial applications in retail and healthcare, or special applications like cinematography. Light-emitting diode (LED) technology has opened up enormous flexibility in the design of lighting systems while simultaneously increasing energy efficiency over traditional technologies. The flexibility of LED is both an opportunity and a curse: through spectral tuning, LEDs can maximize quality of light and preference for object color rendition – or if not done well, drastically distort object colors. Further, LED spectra can be tuned to influence circadian rhythms via melanopic response. This course explains the ways that color, color rendition, chronobiology, and quality of light can be affected in LED as well as OLED lighting. It explores the different ways systems produce white light,



including different phosphor technologies, primaries, and spectral tuning solutions. Measures of efficacy and color rendition are explained, and situations where metrics and measures remain insufficient are discussed..

Benefits: Attendees will be able to:

- Explain different LED color architectures, including RGB, RGBA, phosphor-converted blue pump, tunable white, and warm-dim systems.
- Understand how spectral characteristics of “white” LEDs affect rendered object colors and what this means for perceived naturalness and preference.
- Understand multi-primary solution approaches for creating spectral power distributions from discrete LEDs with different optimization goals.
- Apply and compare color rendition measures including CIE Ra, CIE Rf, TM-30 Rf/Rg.
- Evaluate spectral power distributions of light for melanopic / chronobiological response.

Intended audience: scientists, engineers, and students using or interested in LED lighting systems for research, image capture, or image/product evaluation. Basic knowledge of colorimetry is assumed, but no specialized knowledge of lighting is expected.

Michael Murdoch is an assistant professor in Rochester Institute of Technology’s Munsell Color Science Laboratory, where he teaches psychophysical methods, MATLAB programming, and lighting perception topics. His current research includes the effects of temporally dynamic lighting on visual adaptation and perceived rate of change, inter-observer effects on lighting color rendition, and color appearance and visual adaptation in augmented/mixed reality (AR/MR). Murdoch has deep experience with color perception and system design for solid state lighting, LCD, and OLED displays, rooted in industrial work at Kodak Research and Philips Research. He has co-authored more than 28 journal and conference papers and 18 patents, and

he served as the general chair of CIC25 in Lillehammer. His education includes a BS in chemical engineering from Cornell, MS in computer science from RIT, and PhD in human-technology interaction from Eindhoven University of Technology.

SC14: Using the New Colour Management Technology, iccMAX: Architecture and Practical Applications

13:30 – 15:30

Instructor: Philip Green, Norwegian University of Science and Technology

Level: Intermediate

ICC’s iccMAX colour management technology was published as an ISO standard in February 2019 and is now a stable platform for development. iccMAX introduces many new features and capabilities; foremost among these is the move away from a fixed D50 colorimetric intermediate color space to an ability to connect profiles using any illuminant or observer for colorimetric data or spectral data in any form. ICC has provided a Reference Implementation which greatly simplifies the process of making profiles and applying them to data and images. This course introduces the new features that iccMAX adds to color management and provides detail on the most widely-used processing elements. It shows how to build profiles that incorporate these elements and how to connect profiles, either to other iccMAX profiles or to v2 or v4 profiles. It also shows how to define a sub-set of the new specification for a particular use case.

Benefits: Attendees will be able to:

- Identify the situations where iccMAX can be used to address color management needs that cannot be handled in ICC v4.
- Learn how to use iccMAX in their own implementations, including both research and commercial development.
- Generate iccMAX profiles and apply them to device data, colorimetry, and spectral data.

Intended audience: attendees will have basic knowledge and experience of color management with ICC v2 or v4, and a desire to understand the next-generation color management technology, iccMAX.

Philip Green is professor of colour imaging at the Colour and Visual Computing Laboratory, NTNU, Norway. He supervises PhD and master students and teaches courses on a range of color-related topics including cross-media color reproduction and advanced color management. Green has been technical secretary of the International Color Consortium since 2005.

NEW SC15: Color Imaging Challenges with Compact Camera Optics

13:30 – 15:30 (2 hours)

Instructor: Kevin J. Matherson, Microsoft Corporation

Level: Introductory

This short course describes the color imaging challenges created by the unique characteristics of compact camera modules, including AR/VR, automotive, machine vision, and consumer applications. First introduced are the fundamentals of camera optics in small formats for which the availability of suitable materials impacts color quality. Steep chief ray angles result in spatially varying spectral sensitivity and interact with the goniometric properties of IR-cut filters, dielectric materials, sensor microlenses, color filter array crosstalk, and color shading. Also covered are spherical aberration, spherochromatism, extended-depth-of-field imaging, sharpness transport algorithms, and the design of lenses in which axial color is used to ensure all color planes are in focus. This short course gives the attendee an understanding of the physics and interaction of light, optics, and color as well as the algorithmic foundations for image signal processors in which the optics and ISP are jointly designed with the goal of improving the overall system image quality.

Benefits: Attendees will be able to:

- Understand the fundamental challenges posed by compact camera optics on color image processing.
- Specify the color corrections required to compensate for compact camera optics limitations.
- Evaluate ISP-based solutions to correct chromatic aberrations and color shading in compact camera systems.

Intended Audience: engineers, project leaders, and managers involved in camera image processing, pipeline development, image quality engineering, and production-line quality assurance, and those who want to understand the challenges of compact camera optics.

Kevin J. Matherson is a director of optical engineering at Microsoft Corporation working on advanced optical technologies for consumer products. Prior to Microsoft, he participated in the design and development of compact cameras at HP and has more than 15 years of experience developing miniature cameras for consumer products. His primary research interests focus on sensor characterization, optical system design and analysis, and the optimization of camera image quality. Matherson holds a masters and PhD in optical sciences from the University of Arizona.

FOUR-HOUR CLASS

SC08: Camera Color Characterization: Theory and Practice

8:00 – 12:15 (4 hours)

Instructors: Dietmar Wueller, Image Engineering GmbH & Co. Kg, and Eric Walowitz, consultant

Level: Intermediate

This short course covers the process of colorimetric camera characterization in theory and practice. The need for camera characterization and calibration and the impact on general image quality is first reviewed. Known issues in



traditional approaches are discussed. Methodology for building camera colorimetric transforms and profiles are detailed step-by-step. State-of-the-art solutions using current technology are presented including monochromators, multispectral LED light sources, in situ measurements of spectral radiances of natural objects, and modern color transform methods including multidimensional color look up tables. A live demonstration is performed of the end-to-end process of spectral camera characterization, camera transform generation, and matching from capture to display. This short course provides the basis needed to implement advanced color correction in cameras and software.

Benefits: Attendees will be able to:

- Understand the need for camera colorimetric characterization and the impact of color calibration on image quality and manufacturing yield.
- Perform target-based and spectral-based camera characterization.
- Solve for colorimetric camera transforms and build profiles using linear and nonlinear techniques.
- Evaluate current colorimetric camera characterization hardware and software technology and products.

- Participate in hands-on spectral camera characterization, camera transform generation, and matching from capture to display.

Intended Audience: engineers, project leaders, and managers involved in camera image processing pipeline development, image quality engineering, and production-line quality assurance.

Detmar Wueller studied photographic sciences (1987-1992) in Cologne. He is the founder of Image Engineering, one of the leading suppliers for test equipment for digital image capture devices. Wueller is a member of IS&T, DGPH, and ECI; he is the German representative for ISO TC 42 WG 18 and also participates in several other standardization activities.

Eric Walowit's interests are in color management, appearance estimation, and image processing pipelines for digital photographic applications. He is founder (retired) of Color Savvy Systems, a color management hardware and software company. He graduated from RIT's Image Science program (1985), concentrating in color science. Walowit is a member of ICC, ISO TC 42, IS&T, and CIE/JTC 10.



Photo: Michael Murdoch.

CIC 27 take place in the Quartier Latin, 5e Arrondissement, a short walk from the iconic Notre Dame, seen here prior to the recent fire. Other nearby highlights include Jardine des Plantes, Musée de Cluny, Luxembourg Gardens, and the Institut du Monde Arabe.

CIC27 Workshops: Tuesday 22 October

All workshops take place from 15:45 to 18:15 after the short course program. The goal of CIC Workshops is to encourage discussion and exchange of ideas.

Please Note: Workshops are included with a full conference registration; those not attending the full conference may purchase a workshop ticket that also includes admission to the Welcome Reception, which follows at 18:15.

W1: Future Directions in Image Quality

15:45 – 18:15

Chairs/Conveners: Marius Pedersen and Seyed Ali Amirshahi, NTNU (Norway)

During the last few decades image quality assessment has been an important and attractive field of research. While current state-of-the-art image quality metrics show a high correlation with subjective scores, many challenges still exist. This workshop aims to bring experts from both academia and industry to introduce challenges and possible directions needed to be taken in subjective and objective image quality assessment. A discussion and Q&A session to address possible solutions for these new challenges rounds out the afternoon.

Confirmed speakers/topics:

- Azeddine Beghdadi (Galilee Institute): [image enhancement and issues on quality assessment](#)
- Aladine Chetouani (Université d'Orléans – Polytech'Orléans): [recent trends in machine learning for image quality](#)
- Christophe Charrier, Université de Caen Normandie): [image quality in biometrics](#)
- Chaker Larabi (University of Poitiers): [quality assessment of xr applications](#)
- Claudio Greco (DxOMark Image Labs): [color image quality assessment in smart-phones](#)
- Seyed Ali Amirshahi (NTNU): [future of subjective evaluation and crowdsourcing](#)

- Razvan Lordache (GE Healthcare France): [challenges in medical image quality assessment](#)
- Frédéric Dufaux (University Paris-Sud): [the future of video quality metrics](#)

Marius Pedersen is a professor at the Norwegian University of Science and Technology (NTNU) whose work is centered on image quality assessment. He holds more than 60 publications in this field. Pedersen received his PhD in color imaging (2011) from the University of Oslo. He is currently the head of the computer science group in the department of computer science, as well as the head of the Norwegian Colour and Visual Computing Laboratory, both at NTNU.

Seyed Ali Amirshahi is a Marie Curie post-doctoral Fellow in the Norwegian Colour and Visual Computing Laboratory at the Norwegian University of Science and Technology (NTNU). His research is mainly focused on different aspects of image and video quality assessment and computational aesthetics. He received his PhD from the Friedrich Schiller University of Jena in Germany (2015). Prior to joining NTNU, he was a post-doctoral Fellow at the International Computer Science Institute in Berkeley, California.

W2: Lighting and Chromatic Adaptation

15:45 – 18:15

Chair/Convener: Michael J. Murdoch, RIT (US)

Chromatic adaptation is a marvelous capability of the human visual system, allowing us to respond to changes in illumination and perceive object colors to be relatively stable. Concepts of corresponding colors, color constancy, and illumination estimation are all relevant.

This workshop is organized to explore current research related to lighting and its relationship to chromatic adaptation. Key topics for discussion include:

- Mechanisms for chromatic adaptation and models for chromatic adaptation transforms (CATs)



- Experimental methods for measuring and tracking visual adaptation
- Limits of adaptation and factors affecting them
- Effects of adaptation on visual performance, color discrimination, etc.

Call for speakers: Researchers who want to participate in the discussion or to give a presentation are welcome to submit their proposal for review via color@imaging.org (subject line: *Lighting Workshop*).

Confirmed speakers/topics:

- Marcel Lucassen (Signify): **chromatic discrimination under different spectral lighting conditions**
- Michael Murdoch (RIT): **chromatic adaptation to temporally-dynamic lighting**
- Kevin Smet (Katholieke Universiteit Leuven): **chromatic adaptation, effects of background field size, mixed illumination, and chromatic lighting**

Michael Murdoch is an assistant professor in RIT's Munsell Color Science Laboratory, where he teaches psychophysical methods, MATLAB, and lighting topics. His research covers temporally dynamic lighting, perception of advanced displays, and color appearance in augmented reality. Murdoch's experience with color perception and system design for solid state lighting, LCD, and OLED displays is rooted in industrial work at Kodak Research and Philips Research. He has studied at Cornell, RIT, and Eindhoven University of Technology.

W3: The Art and Science of High-End Digital Color Print-Making

15:45 – 18:15

Chairs/Conveners: Peter Morovic, HP Inc. (Spain) and Ján Morovic, HP Inc. (UK)

Creating subtle yet impactful fine-art prints—be it reproductions of other forms of art or originals produced directly as digital prints such as graphic design, digital art, or pho-

tography—used to be the exclusive domain of artisanal processes mastered by highly-skilled print-makers with many years of experience, often working alongside the artists themselves. Over the past few decades, many applications previously reserved for these traditional, analogue processes have given way to digital technologies. For example, fine art photographers – whether they capture in analogue or digital – have been exploring the possibilities of digital print and its new potential.

Printing technologies have evolved to multi-primary printing, higher printing resolutions, smaller and more precise drops, and ink and substrate development resulting in large color gamuts, as well as unprecedented light-fastness on the order of hundreds of years. Likewise, printing pipelines and workflows have undergone drastic innovations in the areas of color management, color separation and halftoning, and an ability to handle the multitude of complex transformations required to go from the digital input to the final, physical print. Even staunch analogue advocates experiment with digital, whether by considering a full transition or combining analogue and digital processes, such as digital negatives.

This workshop brings together state-of-the-art in all the aspects that work in concert to deliver high-end, fine art prints, while at the same time highlights areas where there are still opportunities for improvement or new applications that are impossible today. While in some areas, science and technology have closed the gap with analogue print making processes, the opportunities with digital printing are still to be discovered. This workshop combines talks on relevant topics with demos and print samples, to be reviewed by attendees and discussed together.

Confirmed speakers:

- Clotilde Boust (Louvre)
- Cyril Bertolone (Canson Infinity)
- Ján Morovic (HP Inc.)
- Peter Morovic (HP Inc.)

- Stefan Neumann (Hahnemühle)
- Joseph Padfield (National Gallery London)
- Marianna Santoni (Canson Infinity Ambassador)

Peter Morovic received his PhD in computer science from the University of East Anglia, UK (2002) and holds a BSc in theoretical computer science from Comenius University, Slovakia. He has been a senior color and imaging scientist at HP Inc. since 2007, has published more than 60 scientific articles, and has more than 150 US patents filed (45 granted) to date. His interests include 2D/3D image processing, color vision, computational photography, and computational geometry; his Erdos number is 4.

Ján Morovic received his PhD in color science from the University of Derby, UK (1998), where he then worked as a lecturer. Since 2003 he has been at HP Inc. as a senior color scientist and later master technologist. He also has served as the director of CIE Division 8 on Image Technology. He is the author of Color Gamut Mapping (Wiley and Sons) and more than 100 papers, and has filed more than 150 US patents (48 granted).

W4: Cultural Heritage Digitalization

15:45 – 18:15

Chair/Convener: Sony George, NTNU (Norway)

Cultural heritage digitalization is high interdisciplinary. By facilitating the interaction between color experts, imaging scientists, and people working in the cultural heritage sector, our goal is to help researchers better understand the challenges and opportunities in this area. Research and case studies conducted by experts from different domains help us understand strategies for acquisition, analysis, and the constraints/needs of the end-users. The expert panel includes conservation scientists, technology researchers, and industry representatives. Presentations focus on the objective of digitization, data quality standards, location of critical areas or interest, challenges specific to artefacts, etc. Dis-

cussions highlight the needs and challenges in this sector including conducting research, applications of new technologies, importance of interdisciplinary collaboration, and new skills acquisition. Panelists address strategy and propose solutions related to digitization methods, multimodal imaging systems, possible analysis and limitations, supporting restoration, visualization, tools for analysis, time and accuracy, and data reuse.

Confirmed speakers/topics:

- Christian Degriigny (Haute Ecole Arc Conservation-Restoration): [technical study and conservation condition of Château de Germolles' wall paintings using imaging techniques combined with non-invasive analytical techniques](#)
- Lindsay McDonald (University College London): [TBA](#)
- Robert Sińnik (Warsaw University): [3D documentation process of cultural heritage objects: towards automation](#)
- Vitaliy V. Yurchenko (Norsk Elektro Optikk A/S): [key quality indicators of hyperspectral cameras: current status and case study from pigment analysis](#)

Since 2017, Sony George has been an associate professor at the department of computer science at the Norwegian University of Science and Technology (NTNU). He is a member of the Norwegian Colour and Visual Computing Laboratory (www.colourlab.no), where he teaches, supervises students, and serves as the Norwegian coordinator for the French-Norwegian International Master Degree. George obtained a PhD in photonics from the Cochin University of Science and Technology in India (2012). His research interests are in the field of color imaging, hyperspectral-multispectral imaging, and 3D imaging. He has been involved in several national and EU projects in multiple roles, including H2020 EU MSCA-ITN projects, HiPerNav, and CHANGE (<https://change-itn.eu/>).



CIC27 Conference Registration

Go to www.imaging.org/color to register online.

Name _____

Title/Position _____

Company _____

Mailing Address _____

Telephone _____ Fax _____ Email _____

Conference registration includes admission to all technical sessions, CIC workshops, coffee breaks, exhibit, Welcome and Conference Receptions, and conference abstract book with proceedings on USB. Separate registration fees are required for short courses. Student registration includes membership. To serve the needs of non-students, IS&T is offering conference registration options that include membership with JIST or JEI, at the same rate as non-member fees. You may use this to renew your membership for 2020, as well.

1. Technical Conference Registration (includes one workshop) (CHECK ONE)

Please check ALL that apply. I am a: ☐ speaker ☐ session chair ☐ committee member
☐ IS&T member ☐ only taking short courses and/or a workshop ☐ short course instructor

All fees are charged in US\$*

	REGULAR		STUDENT	
	thru 22 Sept	after 22 Sept	thru 22 Sept	after 22 Sept
<input type="checkbox"/> Conference registration: current IS&T/ISJ Member	\$815	\$915	\$205	\$255
<input type="checkbox"/> Conf. registration (+ new or renewing membership + JIST)* Membership begins within 2 weeks of registration and expires 12/31/20	\$940	\$1,040		
<input type="checkbox"/> Conf. registration (+ new or renewing membership + JEI)* Membership begins within 2 weeks of registration and expires 12/31/20	\$940	\$1,040		
<input type="checkbox"/> Conference non-member registration	\$940	\$1,040		
One-day: <input type="checkbox"/> Wed <input type="checkbox"/> Thurs <input type="checkbox"/> Fri	\$445	\$495	\$125	\$175

Select the Tuesday afternoon workshop that goes with your conference registration:

- ☐ W1: Future Directions in Image Quality ☐ W2: Lighting and Chromatic Adaptation
☐ W3: The Art and Science of High-End Digital Color Print/Making ☐ W4: Cultural Heritage Digitalization

2. Extras

___ Additional copy of conf. proceedings Note: One copy comes with conference registration. \$140 \$ _____
 ___ Additional/Guest ticket for Welcome Reception \$45 \$ _____
 ___ Additional/Guest ticket for Conference Reception \$85 \$ _____
 ___ Additional/Guest ticket for Welcome and Conference Reception \$115 \$ _____

Name/Affiliation of Guest for badge: _____

Page Subtotal \$ _____
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* Membership benefits include access to the IS&T Digital Library, an online subscription to the *Journal of Imaging Science and Technology* (JIST) or *Journal of Electronic Imaging* (JEI), *The Reporter* newsletter, conference fee discounts, and access to the member directory, among other things. Membership takes within affect 2 weeks of registration and expires 12/31/20. This offer may be used for renewals.

3. Short Course and/or Workshop + Welcome Reception Registration

Please note: Course notes for most classes are provided electronically prior to the conference for printing or viewing on your computer. Instructors without e-notes will provide hardcopies in class. The workshop option includes the Welcome Reception; none of the short courses include the Welcome Reception.

One-day class	thru 22 Sept	after 22 Sept	TOTAL
Member <input type="checkbox"/> SC01	\$510	\$560	\$ _____
Non-member <input type="checkbox"/> SC01	\$560	\$610	\$ _____
Student <input type="checkbox"/> SC01	\$195	\$220	\$ _____

Four-hour classes

Member (per class; select below)	\$290	\$340	\$ _____
Non-member (per class; select below)	\$315	\$365	\$ _____
Student (per class; select below)	\$95	\$120	\$ _____

Check one ☐ SC04 ☐ SC08

Two-hour classes

Member (per class; select below)	\$185	\$235	\$ _____
Non-member (per class; select below)	\$210	\$260	\$ _____
Student (per class; select below)	\$65	\$90	\$ _____

Check all that apply ☐ SC02 ☐ SC03 ☐ SC05 ☐ SC06 ☐ SC07 ☐ SC09
☐ SC10 ☐ SC11 ☐ SC12 ☐ SC13 ☐ SC14 ☐ SC15

Workshop + Welcome Reception

Regular	\$175	\$225	\$ _____
Student	\$65	\$90	\$ _____

Check one: ☐ W1: Future Directions in Image Quality
☐ W2: Lighting and Chromatic Adaptation
☐ W3: The Art and Science of High-End Digital Color Print/Making
☐ W4: Cultural Heritage Digitalization

OR

Take ANY three or more classes or workshops and receive 10% off the total price

Enter three or more courses/workshops, fill in member or non-member fee next to each, add, and multiply by .9 to get your price, representing 10% savings; add additional lines if needed; students may not take advantage of this offer. If registering online, use 2019Pick3 as coupon code at checkout.

W/SC_ \$ _____ + SC_ \$ _____ + SC_ \$ _____ = \$ _____ x .9 = \$ _____

total from previous page \$ _____

Wire transfer fee (\$25 if applicable) \$ _____

GRAND TOTAL \$ _____

Payment Method: ☐ AmEx ☐ MasterCard ☐ VISA ☐ Discover ☐ Wire Transfer ☐ Check
 Card#: _____ Exp. Date: _____

Name as it appears on card: _____

Authorization Signature: _____

Return this form with signed credit card authorization to IS&T, 7003 Kilworth Lane, Springfield, VA 22151 or fax to 703/642-9094. Contact registration@imaging.org for wire transfer information; \$25 must be added to the total for wire transfer payments to cover bank costs.

Please note: To cover bank charges and processing fees, there is a cancellation fee of \$75 until September 22, 2019. After that date, the cancellation fee is 50% of the total plus \$75. No refunds will be given after October 18, 2019. All requests for refund must be made in writing.