September 11-15, 2017
Lillehammer, Norway

FINAL PROGRAM AND PROCEEDINGS

Twenty-fifth Color and Imaging Conference

Color Science and Engineering Systems, Technologies, and Applications

Collocated with 19th International Symposium on Multispectral Colour Science

Sponsored by the
Society for Imaging Science and Technology

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The papers in this volume represent the program of the Twenty-fifth Color and Imaging Conference (CIC25)
held September 11-15, 2017, in Lillehammer, Norway.

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Velkommen til CIC25!

A warm welcome to the 25th Color and Imaging Conference. We're happy to bring this edition to Lillehammer, Norway—our second and now biennial trip to Europe—where we will have a familiar mix of events in beautiful new surroundings. It's the 25th CIC! Such a round number certainly makes many of us look back on what's happened in the past 25 years, including developments in digital imaging, color models, understanding of human vision, and machine intelligence. When CIC began in 1992, the internet was just getting started, cell phones were bricks, photofinishing was easy to find, and CRTs weighed down desks worldwide.

Consistent with the past 24 events, the core of CIC25 is a rich 3-day technical program of peer-reviewed papers, including 31 oral, 25 interactive, and 3 keynote papers. We have a record number of JIST-First papers (9!), meaning they have been reviewed and accepted for publication in the *Journal of Imaging Science and Technology,* and are included in the CIC program as reprints. The CIC technical program, assembled by program chairs Marius Pedersen and Nicolas Bonnier, represents the cutting edge in color science research and application from industry and academia, with topics including image quality, material appearance, lighting, adaptation, printing, and 3D printing.

A similar breadth of topics is covered by CIC25's short courses and workshops. Please take advantage of Friday's workshops! Delivered by industrial and academic experts, workshops are a mix of lecture, technical presentation, and discussion that we hope will let you dive deeply into a topic for a few hours—whether it's your core interest or an interesting diversion.

We have a very interesting and diverse lineup of keynote speakers for CIC25. Kicking off the technical program on Wednesday morning, Paul Hubel of Apple speaks about computational imaging and the development of mobile imaging. Thursday morning, Anya Hurlbert of Newcastle University talks about the progress made in understanding the complexity of color constancy in human vision. Friday afternoon, our final keynote speaker, Malcolm Innes of Edinburgh Napier University, discusses the challenges creating meaningful metrics for light and color and how they relate to the experience of artists and designers. We hope that the range and depth of these speakers instills deeper understanding, inspires future research, and spurs meaningful conversation during the social breaks.

Speaking of which, I'm sure you agree that one of the most valuable aspects of attending CIC is the opportunity to network and collaborate with peers from around the world. The single-track program, long coffee breaks, group lunches, welcome reception and conference banquet, and even our special CIC25 evening event are all arranged to maximize social interaction—for business, for fun, for you. Please reconnect with old friends, strengthen business contacts, and meet someone new while we are all together in Lillehammer. I'm sure the "locals" from nearby Gjøvik will be more than happy to help you feel at home in Norway, and the conference committee and IS&T staff are available to help however we can.

On the next page is the full list of conference committee chairs, technical reviewers, JIST-First editors, and CIC steering committee members. Please join me in thanking all of them for the substantial and rewarding work of putting together our conference. Thanks also to the exhibitors, sponsors, and several Research Council of Norway projects for their help in making the conference possible. Make the best of it! Tell us what you think, and please let us know if you have ideas that can make the next one even better.

—Michael Murdoch, CIC25 General Chair

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SILIOS TECHNOLOGIES

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WEDNESDAY SEPTEMBER 13, 2017

WELCOME AND OPENING KEYNOTE

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

9:00 – 10:00

SPONSORED BY HP INC.

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 DIMENSIONS

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

10:00 – 10:40

10:00 **Multidimensional Estimation of Spectral Sensitivities,** *Eric Walowit[1], Holger Buhr[2], and Dietmar Wueller[2]; [1]consultant (USA) and [2]Image Engineering GmbH & Co. KG (Germany)* **1**

An important step in the color image processing pipeline for modern digital cameras is the transform from camera response resulting from scene spectral radiance to objective colorimetric or related quantities. Knowledge of the camera spectral sensitivities is essential for building robust camera transforms for arbitrary capture and viewing conditions. Monochromator-based techniques are well-known but are cumbersome, slow, and impractical for routine use such as production-line camera calibration. It has been shown that with suitable characterization data it is possible to accurately estimate spectral sensitivities without the use of a monochromator. However, these methods are inherently highly metameric and the performance on likely scene capture spectra is unclear. In the current work, it is shown that combining highly-dimensional characterization data with multidimensional analysis of typical camera responses produces spectral sensitivity estimates for a test camera that performs extremely well on likely scene spectra while minimizing the opportunity for camera observer metamerism.

10:20 **Color Formation in Virtual Reality 3D 360° Cameras,** *Bartek Pawlik, Veli-Tapani Peltoketo, Ossi Pirinen, and Petri Nenonen, Nokia Technologies (Finland)* **7**

In digital camera applications observed color is formed by light reflecting from or transmitted through a medium, observed by a sensor. The final digital value output by a camera is a composite of the spectrum of emitted light, reflectance (or transmittance) properties of a material and spectral response of the observing sensor. In this paper, we demonstrate how even small changes in any of the mentioned properties can cause clearly visible and sometimes unwanted changes in the digital numbers produced by a camera. Additionally, we explore this problem from the point-of-view of a 3D 360° camera, show how these problems are even more severe in this particular case as well as propose a solution relying on accurate measurement of both light as well as camera's response to it.

10:40 – 11:20

COFFEE BREAK / EXHIBIT OPEN

YOU BE THE JUDGE

with support from IQ-MED: Image Quality enhancement in MEDical diagnosis, monitoring, and treatment project; funded by the Research Council of Norway – project number 247689

Session Chair: Jae Young Park, Apple Inc. (USA)

11:20 – 12:00

11:20 **Image Quality Assessment of Displayed and Printed Smartphone Images,** *Gaurav Sheth, Katherine Carpenter, and Susan Farnand, Rochester Institute of Technology (USA)* **13**

Smartphones have become ingrained in our daily activities, driving Smartphone cameras to become better with every generation. As more and more images are being taken by smartphones it has become increasingly important to assess the quality of the images taken by different phones. The Cell Phone Image Quality (CPIQ) Group created the IEEE P1858 CPIQ Standard. To subjectively validate the group's metric, psychophysical tests were performed; each tested observers' preferences for a wide range of images. While many smartphone images are only viewed electronically, many images also get transformed into printed images, especially photobooks, as digital printing gets better and cheaper compared to traditional printing processes. The main goals of this research were to evaluate the image quality of smartphone images, both electronically displayed and for several printers, and to compare print quality to displayed quality. The subjective results indicated that the perceived quality of images is well-correlated with the objective results of the IEEE P1858 CPIQ Standard. It was also found that smartphones have a bigger impact on the image quality compared to the digital printers.

11:40 **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)* **20**

Capsule endoscopy, using a wireless camera to capture the digestive track, is becoming a popular alternative to traditional colonoscopy. The images obtained from a capsule have lower quality compared to traditional colonoscopy, and high-quality images are required by medical doctors in order to set an accurate diagnosis. Over the last years several enhancement techniques have been proposed to improve the quality of capsule images. In order to verify that the capsule images have the required diagnostic quality some kind of quality assessment is required. In this work, the authors evaluate state-of-the-art no-reference image quality metrics for capsule video endoscopy. Furthermore, they use the best performing metric to optimize one of the capsule video endoscopy enhancement methods and validate through subjective experiment.

GROUP LUNCH (PROVIDED)

12:00 – 13:30

COLOR MATTERS

with support from MUVApp — Measuring and Understanding Visual Appearance Project; funded by the Research Council of Norway – project number 250293

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

13:30 – 15:00

13:30 **nmmm "Nano-Micro-Meso-Macro" Colour and Appearance— A Multiscale Approach (Focal Talk),** *Patrick Callet, CAOR-Mines ParisTech-PSL University and Centre Français de la Couleur (France)* **28**

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 all the material compounds acquired separately is illustrated using automotive paints as an example.

14:00 **Appearance Reconstruction of Fluorescent Objects for Different Materials and Light Source,** *Shoji Tominaga, Keiji Kato, Keita Hirai, and Takahiko Horiuchi, Chiba University (Japan)* **34**

This paper proposes a method for reconstructing the scene appearance of fluorescent objects under different conditions of materials and light source. First, the observed spectral image of two fluorescent objects with the mutual illumination effect is described by the multiplication of the spectral functions and the geometric factors. Second, the observed image is decomposed into spectral component images by the ridge regression approach. Third, the geometric factor of the self-luminescent component is separated into the direct and indirect illumination components by taking the spatial distributions of reflection and interreflection into account. Then the scene appearance of the two fluorescent objects under different conditions is reconstructed using the five components of (1) reflection, (2) interreflection, (3) luminescence by direct illumination, (4) luminescence by indirect illumination, and (5) interreflection by fluorescent illumination. The feasibility is shown using two scenes consisting of two fluorescent objects.

14:20 **JIST-First PuRet: Material Appearance Enhancement Considering Pupil and Retina Behaviors,** *Midori Tanaka, Ryusuke Arai, and Takahiko Horiuchi, Chiba University (Japan)*. **40**

In addition to colors and shapes, factors of material appearance such as glossiness, translucency, and roughness are important for reproducing the realistic feeling of images. In general, these perceptual qualities are often degraded when reproduced as digital color images. Therefore, it is useful to enhance and reproduce them. In this article, the authors propose a material appearance enhancement algorithm for digital color images. First, they focus on the change of pupil behaviors, which is the first of the early vision systems to recognize visual information. According to their psychophysiological measurement of pupil size during material observation, they find that careful observation of surface appearance causes the pupil size to contract further. Next, they reflect this property in the retinal response, which is the next system in early vision. Then, they construct a material appearance enhancement algorithm named "PuRet" based on these physiological models of pupil and retina. By applying the PuRet algorithm to digital color test images, they confirm that perceived material appearance, including glossiness, transparency, and roughness, in the images is enhanced by using their PuRet algorithm. Furthermore, they show possibilities to apply their algorithm to a material appearance management system that could produce equivalent appearance qualities among different imaging devices by adjusting one parameter of PuRet.

14:40 **JIST-First Analysis of Material Representation of Manga Line Drawings Using Convolutional Neural Networks,** *Takahiko Horiuchi, Yuma Saito, and Keita Hirai, Chiba University (Japan)* **48**

Visual perception of materials that make up objects has been gaining increasing interest. Most previous studies on visual material-category perception have used stimuli with rich information, e.g., color, shape, and texture. This article analyzes the image features of the material representations in Japanese "manga" comics, which are composed of line drawings and are typically printed in black and white. In this study, the authors first constructed a manga-material database by collecting 799 material images that gave consistent material impressions to observers. The manga-material data from the database were used to fully train "CaffeNet," a convolutional neural network (CNN). Then, the authors visualized training-image patches corresponding to the top-n activations for filters in each convolution layer. From the filter visualization, they found that the filters reacted gradually to complicated features, moving from the input layer to the output layer. Some filters were constructed to represent specific features unique to manga comics. Furthermore, materials in natural photographic images were classified using the constructed CNN, and a modest classification accuracy of 63% was obtained. This result suggests that material-perception features for natural images remain in the manga line-drawing representations.

15:00 – 15:40

COFFEE BREAK / EXHIBIT OPEN

OUT OF THE SHADOWS

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

15:40 – 17:00

15:40 **Evaluating LED Luminaires Supporting Colour Critical Assessment,** *Andreas Kraushaar, Fogra (Germany)*. **58**

Colour critical assessment in the graphic arts industry is performed by using D50 simulators that obey rigorous criteria stipulated in ISO 3664 for years. Here multichannel LED based viewing cabinets are increasingly used. However the impact of phosphor converted LED based lighting for general lighting applications in lieu with colour assessment in prepress and press environments can be critical. Incorrect lighting might destroy ISO 3664 conformance and lead to colour differences that are larger than the domain of application of the advanced colour tolerances equations. A user friendly collection of metameric pairs was designed to solicit actual visual differences under 10 typical LED-based luminaires and six ISO 3664 compliant cabinets. These findings were correlated with modern colour rendering metrics including the new CIE fidelity index. Finally colour rendering tolerances will be proposed for general lighting that is used to support colour critical viewing and to certify LED based luminaires.

16:00 **A Curious Problem with Using the Colour Checker Dataset for Illuminant Estimation,** *Graham Finlayson and Ghalia Hemrit, University of East Anglia (UK); Arjan Gijsenij, University of Amsterdam (the Netherlands); and Peter Gehler, University of Tübingen (Germany)* **64**

In illuminant estimation, we attempt to estimate the RGB of the light. We then use this estimate on an image to correct for the light's colour bias. Illuminant estimation is an essential component of all camera reproduction pipelines. How well an illuminant estimation algorithm works is determined by how well it predicts the ground truth illuminant colour. Typically, the ground truth is the RGB of a white surface placed in a scene. Over a large set of images an estimation error is calculated and

different algorithms are then ranked according to their average estimation performance. Perhaps the most widely used publically available dataset used in illuminant estimation is Gehler's Colour Checker set that was reprocessed by Shi and Funt. This image set comprises 568 images of typical everyday scenes.

Curiously, we have found three different ground truths for the Shi-Funt Colour Checker image set. In this paper, we investigate whether adopting one ground truth over another results in different rankings of illuminant estimation algorithms. We find that, depending on the ground truth used, the ranking of different algorithms can change, and sometimes dramatically. Indeed, it is entirely possible that much of the recent 'advances' made in illuminant estimation were achieved because authors have switched to using a ground truth where better estimation performance is possible.

16:20 **A Psychophysical Analysis of Illuminant Estimation Algorithms,** *Roshanak Zakizadeh and Graham Finlayson, University of East Anglia (UK)* **70**

Illuminant estimation algorithms are often evaluated by calculating recovery angular error which is the angle between the RGB of the ground truth and the estimated illuminants. However, the same scene viewed under two different lights with respect to which the same algorithm delivers illuminant estimates and then identical reproductions—and so, the practical estimation error is the same—can, in fact and counter-intuitively, result in quite different recovery errors. Reproduction angular error has been recently introduced as an improvement to recovery angular error. The new metric calculates the angle between the RGB values of a white surface corrected by the ground truth illuminant and corrected by the estimated illuminant. Experiments show that illuminant estimation algorithms could be ranked differently depending on whether they are evaluated by recovery or reproduction angular error. In this paper a psychophysical experiment is designed which demonstrates that observers choices on 'what makes a good reproduction' correlates with reproduction error and not recovery error.

16:40 **JIST-First Video Magnification for Biomedical Dynamic Image Using the Separation of Chromophore Component,** *Munenori Fukunishi, Kouki Kurita, and Norimichi Tsumura, Chiba University (Japan)* **76**

In this article, the authors propose a novel method of video magnification based on separation of the chromophore component. A video magnification method, Eulerian video magnification, was originally proposed by Wu et al. The method is effective in amplifying slight changes of facial color and can visualize the blood flow in the human face effectively. However, the conventional method was evaluated under stable conditions of illumination. It is necessary to enhance its robustness against environmental change for practical use. The proposed method amplifies the variation of the chromophore component which is separated from the shading component. The authors confirm that the proposed method can visualize the blood flow in the human face without artifacts caused by shading change. They also apply the video magnification framework to a tongue movie as preliminary work for medical application and confirm its effectiveness in visualizing the blood pulse and avoiding any clear artifacts.

BEYOND THE RAINBOW

Session Chair: Eric Walowit, consultant (USA)

17:00 – 17:40

17:00 **Two-Band Infrared Video-based Measurement for Non-Contact Pulse Wave Detection on Face without Visible Lighting,** *Ryota Mitsuhashi[1], Genki Okada[1], Kouki Kurita[1], Keiichiro Kagawa[2], Shoji Kawahito[2], Chawan Koopipat[3], and Norimichi Tsumura[1]; [1]Chiba University (Japan), [2]Shizuoka University (Japan), and [3]Chulalongkorn (Thailand)* **83**

In this paper, we propose a novel non-contact pulse wave monitoring method which is robust to fluctuation of illumination by using two-band infrared videos. Since the proposed method uses the infrared light for illumination, we can detect the pulse wave on the face without visible lighting. The corresponding two-band pixel values in the videos can be separated into hemoglobin and shading components by applying separation matrix in logarithmic space for two pixel values. Since the shading component is separated, the extracted hemoglobin will be robust to the fluctuation of illumination. The pixel values of the region of interest (ROI) were spatially averaged all over the pixels for each frame. The averaged values are used to form the raw trace signal. Finally, the pulse wave and pulse rate were obtained from raw trace signal through several signal processing such as detrend, adaptive bandpass filter, and peak detection. We evaluated the absolute error rate for pulse rate between the estimated value and the ground truth obtained by the electrocardiogram. From the experiment, we found that the performance of our method was greatly improved in comparison with the conventional method by means of one-band infrared video.

17:20 **Metamer Mismatch Volumes Using Spherical Sampling,** *Michal Mackiewicz[1], Hans Rivertz[2], and Graham Finlayson[1]; [1]University of East Anglia (UK) and [2]Norwegian University of Science and Technology (Norway)* **88**

In this article, we propose a fast and precise method of calculating a theoretically maximum metamer mismatch volume. Unlike earlier proposed techniques, our method does not use any assumptions on the shape of spectra on the boundary of the mismatch volume. The method utilises a spherical sampling approach and a linear programming optimisation. Experiments described in this paper show that under certain conditions the theoretically maximum metamer mismatch volume is significantly larger than the one approximated using previous method that makes assumptions about the shape of the spectra.

CIC25 SPECIAL EVENING PROGRAM

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

20:00 – 21:30

Scanic Hotel Lillehammer

THURSDAY SEPTEMBER 14, 2017

THURSDAY KEYNOTE AND IS&T AWARDS

Session Chair: Nicolas Bonnier, Apple Inc. (USA)

9:00 – 10:00

with support from The Colour Group Great Britain

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.

COLOR IN THE BALANCE

Session Chair: Ján Morovic, HP Inc. (UK)

10:00 – 10:40

10:00 **CIC25 Best Paper Award A Study of Neutral White and Degree of Chromatic Adaptation,** *Qiyan Zhai[1] and Ming Ronnier Luo[1,2]; [1]Zhejiang University (China) and [2]University of Leeds (UK)* . . . **93**

An investigation was carried out to study the neutral white of chromatic adaptation in colour science. The experiment was conducted for matching neutral whites under different white illuminants using both surface and self-luminous colours to collect data of the neutral whites of human vison under different illuminants (adaptation fields). The result proves the previous study about the chromatic adaptation. Not all the white illuminants are found neutral even the adaptation time is long enough. The baseline illuminant of the 2-step CAT was found as the illuminant with the same chromaticity of the neutral white under it. The results were also used to test models of the effective degree of chromatic adaptation, which was found highly associated with the viewing media in the present study.

10:20 **Whiteness Boundary for Surface Colors,** *Yuzhao Wang[1,2], Minchen Wei[1], and Ming Ronnier Luo[2,3]; [1]The Hong Kong Polytechnic University (Hong Kong), [2]Zhejiang University (China), and [3]University of Leeds (UK)* **98**

A psychophysical experiment was conducted to investigate the whiteness boundary for surface colors. Forty-four color normal observers evaluated the whiteness appearance of 88 color samples using a forced-choice and a magnitude of estimation method under four lighting conditions (*i.e.*, 3000, 4000, 5000, and 6500K) whose spectral power distributions were carefully designed to have strong violet radiation, create obvious blue appearances for the samples with FWAs. The data collected was combined with those from the two recent studies to fit ellipoides in color spaces to define the whiteness boundary for each CCT levels. It was found that the whiteness boundaries are different for different CCT levels. Samples that have a hue of blue and high chroma simultaneously were still judged as white under the 3000K illumination.

10:40 – 11:20

COFFEE BREAK / EXHIBIT OPEN

DO YOU SEE WHAT I SEE?

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

11:20 – 12:20

11:20 **A New Diffusion Computational Model Predicts both the Positive and the Negative Short Afterimage Effects,** *Hadar Cohen-Duwek and Hedva Spitzer, Tel Aviv University (Israel)* **103**

The goal of this research was to develop a compound computational model able to predict the "opposite" effects of the "color dove illusion" and the "filling in the afterimage after the image" effect. Until now, only one study, based on a previous model, FACADE, had attempted to model the negative filling-in effect. However, this model cannot predict the positive effect and was not designed for this purpose. Our proposed model is based on the diffusion equation with bounndary conditions that take the location of the remaining edges into account and assumes that both illusions derive from same visual mechanism. Using the model, we were able, for first time, to obtain accurate perceptual predictions of the core properties of both the positive and negative effects. The suggested model supports the idea that both "conflicting" phenomena stem from the same visual mechanism. In addition, the model was able to predict additional "conflicting" phenomena from different locations of remaining edges, or the direction of the chromatic gradient.

11:40 **JIST-First An App-based Assessment of SiChaRDa, an Image Enhancer for Color-Blind People,** *Cristian Bonanomi, Stefano Sarioli, Sergio Mascetti, Gabriele Gianini, Valeria Alampi, Matteo F. Lanaro, and Alessandro Rizzi, Università degli Studi di Milano (Italy)*. **108**

It is estimated that about 5–10% of the male population has some kind of color vision deficiency (CVD). For them, it is difficult or even impossible to distinguish certain colors. Many image enhancers exist, mostly based on hue changes, since CVDs are usually modeled at spectral level. In this article, the authors consider another point of view, investigating the role of luminance contrast to treat CVD. In the following, the authors present a test, administered as a mobile application, to assess the performance of SiChaRDa, a recently proposed image enhancer, inspired by a model of the human visual system, that modifies the lightness of the image. The results indicate a role of contrast and edges in the readability of images for color vision-deficient people; however, they do not support a clear and unambiguous interpretation.

12:00 **Super Vision Model: What's Peking Robin Seeing?,** *Hiroaki Kotera, Kotera Imaging Laboratory (Japan)*. **117**

Unlike trichromatic human vision, birds are tetrachromats with the fourth UV cone. This paper discusses on "What spectra are visible to Peking robin?" Human can see the spectrum $\mathbf{C^*_A}$ called "fundamental" extracted from the input spectrum **C** through Matrix-$\mathbf{R_A}$. As well, Peking robin can see the fundamental $\mathbf{C^*_B}$ extracted through the extended Matrix-$\mathbf{R_B}$. Matrix-$\mathbf{R_B}$ is given by Peking robin's ROGU (Red Orange Green and UV) cone sensitivities. The super vision spectrum $\mathbf{C^*_B}$ projected onto FCS (Fundamental Color Space) spans up to 300~400 nm UV range.

The key is not to estimate the original hyper spectra but to restore the low-dimensional spectra called "fundamental", truly visible to the tetrachromat. The model doesn't take care the "metameric black" component but tries to predict the fundamental $\mathbf{C^*_B}$ from sRGB camera images under D65.

The fundamental $\mathbf{C^*_B}$ can be restored if the input spectrum **C** is known, but not always. Since the fundamental $\mathbf{C^*_A}$ without "metameric black" carries the unique tri-stimulus value $\mathbf{T_A}$, it's mathematically recovered from $\mathbf{T_A}$ by "pseudo-inverse" projection.

Hence, the fundamental $\mathbf{C^*_B}$ must be recovered from the tetra-stimulus value $\mathbf{T_B}$. The model predicts $\mathbf{T_B}$ from $\mathbf{T_A}$ based on the bold hypothesis that $\mathbf{T_B}$ (ROGU) will change interlocking to $\mathbf{T_A}$ (RGB) for the common scene. The fundamental $\mathbf{C^*_B}$ is restored by the pseudo-inverse projection of predicted $\mathbf{T_B}$. The paper verifies how the model recovers the fundamentals in comparison with the true UV flower's spectra and discusses how it works well or not.

12:20 – 13:50

GROUP LUNCH (PROVIDED)

TWO-MINUTE INTERACTIVE PAPER PREVIEWS I

Session Chairs: Kristyn Falkenstern, Digimarc Corporation (USA), and Tamara Seybold, ARRI (Germany)

13:50 – 14:20

Calculation of Scalars in Neugebauer-Like Models I: Refactoring the Calculations, *J.A. Stephen Viggiano, Rochester Institute of Technology (USA)* **123**

This paper discusses a new way to compute weights (scalars) for Neugebauer-like models that is more flexible than existing methods, simplifying the insertion of a new model for scalar calculation. Specifically, the scalar computing task is refactored into two independent components. In one, the specific dot overlap behavior is specified in a single, often simple, expression. This expression may be implemented for each the three main overlap modalities in a function with a single-statement body. The other component actually computes the scalars, calling the other component as necessary. This second component has been described algorithmically, and open-source software to demonstrate it has been made available.

JIST-First N-LMMSE Demosaicing for Spectral Filter Arrays, *Prakhar Amba[1], Jean-Baptiste Thomas[2,3], and David Alleysson[1]; [1]Universite Grenoble Alpes (France); [2]The Norwegian Colour and Visual Computing Laboratory (Norway); and [3]Université de Bourgigne (France)*. **130**

Spectral filter array (SFA) technology requires development on demosaicing. The authors extend the linear minimum mean square error with neighborhood method to the spectral dimension. They demonstrate that the method is fast and general on Raw SFA images that span the visible and near infrared part of the electromagnetic range. The method is quantitatively evaluated in simulation first, then the authors evaluate it on real data by the use of non-reference image quality metrics applied on each band. Resulting images show a much better reconstruction of text and high frequencies at the expense of a zipping effect, compared to the benchmark binary-tree method.

Spectral Divergence for Cultural Heritage Applications, *Alice Plutino[1], Noel Richard[1], Hilda Deborah[2], Christine Fernandez-Maloigne[1], and Nicola Ludwig[3]; [1]University of Poitiers (France), [2]The Norwegian Colour and Visual Computing Laboratory (Norway) and [3]State University of Milano (Italy)* **141**

Using reflectance spectra allows to compare the pigment mixtures in paintings. In order to improve the actual subjective spectral comparison, we propose to use spectral similarity measures. The Kullback-Leibler spectral Pseudo-Divergence (KLPD) is selected due to his expected metrological properties. The comparison between a subjective assessment and the objective assessment is developed for mixture of pigments coming from a cultural heritage painting. The obtained results show the good quality of the relationship between the subjective results and the objective ones using the KLPD.

Both of gloss and gloss unevenness are important quality for printing paper. It is difficult to measure gloss unevenness of printing paper with gloss meter. It is assumed that gloss unevenness is caused by surface topography. Thus, measuring surface topography is useful in evaluating gloss unevenness. In this paper, we propose a new method that is composed of a collimator optical system and a telecentric optical system for the low price and quick evaluation. The statistical properties of the surface normal distribution are acquired by the collimator optical system. The spatial frequency property of the unevenness is acquired by the telecentric optical system. To estimate surface topography, we assume that surface topography is expressed as the Perlin noise. The method is proposed to derive the parameters which decide about the Perlin noise model from the measured statistical properties. We estimate the surface topography with this method and verify the validity of the proposed model.

This paper compares the results of the colour analysis of about 40 different fat spreads using a digital colour imaging system (DigiEye) and two different colorimeters, e.g. the Hunterlab colorimeter (Labscan II) and Minolta colorimeter (Chroma Meter CR400). The colour and appearance of fat spreads is shown to influence the flavour perception and consumer liking. The DigiEye system records colorimetrically accurate images suitable for the measurement of colour uniformity. The three methods were used to analyse the bulk colour. The DigiEye was also used for the determination of the colour of the surface (after removal of the sealing). Linear relations were found between the colour values measured by the tested systems. However better correlations were found between the DigiEye and the Hunterlab Labscan. A linear relation was observed between the sensory scores on yellowness and those obtained by DigiEye, Hunterlab and Minolta. The short term precision of the determination of the yellowness using the DigiEye system is somewhat better than those of the colorimeter. Instead of yellowness also the b* value can be used. The additional benefit of the DigiEye is the assessment of the appearance. For instance the colour and colour uniformity of the surface of the fat spread.

In this paper, we propose the method of remote estimation for heart rate (HR) and heart rate variability spectrogram (HRVS) by analyzing hemoglobin concentration from facial RGB images in low light environment. The emotion monitoring has a great potential in areas such as market

research, safety measure, medical, and robot systems and so on. Various methods were proposed for the remote emotion estimation. Especially, the methods to estimate emotion by analyzing physiological signals from RGB video are expected to be used practically. However, these studies could not be applied in dark places where monitoring is necessary such as infant's bedrooms, crime prone roads, and car drivers. Therefore, the proposed method uses the high sensitivity RGB camera capable of capturing videos at low illuminance. As the result, we could measure HR with over 99% accuracy and estimate HRVS with high accuracy in low light environments of 10 lux that is the same brightness as the twilight where this low light environment is required in monitoring infant's bedrooms, crime prone roads, and car drivers.

Skin Color Simulation—Review and Analysis of Available Monte Carlo-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 (the Netherlands)* **165**

Optical assessment is a useful tool for non-invasive skin assessment avoiding scarring, time delayed diagnosis, hurting, and inconvenience for patient and practitioner. This has led to wide adaption of digital imaging and other optical technologies in dermatology. Many of these optical technologies lack quantifiability, therefore, the reproduction, comparison or absolute meaning of measurements or images is an open challenge. Monte Carlo simulation for multi-layered turbid media provides an accurate tool for simulating the optical path of photons traversing in the skin and the diffuse spectral reflectance of skin. With this tool at hand the missing link between health metrics and measurable optical phenomena can be provided and it can help to establish optical assessment and digital images as a standard for health monitoring of skin. A number of publicly available simulation codes and several different approaches have been proposed. In this work we give an overview of three Monte Carlo simulation tools and compare the different approaches. Furthermore, we will use Monte Carlo Simulations to generate different spectra based on varying optical properties and use these spectra to generate colour patches to analyse the impact of different optical properties on the resulting RGB colour patches.

Blind Image Quality Assessment Designed by Learning-based Attributes Selection, *Christophe Charrier, Universite de Caen Normandie; Abdelhakim Saadane, Universite de Nantes; and Christine Fernandez-Maloigne, Universite de Poitiers (France)* **171**

With the rapid growth of image processing technologies, objective Image Quality Assessment (IQA) is a topic where considerable research effort has been made over the last two decades. IQA algorithms based on image structure have been shown to correlate well with Mean Opinion Scores (MOS). No-Reference (NR) image quality metrics are of fundamental interest as they can be embedded in practical applications This paper deals with a new NR-IQA metric based on natural scenes statistics. It proposes to model the best correlated statistics of seven well known no-reference image quality algorithms by a MultiVariate Gaussian Distribution (MVGD). A part of LIVE database is used with the associated DMOS to fit the MVGD model, namely Model Image Quality Index (MIQI). Hence, the quality of a distorted image is given by the DMOS that maximizes the multivariate Gaussian probability density function. Experimental results demonstrate the method effectiveness for a wide variety of distortions.

Spectral and Color Characterization of a Quantum Dots Display for Gonio-Apparent Colors, *Khalil Hurabait[1], Esther Perales[1], Eric Kirchner[2], Ivo van der Lans[2], Alejandro Ferrero[3], Joaquín Campos[3], and Francisco Miguel Martinez Verdu[1]; [1]Universidad de Alicante (Spain), [2]AkzoNobel Performance Coatings (the Netherlands), and [3]Instituto de Óptica (Spain)* **177**

Digital simulation by rendering gonio-apparent coatings and thereby visualizing the variation of visual attributes such as color and texture with geometry is requested for different industries. Recently, quantum dots (QD) displays appeared in the market with attractive characteristics such as a wider color gamut. Therefore, a proper color characterization and calibration of this type of displays is needed. In this work, we focused on the color and spectral characterization of the new quantum dots display technology. Philips Brilliance LCD Quad HD monitor was used. The spectral radiance of a set of images (stepped digital count levels from 0 to 255) was measured by the Konica-Minolta CS2000 tele-spectroradiometer. Another set of images with different combinations of digital count levels are generated for the validation. As results, a good primaries constancy was obtained after black correction. Channel additivity with errors less than 0.77 was confirmed. The electro-optical transfer function can be correctly adjusted to a power function. The GOG model was applied giving good characterization of this display. Color reproduction is evaluated using the color-difference formula CIEDE2000. The average color difference ΔE_{00} between the generated images and the objects is 1.39 for the validation generated images. Therefore, we conclude that the accuracy obtained with the GOG model is sufficient to get good performance in 3D rendering. Furthermore, the color appearance of a gonio-apparent coating is reproduced on a QD display and on a sRGB display. It is checked that the QD display provide a more chromatic gamut, which is very useful for the color rendering of gonio-apparent coatings.

Evaluation of Gradient Operators for Hyperspectral Image Processing, *Hilda Deborah[1], Noel Richard[2], Jon Y. Hardeberg[1], and Christine Fernandez-Maloigne[2]; [1]Norwegian University of Science and Technology (Norway) and [2]University of Poitiers (France)* **182**

Gradient is an important image processing tool allowing to carry out edge detection, segmentation, and texture analysis. It is expected to provide significantly more accurate and complete information when combined with the hyperspectral imaging technology. And such gain in accuracy justifies the cost and complexity of a hyperspectral acquisition. But how to measure accuracy? This article presents our first study in the accuracy assessment of hyperspectral gradient, where an assessment protocol based on a basic edge detection task is proposed. This protocol is then used to evaluate the full-band gradient approaches, where the results suggest to improve the protocol to include more complexity.

Conflicting Colors: Film Scanning versus Film Projection, *Giorgio Trumpy, University of Zurich, and Rudolf Gschwind, University of Basel (Switzerland).* **188**

The directional arrangement of the illumination plays an important role on image contrast and sharpness of silver-based photographic film. This paper explores how the directional arrangement of light (directed or diffuse) affects cinematographic colors. The experimental results show that a consistent color difference can be observed between the image projected on screen (directed illumination) and the image acquired with a scanner (diffuse illumination), no matter how well the scanner is calibrated. This fact has to be properly considered in film scanning and color correction; otherwise early color films can be notably distorted during the digitization process.

Multispectral Reconstruction from Single RGB Image based on Camera Response Expansion and Local Inverse Distance Weighted Optimization, *Jinxing Liang and Xiaoxia Wan, Wuhan University (China)* **192**
Multispectral reconstruction from single RGB image can eliminate the geometric distortion problem existing in optical bandpass filters-based multispectral cameras and save the capturing time, but the reconstruction accuracy is limited by just using the original three channels response. Camera response expansion is an optimal choice to increase the dimensions of the input information for multispectral reconstruction as the imaging and processing is practically not linearity for the trichromatic digital cameras. In this paper, the camera response expansion based on polynomial model was tested for multispectral reconstruction from single RGB image, the pseudoinverse method was adopted for the training-based multispectral reconstruction, and the local inverse distance weighted (LIDW) optimization was proposed to improve the reconstruction accuracy. The proposed method was compared with the current existing methods through practical experiment, and the results indicated that it outperformed existing methods.

SUBTRACTIVE ADDITIONS

Session Chair: Javier Vazquez-Corral, Universitat Pompeu Fabra (Spain)
14:20 – 15:40

14:20 **HANS Print Smoothness Optimization and Continuous Control,** *Ján Morovic, HP Inc. (UK) and Peter Morovic, HP Inc. (Spain)* **198**
A print property closely related to color and with a strong dependency on the choices made for the sake of color separation is the smoothness of a printed pattern. While certain obvious choices are simply related to grain, such as the degree of black ink use in colorant-channel imaging pipelines, the domain of all possible printable patterns that HANS (Halftone Area Neugebauer Separation) provides access to eludes such simple rules of thumb. At the same time, the magnitude of the new control domain gives access to new patterns that allow for a reduction of grain and an increase in smoothness beyond what is possible using conventional techniques. In this paper, a framework for optimizing smoothness is presented first, followed by a mechanism for varying it in a controlled and continuous way, when the aim is a given trade-off between smoothness and other attributes such as colorant use efficiency or robustness to perturbations.

14:40 **JIST-First Data Hiding by White Modulation in Color Direct Binary Search Halftones,** *Vlado Kitanovski[1], Reiner Eschbach[2], Marius Pedersen[1], and Jon Hardeberg[1]; [1]Norwegian University of Science and Technology, (Norway) and [2]National University of Science and Technology (Norway)/Monroe Community College (USA)* **204**
In this article, the authors propose a method for hiding a visual watermark in color printed images with arbitrary, natural content. The embedded watermark is imperceptible under normal illumination, but it is revealed under UV illumination. Their method is using the white-paper fluorescence as a source of the watermark signal. The binary visual watermark is embedded by controlling the amount of fluorescence during the halftoning process, which is achieved by modulating the fractional white area of exposed paper substrate. The method is based on the iterative Color Direct Binary Search halftoning, which ensures high quality of the printed images, and uses a suitable error metric to control the perceived distortion due to the watermark embedding. Results show that the proposed method achieves low perceptibility of the embedded watermark under normal illumination, while the watermark is easily detectable using a portable UV flashlight even in bright daylight conditions.

15:00 **Gamut Reduction Through Local Saturation Reduction,** *Syed Waqas Zamir, Javier Vazquez-Corral, and Marcelo Bertalmío, Universitat Pompeu Fabra (Spain)* **214**
This work presents a local (spatially-variant) gamut reduction algorithm that operates only on the saturation channel of the image, keeping hue and value constant. Saturation is reduced by an iterative method that comes from inverting the sign in a 2D formulation of the Retinex algorithm of Land and McCann. This method outperforms the state-of-the-art both according to a quantitative metric and in terms of subjective visual appearance.

15:20 **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)* **219**
3D printing enables the production of objects that combine materials in hitherto infeasible ways, with the potential of varying their use with a granularity of up to individual print-resolution voxels. By combining printing materials, such as powders, fluid agents, etc., in volumetrically different ways, a limited number of materials can be used to yield a great variety of object properties, such as stiffness, strength, density, translucency, and color. A key challenge is to ensure that an input object with volumetrically-specified properties is appropriately transformed to yield per-voxel recipes for how to combine a printing system's materials. To ensure that such a transformation is performed in a way that maintains volumetric control with up to voxel precision, the present paper introduces a content processing pipeline that has individual printed voxel contents as its basic building blocks and that controls their placement in a natively volumetric domain. This pipeline is an evolution of the HANS print control paradigm. First results, applied to control color of 3D printed objects are reported.

TWO-MINUTE INTERACTIVE PAPER PREVIEWS II

Session Chairs: Kristyn Falkenstern, Digimarc Corporation, (USA) and Tamara Seybold, ARRI (Germany)
15:40 – 16:10

JIST-First An Adaptive Combination of Dark and Bright Channels Priors for Single Image Dehazing, *Vincent Whannou de Dravo[1], Jessica El Khoury[2], Jean-Baptiste Thomas[1,2], Alamin Mansouri[2], and Jon Yngve Hardeberg[1]; [1]Norwegian University of Science and Technology (Norway) and Université de Bourgogne, (France)* **226**
Dehazing methods based on prior assumptions derived from statistical image properties fail when these properties do not hold. This is most likely to happen when the scene contains large bright areas, such as snow and sky, due to the ambiguity between the airlight and the depth information. This is the case for the popular dehazing method Dark Channel Prior. In order to improve its performance, the authors propose to combine it with the recent multiscale STRESS, which serves to estimate Bright Channel Prior. Visual and quantitative evaluations show that this method outperforms Dark Channel Prior and competes with the most robust dehazing methods, since it separates bright and dark areas and therefore reduces the color cast in very bright regions.

Visibility and the Preferred Gamma in a Transparent OLED Display, *Hyosun Kim, Young-Jun Seo, Byungchoon Yang, and Hye Yong Chu, Samsung Display Co. Ltd., and Youngshin Kwak, Ulsan National Institute of Science and Technology (South Korea)* **235**
There have been some studies to examine how people perceived images presented on a transparent display, but there is little research to conduct experiments using a real transparent OLED display. In order to increase visibility of images presented in a transparent OLED display, we find the

preferred display gamma value. Before conducting main experiment, we examined the pre-test that showed the change of visibility as surround luminance increased. We confirmed that visibility of low gray levels on the image degraded when the surround condition was bright. Next, we investigated the preferred display gamma value of a transparent OLED display under various surround conditions. The result showed that the preferred gamma value decreased as surround luminance increased. Finally, we explored the cause of lowering of the preferred gamma value by measuring distinguishability of various gammas. This result implied that the lower gamma might be preferred because distinguishability of the low gray levels on the images increases as the surround luminance increases.

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)* **240**

We found a similarity between the effect of temporal chord transition in music and temporal color transition in visual perception. Human visual impressions between a color arrangement and a temporal transition from a modified arrangement to the original arrangement were compared in experiments with sensory tests. The experimental results showed that the consonance of color arrangements can be enhanced by a "pivoted" transition, in which some appearance parameters like hues and color tones are preserved, from a dissonant arrangement in comparison with a static presentation of the original arrangement. The results suggest that an enhancement effect of consonance similar to resolution of chords in music exists in a higher order mechanism of human color vision.

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)*. **245**

Illuminant estimation is the primary step to solve the colour constancy problem. Already, various unitary algorithms were proposed to estimate illuminant chromaticity. Since the existing methods are all based on specific spatial and spectral characteristics of images, there is no unique algorithm which can perform well on images with different settings and scenes. Therefore, this paper proposes an illuminant estimation framework which combines the best performing unitary methods using dynamic weight. The proposed method uses edge and colour features to generate the dynamic weight. Experimental results on real-world data set clearly demonstrate the effectiveness of the proposed method.

Spectral Predictions of Rough Ink Layers Using a Four-Flux Model, *Théo Phan Van Song[1,2], Christine Andraud[2], and Maria Ortiz-Segovia[1]; [1]Océ Print Logic Technologies and [2]Centre de Recherche sur la Conservation des Collections (France)* **251**

Predicting how light propagates through a stack of ink layers for spectral reproduction is a challenge only optical models can face. In particular, the four-flux model offers directional information about the part of light specularly reflected and transmitted and the part of light scattered in other directions. The surface roughness influences strongly the ratios of collimated and diffused light. In this paper, we describe how a radiative transfer four-flux matrix model can account for rough interfaces and show how roughness impacts the measured components of the reflectance and the transmittance of stacks of ink printed with different textures. The measurements are then compared to computations of the model with colorimetric and spectral metrics. Results are encouraging, considering that the predictions are made without any measurements directly inputted into the model, with the median color difference mostly below 2 ΔE_{94} units for total reflectance and transmittance whatever the roughness.

Effect of Area on Color Harmony in Simulated Interiors, *Seden Odabasioglu, Marmara University, and Nilgün Olguntürk, Bilkent University (Turkey)* **258**

The main aim of this study is to examine the effect of area on color harmony in simulated interior spaces. Area in color harmony is the relative amount of different color areas represented as a proportion, on which color harmony depends. Colors in the color scheme of an interior space are usually not applied in equal proportions of surface areas. Considering the complex relations of colors in interiors, it is important to search for the principles of color harmony and area effects. The secondary aim of the study is to investigate how the term color harmony is defined and the link between color harmony and related terms used to define it. The related terms that are used to define color harmony can explain why a color scheme is evaluated as harmonious. In this study, three primary (red, blue, yellow) and three secondary (green, purple, orange) colors of Itten's color wheel were studied in a simulated office interior with three-color schemes emphasizing different proportional use of each color. There were four color combinations, each consisting of six images differing in areas of the constituent colors. Firstly, participants evaluated the harmony content of the images by comparing them in pairs. Secondly, they evaluated each image regarding the thirteen terms related to color harmony. Findings indicated that area had an effect on color harmony for two of the color combinations (warm and cool color schemes). However, there were no strong but rather moderate and weak correlations between color harmony and the terms.

A Uniform and Hue Linear Color Space for Perceptual Image Processing Including HDR and Wide Gamut Image Signals, *Muhammad Safdar[1], Ming Ronnier Luo[1,2], Guihua Cui[3], and Youn Jin Kim[4]; [1]Zhejiang University (China); [2]University of Leeds (UK); [3]Wenzhou University (China); and [4]Huawei Technologies Co., Ltd. (China)* **264**

A color space that is perceptually uniform, linear in iso-hue directions, can uniformly encode high dynamic range and wide gamut signals, and is computationally efficient, has been long desired. The available color spaces do not meet all these requirements satisfactorily and comprehensively. Performance of a recently proposed uniform and hue linear color space, Jzazbz, is compared with the state of the art color spaces and results are presented. This study suggests a single uniform color space for perceptual image processing, wherever desired, in different applications.

Device Independent Graininess Reproduction: Preliminary Study, *Junki Yoshii[1], Shoji Yamamoto[2], Yuto Hirasawa[1], Hiroshi Kintou[3], and Norimichi Tsumura[1]; [1]Chiba University, [2]Tokyo Metropolitan College of Industrial Technology, and [3]Nikon Corporation. (Japan)* **269**

In this paper, we propose a psychophysically-based model of graininess perception for device independent graininess reproduction system. This model is developed by conducting an experiment to explore the relationship among 1) subjective evaluation values for various graininess objects, 2) physical parameters used to generate the graininess objects and 3) values of maximum luminance on the display for reproduction. In the experiment to obtain the subjective evaluation values, the magnitude estimation method was used to quantify the graininess perception. The graininess model obtained by multiple regression analysis for the above values can be used to calculate curved surfaces where the graininess objects are observed as the equal appearance. This surface can be used for device independent graininess reproduction process to match the graininess under the displays with various maximum luminance. In this process, even if the values of maximum luminance on the display is changed in the model, the value of graininess under the changed luminance is hold by changing the physical parameters of graininess generation in the model. In the practical experiment, we found that the

proposed model and process for device independent graininess reproduction were effective for our adopted displays with various maximum luminance.

System for Evaluating Pathophysiology Using Facial Image, *Futa Matsushita[1], Kaoru Kiyomitsu[1], Keiko Ogawa-Ochiai[2], and Norimichi Tsumura[1]; [1]Chiba University and [2]Kanazawa University Hospital (Japan)* **274**

Facial diagnosis is an important diagnostic method in Japanese-traditional (Kampo) medicine. Major disease states by facial diagnosis are blood stagnation, blood deficiency, and yin deficiency. These facial diagnoses are subjective and empirically obtained. To solve these problems, we proposed to construct a system to output the score (1 to 5) for evaluating pathophysiology of the patient by using facial image obtained by RGB camera. We evaluate this system by calculating mean squared error (MSE) between the score given by medical doctor and estimated by the system. Our method achieved to estimate the score accurately as the MSE is less than 1.0. From the results of construction of the system, we found the important regions of the face for diagnosing disease states by medical doctor using the method of significant feature selection.

Luminance, Reflectance, and Chromaticity from RAW Scene Capture, *John J. McCann, McCann Imaging (USA)* **280**

This paper measures the effect of increased dynamic range on the accuracy of scene radiance measurements made from photographs of scenes. The experiment uses a constant scene with constant illumination and constant camera exposure settings. A small lightbox in the scene had luminances that varied from off to 19200 cd/m^2. It varied the dynamic range of the scene, while leaving the rest of the scene radiances unchanged. Optical veiling glare altered a image's radiances on a camera's image plane. The camera's optics spread some of the light from the lightbox into the rest of the camera image. This article measures how optical glare affects camera-based calculated luminance, reflectance, and chromaticity values.

The Preferred Luminance of Head Mounted Display (HMD) Over Time Under Two Different Surround Conditions, *Hyeyoung Ha and Youngshin Kwak, Ulsan National Institute of Science and Technology, and Hyosun Kim, Young-Jun Seo, and Won-Sang Park, Samsung Display Co. Ltd. (South Korea)* **286**

The most preferred luminance of Head Mounted Display (HMD) was investigated under two initial surround lights. It is found that though the initial preferred HMD luminance was affected by the surround lights, the preferred luminance of HMD is about 28 cd/m^2 after 2 minutes regardless of the initial surround conditions. From the verification experiment using the complex images, it is confirmed that low luminance image is preferred than the original for 81% cases.

Correlation Analysis between Wood Eigen Textures and Perceptual Qualities, *Yoshimitsu Yamada, Keita Hirai, and Takahiko Horiuchi, Chiba University (Japan)* **290**

In this paper, we analyzed the relationship between wood Eigen textures and the human perception. First, we developed a database of one hundred wood textures. Then, through our experiment that was designed based on the Fleming's subjective experiment (Journal of Vision, 2013), nine types of perceptual quality scores were assigned to each texture. The perceptual qualities are glossiness, transparency, colorfulness, roughness, hardness, coldness, fragility, naturalness, and prettiness. Second, we statically analyzed the one hundred wood textures using the principal component analysis (PCA). The PCA bases of the wood texture database are called "wood Eigen textures." Finally, we obtained correlation coefficients between weights of wood Eigen textures and perceptual quality scores. Our results showed the first wood Eigen texture (the first principal component) was correlated with the perceptual qualities of "glossiness" and "coldness." The second one was correlated with the perceptual qualities of "coldness" and "colorfulness." Based on the analysis, we demonstrate a texture generation technique for arbitrary perceptual qualities.

Statistical Design of Experiments Applied on Sparkle Visual Detection, *Omar Gómez Lozano, Esther Perales, Barbara Mico, Valentin Viqueira, Khalil Hurabait, and Francisco Miguel Martinez-Verdu, University of Alicante (Spain)* **296**

In this work, we have focused on analyzing how different variables affect in the process of detecting the sparkle texture effect, since there are few works related to this issue. A large number of samples were available with different characteristics depending on the needs of each psychophysical experiment. The studied parameters were structural variables such as pigment type, size and concentration, and environmental variables such as illumination and viewing conditions.

Due to the large sample number, the design of experiments (DoE) was applied to optimize the psychophysical experiments and to evaluate which variables affect individually on the sparkle detection, as well as if there are interactions among them. After collecting all the information from the psychophysical experiments, with more than 35.000 visual assessments performed, the correlation with the instrumental data of the BYK-mac was verified to corroborate its reliability.

It has been possible to demonstrate the influence of multiscale parameters on the sparkle appearance and to extract which variables affect to a greater extent when detecting the sparkle texture effect. This issue was fundamental because, there was no previous study addressing these issues, which was of vital importance for the industry to analyze how the sample texture is detected depending on various conditions, whether structural, environmental, etc.

In addition, a reliable and applicable methodology has been implemented for other types of existing goniochromatic pigments with novel texture effects. It has been possible to implement the design of experiments as a main tool to limit the visual experiments to be performed, making the fewest visual evaluations possible and obtaining the maximum results.

Thanks to psychophysical experiments, it has been successfully tested the visual and instrumental correlation of sparkle detection between the only multi-angle device on the market to date, and the visual assessments obtained from a large number of observers.

Underwater Color Correction, *Thor Olson, Electronics for Imaging (USA)* **302**

An introduction to light in an absorbing, scattering medium is offered, with application to correcting the colors in underwater photographs. The "waterlight" model is presented which quantifies the amount of light scattered in the direction of the camera from the medium itself. A spectral model for ocean water is described along with a method to represent it in three bands (e.g. RGB). Given these models, the radiance of a diffuse reflector at known depth and distance can be computed. At infinite distance, this becomes the "abyss color", a new and useful concept with which to estimate camera response, and the water parameters. The color correction procedure for a given depth and distance is outlined and illustrated. Unknown causes of color shifts from camera or water are addressed via a "blue balance" transform, which maps the recorded abyss color to the modeled abyss color. A compact vector expression for the correction is presented and examples where it is applied to underwater scenes are provided.

INTERACTIVE SESSION / EXHIBITS OPEN / COFFEE BREAK

16:10 – 17:40

CONFERENCE BANQUET

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

19:30 – 22:00

FRIDAY SEPTEMBER 15, 2017

COLOR AND IMAGING WORSHOPS

Session Chairs: Rafael Huertas, Universidad de Granada, and Maria Vanrell, Universitat Autònoma de Barcelona (Spain)

with support from Research Council of Norway – project number 272939

W1: MEDICAL APPLICATIONS: IMAGE PROCESSING, CHALLENGES, AND PERSPECTIVES

Chair: Faouzi Alaya Cheikh, NTNU (Norway)

8:00 – 12:00

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 non-contact 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

Chair: Marcelo Bertalmio, Universitat Pompeu Fabra (Spain)

8:30 – 12:00

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 not sufficiently— integrate 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 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 is performed in real-time.

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

Chair: Sony George, Norwegian University of Science and Technology (Norway)
9:00 – 12:00

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 digitization, 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 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, titles, and abstracts of 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.

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 three-dimensional 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 third-party 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.

GROUP LUNCH (PROVIDED)

12:00 – 13:00

CLOSING KEYNOTE AND CIC AWARDS

Session Chair: Marius Pedersen, Norwegian University of Science and Technology (Norway)

13:00 – 14:00

True Colours: Exploration in Art, Design, and Research, *Malcolm Innes, Edinburgh Napier University (UK)* **309**
It is always an interesting question: do you see colour the same way that I see colour? As my initial training was as an artist, it is possible that I approach colour very differently from someone with a scientific background. But do all artists or all scientists see the same, how do specialists in each discipline see colour? Does a chemist see colour differently from a physicist and do they see colour differently from a neurologist? Does a painter see colour differently from a graphic designer or an advertising art director? How much does our training contribute to our view of colour and do our professional silos prevent us from seeing the world as others do? As someone whose practice crosses art, design and strays into science, I am always intrigued to know how other people's training and professions shape the way they see the world.

GREEN WITH ENVY

Session Chair: Youngshin Kwak, Ulsan National Institute of Science and Technology (South Korea)

14:00 – 14:40

14:00 **Gamut Mapping for Visual Attention Retargeting,**
Javier Vazquez-Corral and Marcelo Bertalmío, Universitat Pompeu Fabra (Spain) **313**
Visual attention retargeting attempts to modify an image such that the viewer's attention is directed to specific regions. Goals include highlighting a particular object or hiding possible prob-lems in the image. In this work, we show that we can pose the visual retargeting problem in terms of gamut mapping. In short, visual attention retargeting can be achieved by performing gamut extension in those regions that we want to highlight and gamut reduction in the other regions.

14:20 **EmoTune - Changing Emotional Response to Images,**
Katharina Schwarz, Christian Fuchs, Manuel Finckh, and Hendrik P. A. Lensch, University of Tuebingen (Germany) . . . **317**
Images and videos can be touching, triggering emotional re-sponses or even changing the mood of the observer. The response is influenced both by the image content as well as the appearance of the image. In this paper, we investigate how solely simple image processing, i.e., modifying the brightness, the saturation, or the color temperature, actually changes the emotional perception. We collect empirical data on images associated with emotion labels and analyze the valence ratings of the different modifications and their strengths. We show that these relationships tend to be linear only in a limited range while sometimes stronger modifications lead to the opposite effect. Pushing the modifiers towards the boundaries we derive from those ranges and combining them successfully shifted the emotional affect on 92% on around 80 samples. From these findings we derive our EmoTune filter which allows for almost linear control by combining specific modes and demonstrate successful application to both images and videos.

14:40 – 15:10
COFFEE BREAK

19TH INTERNATIONAL SYMPOSIUM ON MULTISPECTRAL COLOUR SCIENCE (MCS)

Session Chair: Jon Hardeberg, Norwegian University of Science and Technology (Norway)

15:10 – 16:30

15:10 **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)* **324**

The Kubelka-Munk (K-M) theory combined with the mixing theory has been successively applied to the color prediction of colorant such as paints, dyes, and printing inks with fine colored particles. Limited by ancient grinding and sieving technology or for intended use, the mineral pigments used in colored relics usually have a relatively larger particle size. This work investigates the spectrophotometric color prediction of mineral pigments with large particle size by applying the single- and two-constant K-M theory. Results indicate that (a) one sample (*i.e.,* a tint with 80% colored and 20% white mineral pigment) and two samples (*i.e.,* a masstone and a tint with 40%-60% colored mineral pigment) are sufficient to characterize the optical constants of the colored mineral pigment for single- and two-constant K-M theory respectively, and (b) that two-constant K-M theory has a significantly higher prediction accuracy due to the specific particle size and film formation mechanism of the mineral pigments.

15:30 **JIST-First RGB–NIR Image Enhancement by Fusing Bilateral and Weighted Least Squares Filters,** *Vivek Sharma, Katholieke University Leuven (Germany), and Jon Hardeberg and Sony George, Norwegian University of Science and Technology (Norway)* **330**

Image enhancement using visible (RGB) and near-infrared (NIR) image data has been shown to enhance useful details of the image. While the enhanced images are commonly evaluated by observers' perception, in the present work, we rather evaluate it by quantitative feature evaluation. The proposed algorithm presents a new method to enhance the visible images using NIR information via edge-preserving filters, and also investigates which method performs best from an image features standpoint. In this work, we combine two edge-preserving filters: bilateral filter (BF) and weighted least squares optimization framework (WLS). To fuse the RGB and NIR images, we obtain the base and detail images for both filters. The NIR-detail images for both filters are simply fused by taking an average/maximum of both, which is then combined with the RGB-base image from the WLS filter to reconstruct the final enhanced RGB-NIR image. We then show that our proposed enhancement method produces more stable features than the existing state-of-the-art methods on RGB-NIR Scene Dataset. For feature matching, we use the SIFT features. As a use case, the proposed fusion method is tested on two challenging biometric verifications tasks using CMU hyperspectral face and CASIA multispectral palmprint databases. Our exhaustive experiments show that the proposed fusion method performs equally well in comparison to the existing biometric fusion methods.

15:50 ***Old Man in Warnemünde* (1907) Colouring Palette: A Case Study on the Use of Hyperspectral Imaging for Pigment Identification,** *Hilda Deborah[1], Jin Strand Ferrer[2], Irina Sandu[2], Sony George[1], and Jon Hardeberg[1]; [1]Norwegian University of Science and Technology and [2]The Munch Museum (Norway)* **339**

The paper presents results from hyperspectral identification of the colouring palette used by Edvard Munch in a canvas painting entitled "Old Man in Warnemünde". The painting is part of a collection at the Munch Museum in Oslo. A collaboration between the Conservation Department of the Munch Museum and the Norwegian Colour and Visual Computing Laboratory from NTNU has allowed to analyze several points of the painting by means of hyperspectral imaging and identify thus the pigments present. The hyperspectral pigment identification involves a use of two pigment databases (Kremer and ENST) which were created using different binding media. Some results from the hyperspectral analysis were also validated through elemental analysis by means of XRF. The pigment identification method employs the shape component of spectral Kullback-Leibler pseudo-divergence function, instead of the widely-used but inaccurate spectral an-gle mapper. In addition to the interest of this pigment analysis for conservation practice of this particular painting, an important contribution of this paper is the validation of hyperspectral imaging and processing methods for pigment identification.

16:10 **Infrared Imaging Spectroscopic System for the Detection of Skin Cancer: Preliminary Results,** *Laura Rey Barroso[1], Francisco J. Burgos-Fernández[1], Xana Delpueyo[1], Miguel Ares[1], Santiago Royo[1], Josep Malvehy[2], Susana Puig[2], and Meritxell Vilaseca[1]; [1]Universitat Politècnica de Catalunya and [2]Dermatology Department of the Hospital Clinic of Barcelona (IDIBAPS) (Spain)* **345**

Skin cancer is a disease of the twenty-first century mainly caused by the excessive exposure to the sun without the appropriate solar protection. Melanoma, which is one of the most aggressive kinds of skin cancer, requires a rapid and effective diagnosis. Clinical examination and biopsies have shown to be slow and costly in many ways, so the possibility of getting a non-invasive optical detection of skin melanomas became a hot topic in biophotonics. In this context, multispectral imaging systems have approached the problem, but none of them worked inside the infrared range yet. Hence, this work has been proposed as an interesting, long-term project to further investigate about the possibilities of infrared imaging spectroscopy for the early detection of skin cancer, especially melanomas.

CLOSING REMARKS AND BEST STUDENT PAPER AWARD

Michael Murdoch, Rochester Institute of Technology (USA)

16:30 – 16:40

AUTHOR INDEX

*No proceedings paper associated with talk

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