

Twenty-fifth Color and Imaging Conference

Color Science and Engineering Systems, Technologies, and **Applications**





Collocated with 19th International Symposium on **Multispectral Colour Science**

Early Registration Deadline: August 13, 2017 www.imaging.org/color



Sponsored by Society for Imaging Science and Technology

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- 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)
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Conference At-a-Glance

Monday, September 11

Scandic Lillehammer Hotel

Registration open

8:00 – 9:00 and 16:45 – 17:45

 Color, Vision, and Basic Colorimetry Short Course (separate registration fee required), see page 10; Lunch provided

Tuesday, September 12

Scandic Lillehammer Hotel

Registration open 7:00 – 16:00

- Short Course Program (separate registration fee required), see page 11; Lunch provided
- Welcome Reception at Lillehammer Art Museum

Wednesday, September 13

Maihaugan Museum

Registration open 8:00 - 16:00

- Opening Keynote: "Computational Photography and the Rise of Mobile Imaging," Paul Hubel (Apple Inc.), see page 3
- Exhibition
- Group Lunch (provided)
- Technical Sessions
 - Color Dimensions
 - You Be the Judge
 - Color Matters
 - Out of the Shadows
 - Beyond The Rainbow
- CIC25 Special Evening Program



Thursday, September 14

Maihaugan Museum

Registration open 8:30 - 16:30

- Keynote: "Twenty-five Years of Colour Constancy," Anya Hurlbert (Newcastle University), see page 5
- IS&T Honors and Awards Presentations
- Exhibition
- Group Lunch (provided)
- Technical Sessions
 - Colorful in Balance
 - Do You See What I See?
 - Interactive Paper Previews I
 - Subtractive Additions
 - Interactive Paper Previews II
- Interactive Paper Session
- Conference Banquet at 1847
 Brenneriet Restaurant

Friday, September 15

Maihaugan Museum

Registration open 7:30 - 13:00

- Color & Imaging Workshops, see page 22
 - Medical Applications: Image Processing Challenges and Perspectives
 - Visual Perception and Emerging Technologies in Cinema: Perspectives from Academia and the Industry
 - Cultural Heritage Digitization: Challenges and Opportunities
- Group Lunch (provided)
- Keynote: "True Colours: Explorations in Art, Design, and Research," Malcolm Innes (Edinburgh Napier University), see page 9
- Technical Sessions
 - Green with Envy
 - 19th International Symposium on Multispectral Colour Science (MCS)
- Best Paper Award Presentations

The view of Lake Mjøsa and the city of Lillehammer as seen from the Olympic ski jump lift.

Conference Venue: Lillehammer, Norway

Settled since the Norwegian Iron Age (500-800 BC), Lillehammer sits at the northern head of Lake Mjøsa and overlooks the river Lågen. The train ride from Oslo International Airport takes you along the shores of the lovely lake, affording picturesque views of the countryside. Surrounded by mountains, Lillehammer is probably best known as the host of the 1994 Winter Olympics.

Lillehammer's main street is a pedestrianonly thoroughfare, filled with restaurants, bars, and stores. An emphasis on locavore eating ensures delightful Norwegian treats. Known for its arts scene, Lillehammer boasts an art museum—site of the CIC25 Welcome Reception—and Fabrikken, a factory converted to artists ateliers, among other sites. In addition to its Olympic venues, Lillehammer is in close proximity to many ski slopes and national parks.

The headquarters hotel for CIC25 and location of the short courses is the wellappointed Scandic Lillehammer Hotel. Located up a steep incline from the city center, the hotel offers many amenities and cozy places to meet colleagues.

CIC25 technical sessions take place in Maihaugen, Northern Europe's largest open-



The color-filled spa at the Scandic Lillehammer Hotel (above) is a new addition to the historic property. The architecturallypleasing Lillehammer Art Museum (right) showcases local and national artists from the 1880s to the present, including works by Edvard Munch, Thorvald Erichsen, and Jakob Weidemann: http://lillehammerartmuseum.com.



The Garmo stave church at Maihaugen was built circa 1150 on the site of a previous church believed to have been built in 1021 by a Viking chieftain. It was moved to the museum in the 1920s.

air museum, a 10-15 minute walk from the hotel.

The average temperature in September is 6°C/43°F to 15°C/59°F. More information: https://en.lillehammer.com/.

Please note: We encourage all attendees to stay at the headquarter hotel (details, page 27). Those who choose to stay elsewhere will incur a \$100 supplemental flat fee, no matter what they are registering for (full program, short course only, one-day, etc.) or how long they are staying. To avoid this fee, please select lodgings at the Scandic Lillehammer Hotel.

Also please note that lunches are provided this year as part of your registration fee.





Conference Program

Monday September 11, 2017

8:30 – 17:45 ONE-DAY SHORT COURSE Scandic Lillehammer Hotel

Color, Vision, and Basic Colorimetry, Gaurav Sharma, University of Rochester, see page 10 for details

Tuesday September 12, 2017

8:00 – 17:45 SHORT COURSE PROGRAM Scandic Lillehammer Hotel Featuring 14 classes, see page 11 for details

18:00 - 20:00 WELCOME RECEPTION

Lillehammer Art Museum

Wednesday September 13, 2017

NOTE: All Technical Sessions will take place at Maihaugan Museum

9:00 - 10:00 WELCOME AND OPENING KEYNOTE

Sponsored by HP Inc.

Session Chair: Michael Murdoch, Rochester Institute of Technology (USA)

Computational Photography and the Rise of Mobile Imaging, Paul Hubel, Apple Inc. (USA)

10:00 - 10:40 COLOR DIMENSIONS

Session Chair: Andrew Stockman, UCL Institute of Ophthamology (UK)

Multidimensional Estimation of Spectral

Sensitivities, Eric Walowit¹, Holger Buhr², and Dietmar Wueller²; ¹consultant (USA) and ²Image Engineering GmbH & Co. KG (Germany)

OPENING KEYNOTE

Computational Photography and the Rise of Mobile Imaging Paul Hubel, Apple Inc. (USA)

The past decade has seen a steep rise in the popularity of mobile imaging driven by convenience, connectivity, and ever increasing image quality. The extreme increases in mobile processing power and innovative algorithms have allowed computational photography to push the image quality of small cameras well beyond much larger systems. Some of the successful methods are discussed as well as a look into the future of mobile imaging.

Color Formation in Virtual Reality 3D 360°

Cameras, Veli-Tapani Peltoketo, Bartek Pawlik, Ossi Pirinen, and Petri Nenonen, Nokia Technologies (Finland)

11:20 - 12:00 YOU BE THE JUDGE

with support from IQ-MED: Image Quality enhancement in MEDical diagnosis, monitoring and treatment project*

Session Chair: Jae Young Park, Apple Inc. (USA) Smart Phone Image Quality Assessment of Displayed and Printed Images, Gaurav Sheth, Katherine Carpenter, and Susan Farnand, Rochester Institute of Technology (USA)

JIST-First Image Quality Metrics for the Evaluation and Optimization of Capsule Video Endoscopy Enhancement Techniques,

Marius Pedersen, Olga Cherepkova, and Ahmed Mohammed, Norwegian University of Science and Technology (Norway)

12:00 - 13:30 GROUP LUNCH (PROVIDED)

*Funded by the Research Council of Norway – project number 247689

13:30 - 15:00 COLOR MATTERS

Session Chair: Jean-Baptiste Thomas, The Norwegian Colour and Visual Computing Laboratory (Norway)

with support from MUVApp — Measuring and Understanding Visual Appearance Project* nmm = Colour and Appearance — A Multiscale Approach: Nano-Micro-Meso-Macro (Focal), Patrick Callet, Centre Français de la Couleur (France) Appearance Reconstruction of Fluorescent

Objects for Different Materials and Light Source, Shoji Tominaga, Keiji Kato, Keita

Hirai, and Takahiko Horiuchi, Chiba University (Japan) JIST-First PuRet: Material Appearance

Enhancement Considering Pupil and Retina Behaviors, Midori Tanaka, Ryusuke Arai, and Takahiko Horiuchi, Chiba University (Japan) JIST-First Analysis of Material Representation of Manga Line Drawings Using Convolutional Neural Networks, Takahiko Horiuchi, Yuma Saito, and Keita Hirai, Chiba University (Japan)

15:30 - 16:50 OUT OF THE SHADOWS

Session Chair: Ming Ronnier Luo, University of Leeds (UK) and Zhejiang University (China)

Evaluating LED Luminaires Supporting Colour Critical Assessment, Andreas

Kraushaar, Fogra (Germany)

A Curious Problem with Using the Colour Checker Dataset for Illuminant Estimation,

Ghalia Hemrit and Graham Finlayson, University of East Anglia (UK); Peter Gehler, University of Tübingen (Germany); and Arjan Gijsenij, University of Amsterdam (the Netherlands)

A Psychophysical Analysis of Illuminant Estimation Algorithms, Roshanak Zakizadeh and Graham Finlayson, University of East Anglia (UK)

JIST-First Video Magnification for Biomedical Dynamic Image Using the Separation of Chromophore Component, Munenori

WEDNESDAY FOCAL TALK

nmmm = Colour and Appearance—A Multiscale Approach: Nano-Micro-Meso-Macro, Patrick Callet, Centre Français de la Couleur (France)

Among optical properties required for characterizing visual appearance in any lighting and viewing conditions, the most fundamental ones play an important role in predictive rendering. Spectroscopic ellipsometry is useful to acquire the complex indices of refraction of any homogeneous material. A multiscale approach using fundamental optical properties that are the components of the complex dielectric tensor of the material compounds acquired separately is illustrated using automotive paints as an example.

Fukunishi, Kouki Kurita, and Norimichi Tsumura, Chiba University (Japan)

16:50 - 17:30 BEYOND THE RAINBOW

Session Chair: Eric Walowit, consultant (USA) **Two-Band Infrared Video-based Measure ment for Non-Contact Pulse Wave Detection on Face without Visible Lighting,** Mitsuhashi Ryota¹, Genki Okada¹, Kouki Kurita¹, Keiichiro Kagawa², Shoji Kawahito², and Norimichi Tsumura¹; ¹Chiba University and ²Shizuoka University (Japan)

Metamer Mismatch Volumes Using Spherical Sampling, Michal Mackiewicz¹, Hans Rivertz², and Graham Finlayson¹; ¹University of East Anglia (UK) and ²Norwegian University of Science and Technology (Norway)

20:00 - 21:30 PM CIC25 SPECIAL EVENING PROGRAM

Grab a drink at the bar and join colleagues to celebrate 25 years of CIC through trivia and other fun.

*Funded by the Research Council of Norway – project number 250293

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Thursday September 14, 2017

9:00 – 10:00 THURSDAY KEYNOTE AND IS&T AWARDS

Session Chair: Nicolas Bonnier, Apple Inc. (USA) with support from The Colour Group Great Britain

Twenty-five Years of Colour Constancy, Anya Hurlbert, Newcastle University (UK)

10:00 - 10:40 COLOR IN THE BALANCE

Session Chair: Ján Morovic, HP Inc. (UK) CIC25 Best Paper Award A Study of Neutral White and Degree of Chromatic Adaptation,

Qiyan Zhai¹ and Ming Ronnier Luo^{1,2}; ¹Zhejiang University (China) and ²Leeds University (UK)

Whiteness Boundary for Surface Colors,

Yuzhao Wang^{1,2}, Minchen Wei¹, and Ming Ronnier Luo^{2,3}; ¹The Hong Kong Polytechnic University (Hong Kong), ²Zhejiang University (China), and ³University of Leeds (UK)

11:20 - 12:20 DO YOU SEE WHAT I SEE?

Session Chair: Maria Ortiz-Segovia, Océ Print Logic Technologies (France)

A New Computational Model Predicts both the Positive and the Negative Short

Afterimage Effects, Hadar Cohen-Duwek and Hedva Spitzer, Tel Aviv University (Israel)

JIST-First Testing SiChaRDa, a Novel Image Enhancer for Color-Blind People: A Survey-

App based Assessment, Cristian Bonanomi, Stefano Sarioli, Sergio Mascetti, Gabriele Gianini, Valeria Alampi, Matteo Lanaro, and Alessandro Rizzi, Università degli Studi di Milano (Italy)

Super Vision Model: What's Peking Robin Seeing?, Hiroaki Kotera, Kotera Imaging Laboratory (Japan)

12:20 - 13:50 GROUP LUNCH (PROVIDED)

THURSDAY KEYNOTE

Twenty-five Years of Colour Constancy Anya Hurlbert, Newcastle University (UK)

Twenty-five years ago, colour constancy was treated as a well-understood perceptual phenomenon that could be framed as the straightforward computational problem of reflectance recovery. Empirical studies have since shown that colour constancy is neither straightforward nor simple, and varies with the object, illumination, and task at hand. This talk reviews parallel developments in the computational and psychophysical approaches to colour constancy, and relates these to new developments in lighting technology, which present new challenges for colour stability.

13:50 – 14:20 TWO-MINUTE INTERACTIVE PAPER PREVIEWS I

Session Chairs: Kristyn Falkenstern, Digimarc Corporation (USA), and Tamara Seybold, ARRI (Germany) Calculation of Scalars in Neugebauer-Like Models. I: Refactoring the Calculations,

J.A. Stephen Viggiano, Rochester Institute of Technology (USA)

Replicating Dark Colours from an Old Master Painting Using Alternative Methods in Inkjet Printing, Melissa Olen¹, Joseph

Padfield², and Carinna Parraman¹; ¹University of the West of England and ²The National Gallery (UK)

JIST-First N-LMMSE Demosaicing for Spectral Filter Arrays, Prakhar Amba¹, Jean-Baptiste Thomas^{2,3}, and David Alleysson¹; ¹Universite Grenoble Alpes (France); ²The Norwegian Colour and Visual Computing Laboratory (Norway); and ³Université de Bourgigne (France) Investigation for Novel Methodologies for Measuring and Applying Personalized Colour Profiles for Rendering Colour in **Digital Media Displays,** Peter Fornaro and Sofia Georgakopoulou, University of Basel (Switzerland)

Spectral Divergence for Cultural Heritage Applications, Alice Plutino¹, Noel Richard¹, Hilda Deborah², and Christine Fernandez– Maloigne¹; ¹University of Poitiers (France) and ²The Norwegian Colour and Visual Computing Laboratory (Norway)

Estimation of Surface Topography Using Collimator and Telecentric Optical Systems,

Masanori Maki¹, Shinichi Inoue², and Norimichi Tsumura¹; ¹Chiba University and ²Mitsubishi Paper Mills Limited (Japan)

Color Boundary Naming Comparison between Young and Elderly, Boonchai Waleetorncheepsawat, Sukhothai Thammathirat Open University (Thailand) Colour Analysis of Fat Spreads, Gerard Dalen and Robert Jan Velden, Unilever R&D (the Netherlands)

Noncontact Heart Rate Measurement Using High Sensitivity Camera in Low Light Envi-

ronment, Genki Okada¹, Keiichiro Kagawa², Shoji Kawahito², and Norimichi Tsumura¹; ¹Chiba University and ²Shizuoka University (Japan)

Skin Color Simulation—Review and Analysis of Available MonteCarlo-based Photon

Transport Simulation Models, Jacob Bauer, Marius Pedersen, and Jon Hardeberg, Norwegian University of Science and Technology (Norway), and Rudolf Verdaasdonk, VU University Medical Center Amsterdam (the Netherlands) Blind Image Quality Assessment Designed

EXHIBIT AT CIC25!

Interested in exhibiting or sponsoring an event at CIC? Exhibit space is limited; contact Donna Smith to learn more about exhibits and sponsorship opportunities at dsmith@imaging.org.

by Learning-based Attributes Selection,

Christophe Charrier, Universite de Caen Normandie; Abdelhakim Saadane, Universite de Nantes; and Christine Fernandez-Maloigne, Universite de Poitiers (France) Spectral and Color Characterization of a Quantum Dots Display for Gonio-Apparent

Colors, Esther Perales¹, Ivo van der Lans², Eric Kirchner², Joaquín Campos³, Francisco Miguel Martinez Verdu¹, Khalil Hurabait¹, and Alejandro Ferrero³; ¹Universidad de Alicante (Spain), ²AkzoNobel Performance Coatings (the Netherlands), and ³Instituto de Óptica (Spain)

Evaluation of Gradient Operators for Hyperspectral Image Processing, Hilda Deborah¹, Noel Richard², Jon Hardeberg¹, and Christine Fernandez–Maloigne²; ¹Norwegian University of Science and Technology (Norway) and ²University of Poitiers (France)

Conflicting Colors: Film Scanning versus Film Projection, Giorgio Trumpy, University of Zurich, and Rudolf Gschwind, University of Basel (Switzerland)

Multispectral Reconstruction from Single RGB Image based on Camera Response Expansion and Local Inverse Distance Weighted Optimization, Xiaoxia Wan and Jinxing Liang, Wuhan University (China)

14:20 - 15:40 SUBTRACTIVE ADDITIONS

Session Chair: Javier Vazquez-Corral, Universitat Pompeu Fabra (Spain)

HANS Print Smoothness Optimization and Continuous Control, Ján Morovic, HP Inc. (UK) and Peter Morovic, HP Inc. (Spain) JIST-First Data Hiding by White Modulation in Color Direct Binary Search Halftones,

Vlado Kitanovski¹, Reiner Eschbach², Marius Pedersen¹, and Jon Hardeberg¹; ¹Norwegian University of Science and Technology, (Norway) and ²National University of Science and Technology (Norway)/Monroe Community College (USA)

Gamut Reduction Through Local Saturation Reduction, Syed Waqas Zamir, Marcelo



Bertalmío, and Javier Vazquez-Corral, Universitat Pompeu Fabra (Spain) HANS3D: A Multi-Material, Volumetric, Voxel-by-Voxel Content Processing Pipeline for Color and Beyond, Peter Morovic, HP Inc.

(Spain); Ján Morovic, HP Inc. (UK); and Ingeborg Tastl, Melanie Gottwals, and Gary Dispoto, HP Inc. (USA)

15:40 - 16:10 TWO-MINUTE INTERACTIVE PAPER PREVIEWS II

Session Chairs: Kristyn Falkenstern, Digimarc Corporation, (USA) and Tamara Seybold, ARRI (Germany) JIST-First An Adaptive Combination of Dark and Bright Channels Priors for Sky and Snow Image Dehazing, Vincent Whannou de Dravo¹, Jessica El Khoury², Jean-Baptiste Thomas¹, Alamin Mansouri, and Jon Hardeberg¹; ¹Norwegian University of Science and Technology (Norway) and Université de Bourgogne, (France) Visibility and the Preferred Gamma in a Transparent OLED Display, Hyosun Kim, Young-Jun Seo, Byungchoon Yang, and Hye Yong Chu, Samsung Display, and Youngshin Kwak, UNIST (South Korea) **Temporal Transition Enhances the Consonance** of Color Arrangements, Akira Asano and Shinji Tatsumi, Kansai University; Chie Muraki Asano, Nagoya Women's University; Katsunori Okajima, Yokohama National University; and Mikiko Kawasumi, Meijo University (Japan)

Combinational Color Constancy Method Using Dynamic Weights, Shibudas Kattakkalil Subhashdas, Ji-Hoon Yoo, Bong-Seok Choi, and Yeong-Ho Ha, Kyungpook National University (South Korea)

Spectral Predictions of Rough Ink Layers Using a Four-Flux Model, Théo Phan Van Song^{1,2}, Christine Andraud², and Maria Ortiz-Segovia¹; ¹Océ Print Logic Technologies and ²Centre de Recherche sur la Conservation des Collections (France)

Effect of Area on Color Harmony in Simulated Interiors, Seden Odabasioglu, Marmara

CONFIRMED EXHIBITORS

Visit CIC25 Exhibitors on Wednesday and Thursday.

🔨 Image Engineering



Image Science Associates



University, and Nilgün Olguntürk, Bilkent University (Turkey)

A Uniform and Hue Linear Color Space for Perceptual Image Processing Including HDR and Wide Gamut Image Signals,

Muhammad Safdar, COMSATS Intitute of Information Technology (Pakistan); Guihua Cui, Wenzhou University (China); Youn Kim, Huawei Technologies Co., Ltd. Shanghai (China), and Ming Ronnier Luo, Zhejiang University (China)

Device Independent Graininess Reproduction: Preliminary Study, Junki Yoshii, Yuto Hirasawa, and Norimichi Tsumura, Chiba University; Hiroshi Kintou, Nikon Inc.; and Shoji Yamamoto, Tokyo Metropolitan College of Industrial Technology (Japan)

System for Evaluating Pathophysiology Using Facial Image, Futa Matsushita¹, Kaoru Kiyomitsu¹, Keiko Ogawa-Ochiai², and Norimichi Tsumura¹; ¹Chiba University and ²Kanazawa University Hospital (Japan) Luminance, Reflectance, and Chromaticity from RAW Scene Capture, John McCann, McCann Imaging (USA) The Preferred Head Mounted Display (HMD) Luminance Levels under Two Different Surround Conditions, Hyeyoung Ha and Youngshin Kwak, Ulsan National Institute of Science and Technology, and Hyosun Kim, Young-lun Seo, and Won-Sang Park, Samsung Display (South Korea) **Correlation Analysis between Wood Eigen** Textures and Perceptual Qualities, Yoshimitsu Yamada, Keita Hirai, and Takahiko Horiuchi, Chiba University (Japan) Statistical Design of Experiments Applied on Sparkle Visual Detection, Omar Gómez Lozano, Esther Perales, Barbara Mico, Valentin Vigueira, Khalil Hurabait, and Francisco Miguel Martinez Verdu, University of Alicante (Spain) Underwater Color Correction, Thor Olson, Electronics for Imaging (USA)

16:10 - 17:40 INTERACTIVE SESSION

19:30 – 22:00 PM CONFERENCE BANQUET

Join colleagues at restaurant 1847 Brenneriet for lively conversation, libations, and dinner.



1847 Brenneriet has an industrial artsy feel and serves excellent food.

Friday September 15, 2017

COLOR AND IMAGING WORSHOPS

see page 22 for details; select workshop when registering for the conference. Workshops time includes mid-morning coffee break.

with support from Research Council of Norway - project number 272939

8:00 - 12:00

W1: Medical Applications: Image Processing, Challenges, and Perspectives Chair: Faouzi Alaya Cheikh, NTNU (Norway)

8:30 – 12:00 W2: Visual Perception and Emerging Technologies in Cinema: Perspectives from Academia and the Industry

Chair: Marcelo Bertalmio, Universitat Pompeu Fabra (Spain)

9:00 – 12:00 W3: Cultural Heritage Digitization: Challenges and Opportunities

Chair: Sony George, Norwegian University of Science and Technology (Norway)

12:00 - 13:00 GROUP LUNCH (PROVIDED)

13:00 - 14:00 CLOSING KEYNOTE AND CIC AWARDS

Session Chair: Marius Pedersen, Norwegian University of Science and Technology (Norway) **True Colours: Exploration in Art, Design, and Research,** Malcolm Innes, Edinburgh Napier University (UK)

14:00 - 14:40 GREEN WITH ENVY

Session Chair: Youngshin Kwak, Ulsan National Institute of Science and Technology (South Korea) Gamut Mapping for Visual Attention Retargeting, Javier Vazquez-Corral and Marcelo Bertalmío, Universitat Pompeu Fabra (Spain)



CLOSING KEYNOTE

True Colours: Explorations in Art, Design, and Research Malcolm Innes, Edinburgh Napier University (UK)

Malcolm Innes is interested in exploring some of the questions that designers tend not to ask: Do colour metrics really help designers? Do metrics reflect our real life experience of light and colour? Are we actually measuring the right things? Illustrated with examples of projects in the areas of light art, architectural lighting design, and conservation lighting for museums and galleries, this talk discusses the personal attempts by an inquisitive artist/designer to understand our complex relationships with light and colour.

EmoTune - Changing Emotional Response to Images, Katharina Schwarz, Christian Fuchs, Manuel Finckh, and Hendrik Lensch, University of Tuebingen (Germany)

15:10 - 16:30 19TH INTERNATIONAL SYMPOSIUM ON MULTISPECTRAL COLOUR SCIENCE (MCS)

Session Chair: Jon Hardeberg, Norwegian University of Science and Technology (Norway) Spectrophotometric Color Prediction of Mineral Pigments with Relatively Large Particle Size by Single- and Two-Constant Kubelka-Munk Theory, Junfeng Li and Xiaoxia Wan, Wuhan University (China) JIST-First Edge Preserving Filters based RGB-NIR Image Enhancement, Vivek Sharma, Katholieke University Leuven (Germany), and Ion Hardeberg and Sony George, Norwegian University of Science and Technology (Norway) Old Man in Warnemünde (1907) Colouring Palette: A Case Study on the Use of Hyperspectral Imaging for Pigment Identification,



Maihaugen Museum offers enchanting places to enjoy lunch with colleagues.

Hilda Deborah¹, Jin Strand Ferrer², Irina Sandu², Sony George¹, and Jon Hardeberg¹; ¹Norwegian University of Science and Technology and ²The Munch Museum (Norway)

Infrared Imaging Spectroscopic System for the Detection of Skin Cancer: Preliminary

Results, Laura Rey Barroso¹, Francisco J. Burgos-Fernández¹, Xana Delpueyo¹, Ferran Sanabria¹, Miguel Ares¹, Santiago Royo¹, Josep Malvehy², Susana Puig², and Meritxell Vilaseca¹; ¹Universitat Politècnica de Catalunya and ²Dermatology Department of the Hospital Clinic of Barcelona (IDIBAPS) (Spain)

16:30 - 16:40 CLOSING REMARKS AND BEST STUDENT PAPER AWARD

Michael Murdoch, Rochester Institute of Technology (USA)

Become part of the CIC online community!

LinkedIn group: "IS&T color and imaging conference"

and

Tweet #CIC25

CIC25 Short Course Program

MONDAY SEPTEMBER 11, 2017

M1: Color, Vision, and Basic Colorimetry New Instructor

8:30 – 17:45 (8 hours) Instructor: Gaurav Sharma, University of Rochester

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 SPIE/IS&T Journal of Electronic Imaging (2011-2015). Sharma is a fellow of IS&T, IEEE, and SPIE.

Short Course Fees Separate registration is required.

If you register:	by Aug 13	after Aug 13
2-hour Member	\$165	\$215
2-hour Non-member	\$200	\$250
2-hour Student	\$65	\$115
4-hour Member	\$270	\$320
4-hour Non-member	\$315	\$365
4-hour Student	\$95	\$145
8-hour Member	\$480	\$530
8-hour Non-member	\$570	\$620
8-hour Student	\$195	\$245

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

10% SAVINGS

Take 3 or more courses and get 10% off your total short course registration fee!

See registration form for details. Use Pick3 coupon code if registering online.



TUESDAY SEPTEMBER 12, 2017

FOUR-HOUR CLASSES 8:00 - 12:15

T1A: Advanced Colorimetry and Color Appearance New Instructor

8:00 – 12:15 (4 hours) Instructor: Gaurav Sharma, University of Rochester

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 widelyused 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.
- Apply the CIECAM02 color appearance model to obtain colorimetric representations for different viewing conditions.
- Understand how relevant color appearance parameters are determined for real-world viewing environments.
- Describe the components of commonlyused spatial color appearance models.

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.

See bio under course M1, page 10

13:30 - 17:45

T3C: Camera Color Characterization: Theory and Practice New Course

13:30 – 17:45 (4 hours) Instructors: Dietmar Wueller, Image Engineering GmbH & Co. KG, and Eric Walowit, consultant

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. Methodologies 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 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 guality assurance.

Dietmar Wueller studied photographic sciences from 1987-1992 in Cologne. He is the founder of Image Engineering GmbH & Co. KG, one of the leading suppliers of test equipment for digital image capture devices. Wueller is a member of IS&T, DGPH, and ECI and the IS&T Secretary. He is the German representative to ISO TC42 WG18 and 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 in 1985, concentrating in color science. Walowit is a member of ICC, ISOTC42, and IST.

SHORT COURSE MONITORS

Interested in taking a class, but lack funding? Volunteer to be a course monitor. Monitors collect tickets, insure participants have class notes, and aid instructors. Interested? Contact Donna Smith at dsmith@imaging.org. Preference given to students.

TWO-HOUR CLASSES 8:00 – 10:00 AM

T1B: Cone Fundamentals, Color Matching Functions, Luminous Efficiency, and Individual Differences

8:00 – 10:00 (2 hours) Instructor: Andrew Stockman, UCL Institute of Ophthalmology

The trichromacy of human color vision depends on the spectral sensitivities of the long-, middle-, and short-wavelength-sensitive (L, M, and S) cones. These functions are also known as the "fundamental" color matching functions (CMFs) or cone fundamentals. They are the physiological determinants of human color matching, and thus all other CMFs should be linear transformations of them. The cone fundamentals of Stockman & Sharpe (2000) have been adopted by CIE TC 1-36 as the "physiologically-relevant" international standard for colorimetry. This course covers the physiological underpinnings of those cone fundamentals, their derivation and their relationship to other color matching functions, and luminous efficiency functions. As well as being important as mean or standard functions, the functions can also be modified to account for individual differences.

Benefits: Attendees will be able to:

- Understand the basics of phototransduction and how it relates to univariance and to cone spectral sensitivities.
- Learn about the determination of cone spectral sensitivities in normal and color deficient observers.
- Appreciate the relationship of cone spectral sensitivities to RGB color matching functions.
- Observe the relationship of cone spectral sensitivities to luminous efficiency functions and the determination of luminous efficiency.
- Appreciate the relationship of cone spectral sensitivities to XYZ color match-



	MONDAY SHORT COURSE								
	M1-Color, Vision, and Basic Colorimetry: 8:30 – 17:45								
	TUESDAY SHORT COURSES								
	8:00 - 10:00	10:15 – 12:15	13:30 – 15:30	15:45 – 17:45					
Appearance & 3D	T1A: Advanced Colorimetry and Color Appearance	T1A continues	T3A: Color 3D Scanning and Documentation Process of Cultural Heritage Objects NEW	T4A: Color and Appearance in 3D Printing					
Vision & Assessment	T1B: Cone Fundamentals, Color Matching	T2B: Fundamentals of Psychophysics	T3B: Characterizing Surface Appearance	T4B: Color Image Quality Assessment					
Cameras & Spectral Measurement	T1C: Fundamentals of Spectral Measurement for Color Science	T2C: Spectral Filter Arrays Technology NEW T3C: Camera Color Characterization: Theory and Practice NEW		T3C continues					
Displays & Documents	T1D: Color Optimization for Displays	T2D: Perceptual Display NEW	T3D: HDR Theory and Technology	T4D: The Role of Color in Counterfeit Detection and Deterrence NEW					

ing functions and the derivation of the CIE TC 1-36 XYZ CMFs.

- Learn how molecular genetics affect cone spectral sensitivity.
- Origins of individual differences in cone spectral sensitivity.
- Adjust standard cone spectral sensitivities to take into account individual differences.
- Measure individual differences.

Intended Audience: scientists and engineers with an interest in the basics of color vision and colorimetry and the application of the new CIE TC 1-36 "physiologically-relevant" international standard.

Andrew Stockman has been the Steers Chair of Investigative Eye Research at University College London (UCL) Institute of Ophthalmology since 2001. His broad research area is visual psychophysics; his specializations include color vision, rod vision, visual adaptation, temporal sensitivity, and clinical psychophysics. He is best known for his work on human spectral sensitivities. The Stockman & Sharpe cone spectral sensitivities and the related luminous efficiency function have been adopted by the Commission Internationale de l'Éclairage (CIE) as an international standard for color definition and color measurement. He is the principal author of the Colour & Vision Research Laboratories database website (www.cvrl.org), a widely-used color resource for both science and industry.

T1C: Fundamentals of Spectral Measurements for Color Science

8:00 – 10:00 (2 hours) Instructor: David R. Wyble, Avian Rochester, LLC

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 (calibration) and the application of CIE geometries for reflectance and transmittance are also covered. To evaluate instruments, the concepts of precision and accuracy of measurement devices are 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, 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 (calibration) 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.

David R. Wyble is president and founder of Avian Rochester, LLC. Since 2011, Avian Rochester has been delivering color standards; traditional and custom measurements; and consulting services to the color industry. Prior to founding Avian Rochester, Wyble was a color scientist within the Munsell Color Science Laboratory, at the Rochester Institute of Technology, and before that a Member of Research & Technology Staff at Xerox Corp. He holds a BS in computer science and MS and PhD degrees in color science from RIT and Chiba University, respectively. **T1D: Color Optimization for Displays** 8:00 – 10:00 (2 hours) Instructor: Gabriel Marcu, Apple Inc.

This course introduces color optimization techniques for various display types (LCDs, plasma, OLED, 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 some color optimization methods for displays are presented.

Benefits: Attendees will be able to:

- Identify the critical color parameters for displays and their impact on display quality for smart phones, tablets, notebooks, desktops, LCD TV, and projectors.
- Understand color performance and limitations for various LCD modes like IPS, MVA, FFS, and performance of the LED backlighting and quantum dot gamut enhancement.
- Select the optimal color model for a display and highlight its dependency on display technology.
- Understand the translation of the color model into the display ICC profile and how it is used by the color management module.
- 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 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 display portable and desktop 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 SPIE/IS&T Electronic Imaging Symposium and of CIC11; he is cochair of the Electronic Imaging Symposium's Color Imaging Conference: Displaying, Hardcopy, Processing, and Applications. Marcu is an IS&T and SPIE Fellow.

10:15 - 12:15

T2B: Fundamentals of Psychophysics

10:15 – 12:15 (2 hours) Instructor: James A. Ferwerda, Rochester Institute of Technology

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.

T2C: Spectral Filter Arrays Technology New Course 10:15 – 12:15 (2 hours)

Instructors: Jean-Baptiste Thomas, Université de Bourgogne; Yusuke Monno, Tokyo Institute of Technology; and Pierre-Jean Lapray, Université de Haute Alsace

This course covers the topic of spectral filter array technology (SFA) from realization to applications through data processing. It looks at three different prototype realizations and discusses specific constraints and achievements. It also covers the design of SFA, such as the SFA pattern and the spectral sensitivity design. The course highlights the SFA imaging pipeline, which includes processing such as demosaicing, high dynamic range, etc. It also provides examples of resulting images and videos, and discuss weaknesses and suggestions for further research and applications. Benefits: Attendees will be able to:

- Knowledge: understand general concepts of multispectral imaging; summarize and classify spectral acquisition systems; definition of SFA.
- Design: spatial resolution versus spectral resolution; identify sources of noise in SFA: filters, energy balance, chromatic aberration, etc.; design of spatial and spectral distribution.
- Pipeline and Processing: denoising, understand and perform demosaicing; visible and NIR interaction; high dynamic range.
- Applications: estimate spectral reflectance from SFA images; general computer vision applications; joint use of VIS and NIR images.

Intended Audience: research staff, engineers, academics, technology users, camera developers, and industrial users.

Jean-Baptiste Thomas holds a BS in applied physics and MS in optics, image, and vision from the Université Jean Monnet (France). He received his PhD from the Université de Bourgogne. Since 2010, he has been associate professor at the Université de Bourgogne. In 2011 he began working on the development of SFA technology. See: http://jbthomas.org/.

Yusuke Monno received his BE, ME, and PhD from Tokyo Institute of Technology. He is currently a postdoctoral researcher at the university. His interests are in the theoretical and practical aspects of computer vision and image processing. See: www.ok.ctrl.titech.ac.jp/~ymonno/.

Pierre-Jean Lapray received his MS in embedded electronics engineering and PhD in computer science, image, and instrumentation (2013) from the Université de Bourgogne. He is currently associate professor at Université de Haute Alsace, in the Modélisation, Intelligence, Processus et Systèmes laboratory in Mulhouse. Research interests include vision systems, embedded processing, and real-time applications using FPGA.

T2D: Perceptual Display New Course

10:15 – 12:15 (2 hours) Instructors: Tara Akhavan, Greg Ward, and Afsoon Soudi, IRYStec

This course introduces perceptual display platform technology aimed at closing the gap between what is shown on a display/screen versus what is perceived by the human visual system. 3D displays, HDR displays, OLED, and QD displays all bring the display experience one step closer to what is seen in the real world. However none of those displays can provide their users with a real-world experience without considering the other perceptual aspects. The course discusses theories as well as best practices on color perception, contrast perception, and perceived brightness of LCD and OLED displays. An important focus is on how color and contrast are two sides of the same coin. They massively influence display perception and modifying each of the two requires modification in the other. The perceptual display platform approach is discussed in detail for a few applications such as mobile, tablets, automotive, and VR.

Benefits: Attendees will be able to:

- Understanding the display pipeline.
- Describe an overview of why perception is the next big thing in the display industry.
- Learn how to measure perceptual processing algorithm performance.
- Understand why color and contrast are two sides of the same coin.
- Describe challenges vs value propositions of deploying perceptual display platform in different markets such as mobile, automotive, and VR.

Intended Audience: graduate students, engineers, scientists, display industry professionals, and capturing industry professionals

Tara Akhavan is a technology entrepreneur and co-founder and CTO of IRYStec a Series-A Montreal based startup in the display industry.



She holds a BS in computer engineering, an MS in artificial intelligence, and is finishing her PhD in image processing and computer vision at Vienna University of Technology. Akhavan is marketing vicechair of the Society of Information Displays (SID).

Greg Ward is a researcher specializing in lighting simulation and rendering, HDR imaging, and photography. He has authored and continues to maintain the Radiance ray-tracing system and the Photosphere HDR image builder and browser. Ward co-invented BrightSide Technologies's HDR display system (now owned by Dolby). He has co-authored two textbooks, one on radiance and another on HDR imaging.

Afsoon Soudi is a dedicated technologist and entrepreneur with a PhD in physics. She is cofounder and VP R&D of IRYStec. Prior to founding IRYStec, she led multiple research groups with an excellent track record of publications in prestigious journals leading to 250+ citations. Her specially is characterization of semiconductor nanomaterials including nanowires and quantum dots with applications in electronics and solar cells.

13:30 - 15:30

T3A: Color 3D Scanning and Documentation Process of Cultural Heritage Objects New Course

13:30 – 15:30 (2 hours) Instructor: Robert Sitnik, Warsaw University of Technology

This course provides a comprehensive overview of the process of full color 3D documentation (capture, processing, evaluation, storage and archiving) of a selected group of cultural heritage (CH) objects, including planning, technical requirements specification, realization, monitoring, final model preparation, and archiving. The course introduces the main factors of the process that influence final data accuracy and quality, including required time and budget. The technical requirements of the final data are defined based on the assumed goals. In addition to state of the art techniques for 3D documentation, new multimodal approaches supporting 3D data with color, BRDF, and Reflectance Transformation Imaging (RTI) are discussed. The course covers topics on automation of acquisition and processing of the 3D documentation campaign. Several examples of 3D scanning campaigns are included throughout the course. Practical challenges and factors influencing the data quality are discussed.

Benefits Attendees will be able to:

- Understand the basics of different 3D scanning technologies and workflow used in the CH sector.
- Explore new trends in 3D documentation of CH objects.
- Understand the benefits and limitations of existing 3D processing pipelines.
- Become familiar with modern approaches to automation of the 3D documentation process, from acquisition and processing perspectives.
- Understand the process of 3D documentation, from the planning phase to long term archiving.
- Effectively select techniques and plan workflow of 3D documentation process for a collection of CH objects.
- Apply concepts introduced in this course to the solution of real-world problems in planning and co-ordination of 3D documentation campaigns.

Intended Audience: scientists, engineers, curators, and managers involved in the development, design, engineering, manufacturing, marketing, planning, realization, or evaluation of 3D documentation hardware, or software supporting 3D documentation processes.

Robert Sitnik is an associate professor at the Institute of Micromechanics and Photonics at the Warsaw University of Technology (WUT), Mechatronics Faculty, Poland. His work is centered on 2D/3D/4D imaging and virtual/augmented reality applications. He has more than 100 publications in this field. He received his MSc in optical engineering and his PhD in 3D imaging from WUT. His dissertation focused on development of a 3D scanning technique using structured light. He received his habilitation in 3D/4D imaging in 2012. Sitnik is the head of the Virtual Reality Techniques Division and OGX research group.

T3B: Characterizing Surface Appearance

13:30 – 15:30 (2 hours) Instructor: James A. Ferwerda, Rochester Institute of Technology

Surface appearance is of critical importance in a wide variety of fields including design, manufacturing, forensics, medicine, and cultural heritage preservation. This short course 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 describes the psychophysical methods that are used to relate the physical properties of surfaces to their visual appearances. Finally, we discuss the potential for using computergraphics techniques to simulate the appearances of complex surfaces and describe how new digital imaging technologies are being used to advance the measurement, modeling, visualization, and communication of surface appearance.

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.

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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 the class.

See bio under T2B, page 15.

T3D: High Dynamic Range Theory and Technology 13:30 – 15:30 (2 hours) Instructors: Alessandro Rizzi, University of Milano, and John McCann, McCann Imaging

High Dynamic Range (HDR) imaging is a continuously evolving part of color. HDR painting was invented in the Renaissance; 50 years ago it was a research topic in understanding scenes in non-uniform illumination (Edwin Land's "Mondrians"); 20 years ago, HDR used multiple exposures to attempt to capture a wider range of scene information (Debevec-Malik's program and Fairchild's Survey); 10+ years ago interest evolved to recreating HDR scenes by integrating widely-used LCD with LED illumination (Helge Seetzen's Brightsides Displays); and today the evolution continues in the current sales of HDR televisions using OLED and Quantum Dot technologies. Standards for HDR video media formats remain an active area of research as well.

This course reviews the science and technology underlying the evolution of HDR imaging from silver-halide photography to HDR TVs. One emphasis is on measuring the actual physical limitations of scene capture, scene display, and most important the interaction of these



systems with human vision. (Vision is itself a HDR sensor with very sophisticated spatial-image-processing algorithms.) A second emphasis is on the differences between single-pixel and spatial comparison HDR algorithms. The course describes the partnership between HDR hardware and human vision that receives, processes, and enjoys HDR reproductions.

After a detailed description of the dynamic range problem in image acquisition, this course focuses on standard methods of creating and manipulating HDR images, replacing myths with scene measurements, camera images, and visual appearances. The course presents measurements about the limits of accurate camera acquisition (range and color) and the usable range of light for displays presented to human vision. It discusses the principles of tone rendering and the role of HDR spatial comparisons.

Benefits Attendees will be able to:

- Explore the history of HDR imaging.
- Understand dynamic range and quantization: the 'salame' metaphor.
- Compare single and multiple-exposures for scene capture.
- Measure optical limits in acquisition and display: scene dependent effects of glare.
- Measure limits of RAW scene capture in LDR and HDR scenes.
- Measure limits of human vision and calculate retinal luminance for models of vision.
- Discuss current HDR TV systems and standards: tone-rendering vs. spatial HDR methods.

Intended Audience: anyone interested in using HDR imaging: science and applications. This includes students, color scientists, imaging researchers, medical imagers, software and hardware engineers, photographers, cinematographers, and production specialists.

Alessandro Rizzi is a full professor, department of computer science, University of Milano. He has studied the field of digital imaging and vision since 1990 with a particular interest in color, visualization, photography, and HDR. He is one of the founders of the Italian Color Group, secretary of CIE Division 8, an IS&T Fellow, and a past vice president. He is topical editor for Applied Color Science of the Journal of Optical Society of America and associate editor of Journal of Electronic Imaging.

John McCann received a degree in biology from Harvard College (1964). He worked in and managed the Vision Research Laboratory at Polaroid from 1961 to 1996. He has studied human color vision, digital image processing, large format instant photography, and the reproduction of fine art. His publications and patents have studied Retinex theory, color constancy, color from rod/cone interactions at low light levels, appearance with scattered light, and HDR imaging. He is a Fellow of IS&T and OSA; a past president of IS&T and the Artists Foundation, Boston; recipient of the IS&T/OSA 2002 Edwin H. Land Medal; and IS&T Honorary Member (2005).

15:45 - 17:45

T4A: Color and Appearance in 3D Printing

15:45 – 17:45 (2 hours) Instructor: Philipp Urban, Fraunhofer Institute for Computer Graphics Research IGD

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.

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. 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.

T4B: Color Image Quality Assessment

15:45 – 17:45 (2 hours) Instructors: Marius Pedersen and Seyed Ali Amirshahi, Norwegian Colour and Visual Computing Laboratory (NTNU)

Image quality assessment is a topic of growing interest that has also been the subject of much recent research. This short course examines the current thinking about color image quality from several different vantage points. The course introduces and presents the core functions used in objective color image quality assessment, including models of the human visual system and how pixel error maps can be converted to a single quality number by spatial summation. Furthermore, it presents some of the most common methods, as well as promising new methods for quality assessment. Also discussed are methods for conducting psychophysical experiments to evaluate specific aspects of image quality and how these results are used to evaluate the performance of objective image quality metrics. The most common performance measures are introduced and examples of the performance of state-of-the-art image quality metrics are shown. The course also focuses on how to identify a set of key image quality attributes, such as tone reproduction, sharpness, contrast, graininess, color fidelity, and artifacts, and to compute these as a set of distinct metrics for evaluating image guality. The use of spider plots to illustrate how they separately and cumulatively affect overall image quality is highlighted. Also illustrated is the use of these image quality concepts for the evaluation of printer workflows. Finally, the use of image quality metrics in biometrics, to evaluate displays, and medical applications is shown

Benefits: Attendees will be able to:

- Understand the basic characteristics of the human visual system.
- Understand methods for conducting psychophysical experiments to subjectively assess image quality.
- Be familiar with the major image quality metrics in use today and how to evaluate their performance.
- Understand methods for pooling the results of spatial image quality maps to yield a single-number assessment of overall image quality.
- Understand what the major image quality attributes are, what they measure, and how they are computed.
- Generate and interpret spider-plots that provide an integrated view of how a given image performs across a set of image quality attributes.
- Gain insight into the application of the concepts introduced in this course to the solution of real-world problems in imaging systems development.

Intended Audience: scientists, engineers, analysts, and managers involved in the design, engineering, manufacturing, marketing, or evaluation of imaging and printing products, algorithms, or systems. Participants should be



familiar with the function and basic properties of imaging systems. A rudimentary knowledge of color science, linear systems, and image processing is helpful, but not essential.

Marius Pedersen is associate professor at the Norwegian University of Science and Technology (NTNU), Norway. His work is centered on image quality assessment; he has more than 60 publications in this field. He received his PhD in color imaging (2011) from the University of Oslo, Norway. He is currently the head of the computer science group in Gjøvik 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 postdoctoral 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.

T4D: The Role of Color in Counterfeit Detection and Deterrence New Course

15:45 – 17:45 (2 hours) Instructor: Joel Zlotnick, US Department of State

Recent years have seen dramatic increases in the availability and quality of color office printing devices that have transformed counterfeiting from a specialist endeavor and made it accessible to individuals without technical printing skills. As a result, industry has generated an ever-increasing roster of hightech security features designed to make counterfeits easy to detect. Despite these advances, the public availability of security feature materials via internet commerce contests the effectiveness of security features as standalone counterfeit deterrence solutions.

EXHIBIT AT CIC25!

Interested in exhibiting or sponsoring an event at CIC? Exhibit space is limited; contact Donna Smith to learn more about exhibits and sponsorship opportunities at dsmith@imaging.org.

Traditionally, the backbone of security design has been careful use of color, artwork, and printing press capabilities to produce a document that is resistant to attack. This course affirms and describes the traditional roles of color and artwork in security document design.

Benefits: Attendees will be able to:

- Describe traditional and digital counterfeiting workflows and why they matter.
- Understand principles of security artwork design used to deter counterfeiting.
- Illustrate the role of color in the design of counterfeit-resistant artwork.
- Differentiate between artwork and halftones used in commercial printing and security printing.
- Compare classes of physical security features that complement security artwork.

Intended Audience: designers, printers, prepress staff, and others interested in counterfeit deterrence strategies for hardcopy documents.

Joel Zlotnick is employed by the US Department of State, Bureau of Consular Affairs, Counterfeit Deterrence Laboratory as a supervisory physical scientist. His current work involves research in security design techniques. He is an instructor on counterfeit detection at the US Department of State Foreign Service Institute. Zlotnick held previous positions at Homeland Security Investigations and US Secret Service forensic laboratories. He holds a BS in chemistry and MSFS in forensic science.

CIC Workshops

A workshop is included with your conference registration, including the Friday, one-day, rate. Support from Research Council of Norway - project number 272939.

W1: Medical Applications: Image Processing, Challenges, and Perspectives 8:00 – 12:00

Chair: Chair: Faouzi Alaya Cheikh, NTNU (Norway)

This workshop discusses the challenges of color image processing in the context of different medical applications. The workshop is a collection of presentations covering a wide range of interests and expertise including: ICC standards, physics and medical technology, image processing, high-performance computing, and business. Speakers for this workshop are:

- How iccMAX can help address colour management challenges in medical applications (Phil Green, NTNU, Norway)
- What possibilities for colon visualizing do we have? Future perspectives (Øistein Hovde, Innlandet Hospital Trust, Norway)
- Optical imaging techniques for noncontact measurements of vital functions and diagnosis of tissues in medicine (Ruud Verdaasdonk, VU University Medical Center Amsterdam, the Netherlands)
- Multispectral optical properties of human hands skin (Martin Drahanski, Brno University of Technology (BUT), Czech Republic)
- Skin Culture Image Analysis (WIMASIS online services) (Daniel Pérez-Rodríguez, Onimagin Technologies, Spain)
- Heterogeneous systems for medical image processing (Juan Gomez-Luna, University of Cordoba, Spain)

W2: Visual perception and emerging technologies in cinema: Perspectives from academia and the industry 8:30 – 12:00

Chairs: Marcelo Bertalmio, Universitat Pompeu Fabra (Spain)

The media industry is constantly pushing the limits of what can be achieved in terms of visual quality in cinema and TV, promoting advances in the capabilities of cameras and displays with regard to contrast, color, resolution, frame rate, etc. Currently the emphasis is on high dynamic range (HDR) and wide color gamut (WCG) technologies, which have been identified as key growth areas for media companies, and there is also substantial work on High Frame Rate (HFR) and Ultra High Definition (4K/8K) imaging. However, industry and standardization bodies also recognise that there are a number of challenges that need to be addressed for a successful adoption of these emerging technologies, including important issues arising due to the complex and not yet fully understood interactions of this new type of image content with the human visual system. In particular, the majority of research in the vision science community has been conducted on standard monitors and therefore there is a lack of accurate vision models that can properly predict the perception of lightness, contrast and color for natural images with the high dynamic range, high brightness, and wide color gamut that emerging displays can provide. Also, the use of these new technologies must imply changes in the way movies are shot, edited and color-graded, not only for the faithful reproduction of color and contrast, but also to avoid the appearance of artifacts or visual discomfort that this enhanced image content might induce.

In order to address these issues, this workshop brings together researchers from academia and key companies in the cinema and TV sector, to present their latest research outcomes



and discuss their outlook on the topic. The goal is to provides an opportunity to encourage a closer collaboration among the image processing and vision research communities. The following is a list of speakers with titles and abstracts of their talks:

Visibility of spatiotemporal noise in digital video, Tamara Seybold, ARRI (Germany)

Tests have shown that video quality is still difficult to reflect with automatic quality metrics. To improve the automatic evaluation of quality, including human

perception, seems prospective. A vast amount of perception research has been conducted in vision science. However, the quality metrics used in image and video processing research do not-or notsufficientlyintegrate our knowledge about human perception. In this talk, we will specifically discuss the visibility of one image degradation type, spatiotemporal noise, which occurs in digital video especially in low-light situations. Noise in digital video can clearly reduce the perceived quality of sequences captured with modern digital cameras. As no experimental study could be found about the visibility of noise, two experiments were conducted aiming to investigate the visibility of spatiotemporal noise. The experiments subsequently evaluate the visibility of noise in different spatial and different temporal frequencies on a monitor. Eight spatial frequencies are investigated and two different video frame rates, 24 fps and 48 fps. The experiment setup and the results are discussed in detail. The talk concludes with an outlook on future research projects and an open discussion about the open questions in vision research.

A colour space for all devices,

Richard Kirk, FilmLight (UK)

For many years the motion picture industry used RGB spaces based on physical display devices. Video RGB was based on the CRT; Kodak's Cineon was based on film negative



The Mesna and Avieta rivers converge and flow through downtown Lillehammer.

densities. The hardware limitations restricted the image data to 8-bit or 10-bit RGB, where each combination of RGB values corresponded to a real display color. Everything has changed. Film is not the dominant medium. There are many alternatives to the CRT with better brightness, contrast, and color gamut. Images can use 16- or 32-bit floating-point formats, which support negative values, and values over 1.0. In this talk, I try to start afresh and determine what a good color space might be and how we might handle an image workflow from a camera to an arbitrary display.

Future imaging technologies like high dynamic range (HDR) and wide color gamut (WCG) require a re-assessment of the human visual system, Jan Froehlich, ARRI (Germany)

Traditional image encodings rely on computationally simple functions like a power function for luminance nonlinearity and a color difference matrix for decorrelation. Higher dynamic range and wider gamut imagery needs advanced methods for efficient storage and manipulation. While our knowledge about human vision has increased significantly over the last decades, even the newest color encoding proposals for high dynamic range and wide color gamut image encoding are surprisingly based on mid- to late-20th century human vision research. We identify those areas, where research in entertainment media is held back by missing psychometric data for the human visual system, and we propose possible steps to close these gaps.

Color and contrast appearance across the luminance range, Rafal Mantiuk, University of Cambridge (UK)

The appearance of contrast and colors varies substantially between dark and bright luminance levels. This change is caused by the transition from cone-mediated photopic vision to the mesopic vision that relies on inputs from both cones and rods. We show that the major effects of that change in appearance can be explained by models of contrast perception, models of rod-contribution to vision, and simple empirical models based on our measurements. The combination of those models can be used to retarget appearance of arbitrary complex images from one luminance level to another. For example, we can simulate the appearance of night scenes on much brighter displays. We can also compensate for the night vision and present images on dimmed displays so that they appear as if they were seen at much higher luminance levels. The latter application is intended to reduce power consumption of electronic displays and improve viewing comfort in dark environments. The appearance retargeting method can be implemented very efficiently on mobile graphics processors so that the compensation if performed in real-time.

Vision models for tone and gamut mapping, Marcelo Bertalmío, Universitat Pompeu Fabra (Spain)

This talk presenta recently proposed image processing techniques based on vision models that address two important problems in the motion picture and TV industries: tone mapping (making high dynamic range images suitable for standard dynamic range displays) and gamut mapping (modifying the color gamut of images so that they properly fit the color capabilities of a given display). By leveraging knowledge from vision science, we are able to develop methods that produce natural-looking results, and are also very fast to execute. See http://ip4ec.upf. edu/.

High Dynamic Range for TV - How the HLG system adapts images to maintain consistent appearance in varying consumer viewing environments, Richard Salmon, BBC R&D (UK) There are two radically different approaches to HDR for TV. Some working in the field postulate that the artistic intent is maintained, no matter what the viewing environment might be, by presenting the major part of images at the same absolute brightness as that seen on the master monitor when the material was graded. The hybrid log-gamma (HLG) system, developed by broadcasters BBC and NHK, however follows the path trodden by conventional TV systems, in that it is based on relative brightness. Thus it is easy to provide a consistent visual appearance by adapting the display characteristic to match the viewing environment and capabilities of the individual display in the viewer's home.

The presentation includes details of work to match the viewing experience to the peak screen brightness and to the background illumination.

W3: Cultural Heritage Digitization: Challenges and Opportunities

9:00 - 12:00

Chair: Sony George, Norwegian University of Science and Technology (Norway)

This workshop aims to discuss and identify the strategies for acquisition, analysis of CH artifacts according to the constraints/needs of the end-users. End-users express their needs/specifications (objective of digitisation, quality of data, location of critical areas or interest, challenges specific to artefacts, etc.). Researchers and technology providers address this strategy and propose solutions digitization methods, multimodal imaging systems, possible analysis and limitations, supporting restoration, visualization, tools for analysis, time and accuracy, data reuse etc.





The Jakob Weidemann Gallery in the Lillehammer Art Museum features the work of one of Norway's most important post-war modern artists.

The joint contribution of experts from different sectors highlights the challenges and opportunities linked to digitization and best practices concerning: safeguarding, management, enhancement, and research and innovation activities. By this, the workshop aims to cover future opportunities and challenges in cultural heritage digitization. Speakers from museums, academia, and industries will contribute to this workshop.

As color and cultural heritage are closely linked in many ways, this workshop is a knowledge-sharing event that facilitates the interaction between color experts, imaging scientists, and people working in the cultural heritage domain. The discussions in the workshop may also help researchers to better understand the challenges and opportunities in this sector and better prepare to meet initiatives like the European Year of Cultural Heritage 2018.

The following is a list of speakers with titles and abstracts of their talks:

Colour research on modern works of art – past, present and future developments at Munch Museum, Irina Crina Anca Sandu, Munch Museum (Norway)

Munch Museum collection in Oslo is encompassing more than 50 years of artistic production of Edvard Munch (1863-1944) and includes several typologies of art objects among which there are approximately 1,150 paintings, 18,000 prints depicting more than 700 different motifs, and 7,700 drawings and watercolors, as well as 13 sculptures. The Conservation Department of Munch Museum is actively engaged in the study of the collection and in identifying strategic research actions oriented by the three research tasks established in the research plan: Characterization of materials and techniques used by Munch; study and monitoring of degradation and deterioration processes; and development and testing of new solutions for conservation.

Spectral, 3D, and RX Imaging for art conservation in French museums, Clotilde Boust, C2RMF, Louvre Paris (France)

The center of research and restoration of french museums is doing several non invasive analyses for art conservation. The center uses spectral imaging (UV to IR, 360-1700nm) to detect varnish removal or pigment identification, 3D from macro to micro scale for tools traces, and form comparisons and RX imaging to study inner structure of objects. Information found helps in conservation decisions or leads to further chemical or ion bean analysis.

3D reconstruction of Royaumon abbey in the XIIIth century, Patrick Callet, CAOR – Robotics Centre, Mines- Paristech, PSL Research University (France)

Compensation of directional reflection component in simultaneous 3D and color

imaging, Grzegorz Maczkowski, Institute of Micromechanics and Photonics, Warsaw University of Technology (Poland)

Digitization of cultural heritage in 3D, beside high resolution shape model, requires accurate color reproduction. This requirement is usually difficult to fulfill in combination with structured light projection because of directional illumination, complicated object shapes, and glossy surfaces. To solve this problem, we propose a multidirectional illumination setup combined with a highlights removal algorithm. This way we are able to separate specular and diffuse components of reflected light. The diffuse component is extracted along with surface normal vectors and illumination and observation directions. It is further used for multispectral color measurement and compensation of uneven illumination. We provide a model for directional reflection compensation based on 3D imaging geometry. The model is backed up by simulations and experimental data from a representative cultural heritage object.

Image processing and analysis of cultural heritage paintings: From pigments to

craquelure, Hilda Deborah, The Norwegian Colour and Visual Computing Laboratory, Norwegian University of Science and Technology (NTNU) (Norway)

Since VASARI and CRISATEL, spectral imaging has been increasingly exploited as a means to accurately document cultural heritage objects. Further processing and analysis steps during acquisition not only allow documentation of objects, but provide more knowledge about and tools for their study, as well as their conservation. For example, pigment identification allows for the accuratechoice of the pigment for inpainting, without having to take physical samples from the painting under evaluation. In this talk, the applications of hyperspectral image processing and analysis to cultural heritage paintings is explored, including challenges and directions for future research.

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Displaying of a medieval funeral effigy: A case study, Malcolm Innes, School of Arts and Creative Industries, Edinburgh Napier University (UK)

A case study of a project I created for the display of a medieval funeral effigy that involved the virtual restoration of the original polychrome finish to the life-size effigy. The recoloring of the object is done with a digital projection that is mapped onto the threedimensional object. The talk discusses the novel, interactive approaches to the interpretation of cultural heritage and the application of high-technology solutions using off-the-shelf components so that processes remain simple and easy to manage without the additional overhead of proprietary software or specialist technical staff.

Monitoring Ships in Museums – A European Review, Amandine Colson, German Maritime Museum (Germany)

The presentation focuses on the on-going initiatives in Europe dealing with deformation monitoring of ships in museum. Based on a few examples from Sweden, Great-Britain, France, and Germany, we construct a portrait of the difficulties encountered by museums. Monitoring is by essence a long-term issue, although nowadays research plans are often short term (3-5 years) and rely on thirdparty money. In this field, the clash of two worlds is everyday life. Interdisciplinarity is praised highly, but when professions that never worked together before come to one table, one should be prepared to invest time and energy on building common ground. Total station theodolite, laser scanning, Coordinate Measuring Machine, and Photogrammetry are all terms that Humanities experts rarely know, and if they do, they don't necessary know what's behind them. "Monitoring Ships in Museums" is the result of dedicated researchers from different fields willing to work together for the next 10 to 20 years to preserve these ships for future generations.



Hotel and Travel Information

Scandic Lillehammer Hotel

Turisthotellvegen 6, Lillehammer, Norway • + 47 61 286 000

Special Note for CIC25: Our ability to provide lunch and other amenities to all attendees is based on attendees staying at the Scandic Lillehammer Hotel. While you are free to choose an alternative lodging option, please note, those who do not stay at the Scandic Lillehammer Hotel will be assessed a \$100 supplemental registration fee.

Rate: NOK 1150 single and NOK 1600 double inclusive. Includes breakfast, wifi, and VAT. The hotel has free parking. **Check in/out:** 14:00/noon

Rate availability: Rate honored three days prior to and three days after the conference dates based on availability.

Reservation Deadline: August 8, 2017 to guarantee room

Reservations:

via www.scandichotels.com/ enter Lillehammer as the destination and select *Scandic Lillehammer Hotel* (note there is more than one Scandic hotel in the city!). Choose date for arrival and departure and number of people in the room. *Important:* Use booking code: BIST070917

via phone: +47 61 286 000 / Reference: IS&T CIC Room Block

Cancellation Policy: There are no penalties for cancellations within 72 hours of expected arrival. After 72 hours or a no-show will be charged at 100% of room nights booked.

Transportation Information

Airport: Lillehammer is served by Oslo Airport Gardermoen (OSL). The official OSL website is www.osl.no.

To/from OSL/Lillehammer via Train: Lillehammer is 145 km (90 miles) from the airport and may be reached via train. There is frequent, direct train service from Oslo Airport (OSL) to Lillehammer every hour, depending on the time/day. Travel time is approximately 1 hour 45 minutes. Trains generally leave from Spor (platform) 1. Train information is at www. nsb.no/en.

After landing, follow signs in the airport to Trains. Tracks are located "below" the main terminal. Ticket kiosks are easily accessible in the main terminal, but may also be bought onboard for a higher fare. Fares vary from approximately NOK 245 (up to 24-hours in advance; you must book for a specific time) to NOK 300 (same day travel).

For those wishing to visit Oslo before or after the conference, travel from the city of Oslo to Lillehammer via train is approximately 2 hours 15 minutes.

To hotel from Lillehammer train station: The hotel is 1.4 km (0.8 miles) from the Lillehammer station. The taxi queue is to the right as you exit and will cost ~NOK 110. The walk is a steep incline all the way and will take 20-40 minutes.

CIC25 Conference Registration

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

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□ I am not staying at the Scandic Lillehammer Hotel	Amount due:	\$100	\$

3. CIC Workshop Selection (free with registration; select ONE)

W1: Medical Applications: Image Processing, Challenges, and Perspectives

UW2: Visual Perception & Emerging Tech. in Cinema: Perspectives from Academia & the Industry

W3: Cultural Heritage Digitization: Challenges and Opportunities

□ I do not plan to attend a workshop

* 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 effect by 9/19/17 and expires 12/31/18. This offer may be used for renewals.

** All conference attendees, no matter what they are registering for (full program, short course only, one-day, etc.) or how long they are staying are subject to this flat fee should they choose not to lodge at the Scandic Lillehammer Hotel.



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

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.

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6. Short Course Lunch on Tuesday

Lunch will be provided for students taking classes Monday and Tuesday. If you wish to participate in Tuesday's lunch at the hotel, please let us know.

I want lunch on Tuesday.
I do not want lunch on Tuesday.

7. Extras

Additional copy of conf. proceedings Note: One copy comes with conference registration	\$140	\$
Additional/Guest ticket for Welcome Reception	\$35	\$
Additional/Guest ticket for Conference Banquet	\$65	\$
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Please note: To cover bank charges and processing fees, there is a cancellation fee of \$75 until September 1, 2017. After that date, the cancellation fee is 50% of the total plus \$75. No refunds will be given after September 15, 2017. All requests for refund must be made in writing.





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Lillehammer main pedestrian-only street.

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