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WEDNESDAY OCTOBER 21, 2015

Welcome and Keynote

Session Chair: Vien Cheung, University of Leeds

9:00 – 10:00

9:00 **Possibilities and Limitations of the Bidirectional Texture Function as Appearance Representation,** *Reinhard Klein, Universität Bonn (Germany)* **1**

Reproducing the characteristic appearance of materials digitally is of considerable importance for the creation of photorealistic images. A successful approach to capture and represent the appearance of a material is the Bi-directional Texture Functions (BTF), which can be considered as an image based representation and comprises thousands of images that have been taken under various light situations and from different viewpoints. In this talk we report on BTF acquisition devices as well as data compression and rendering techniques for BTFs that were developed at our institute within several research projects on this topic. Special emphasis will be put on the discussion of possibilities and limitations of this kind of representation for different application areas ranging from virtual prototyping to cultural heritage.

Putting Color to Work

Session Chair: Andreas Kraushaar, Fogra Graphic Technology Research Association

10:00 – 12:40

CIC23 Best Paper Awardee

10:00 **Spectral and Color Prediction for Arbitrary Halftone Patterns: A Drop-by-Drop, WYSIWYG, "Ink on Display" Print Preview,** *Peter Morovic, Ján Morovic, Xavier Fariña Vargas, Pere Gasparin, Michel Encrenaz, and Jordi Arnabat, Hewlett Packard Company (Spain)* **2**

Accurately previewing the appearance of a print job can make the difference between producing saleable output and wasting expensive materials and is a challenge to which a host of solutions already exist. However, what the majority of these have in common is that they base their predictions on the inputs to a printing system (e.g., continuous-tone data in ink channels) instead of its outputs (i.e., the halftone data that is then printed) and that they are only valid for a given set of choices already made in the printing system (e.g., color separation and halftoning). Alternatively, attempting to make appearance predictions using general-purpose models such as Kubelka Munk, Yule Nielsen and Neugebauer results in limited performance on systems whose behavior diverges from these models' assumptions, such as inkjet printing. As a result of such constraints, the resulting previews either work only under limited conditions or fail to predict some artifacts while erroneously predicting others that do not materialize in print. The approach presented here takes advantage of the flexibility of the HANS framework and the insights into spectral correlation to deliver a print preview solution that can be applied to any printing system, that allows for the variation of fundamental imaging choices without the need for re-computing model parameters and that delivers ICC-profile-level accuracy.

10:20 **Model-based Design of Recto-Verso Prints Displaying Different Images According to the Illuminated Face,** *Serge Mazauric[1,2], Mathieu Hébert[1], and Thierry Fournel[1]; [1]Université de Lyon, and [2]CPE Lyon (France)* **7**

Predicting simultaneously the spectral reflectance and transmittance of halftone prints is now possible thanks to a recently developed model based flux-transfer matrices, called Duplex Primary Reflectance-Transmittance model, valid for single-face printing as well as duplex printing. The model can be calibrated from either spectral reflectance measurements or spectral transmittance measurements; but it can also be calibrated from both measurements by minimizing the distance between the theoretical transfer matrices and experimental transfer matrices. According to the test carried out with paper printed in inkjet, the predictive performances of DPRT model, coupled with the new calibration method, are good enough to permit interesting applications in graphical arts, such as the display of multiple images depending on whether the light source is in front of the duplex color print or beside it.

10:40 – 11:20
Coffee Break and CIC Paper Demonstrations

11:20 **Determining Camera Spectral Responsivity with Multispectral Transmission Filters,** *Lindsay W. MacDonald, University College London (UK)* **12**

Four practical methods were evaluated for determining the spectral responsivity of a Nikon D200 digital camera: (1) Direct measurement by exposure to a monochromator sequence at 5nm intervals; (2) LED colour target with 36 luminous circular patches; (3) filtered illumination, using 16 transmission filters of 20nm bandwidth; (4) filtered camera, using the same set of filters. Taking the monochromator measurements as the reference, the results of the other three methods showed a good correspondence, but systematic differences were observed for fluorescent illumination. Because of the wavelength shift in filter transmittance with angle of incidence, it is recommended that sources with smooth spectral power distributions should be used for filter-based characterisation

11:40 **Hue Plane Preserving Colour Correction Using Constrained Least Squares Regression,** *Michal Mackiewicz[1], Casper F. Andersen[2], and Graham D. Finlayson[1]; [1]University of East Anglia (UK) and [2]Gjøvik University College (Norway)* **18**

Andersen and Hardeberg proposed the Hue Plane Preserving Colour Correction (HPPCC), which maps RGBs to XYZs using a set of linear transforms, where each transform is learned and applied in a subregion of colour space, defined by two adjacent hue planes. A hue plane is a geometrical half-plane defined by the neutral axis and a chromatic colour. A problem with the original HPCC method is that the selection of chromatic colors was a user defined choice (and the user might choose poorly) and the method as formed was not open to optimization. In this paper we present a flexible method of hue plane preserving colour correction which we call Hue Plane Preserving Colour Correction using Constrained Least Squares (HPPCC-CLSQ). This colorimetric characterization method is also based on a series of 3 by 3 matrices, each responsible for the transformation of a subregion, defined by two adjacent hue planes, of camera RGB values to the corresponding subregion of estimated colorimetric XYZ values. The matrices are constrained to white point preservation. In this new formulation, the subregions can flexibly be chosen in number and position in order to regularize and optimize the results, whilst constraining continuity crossing the hue planes. The method is compared to a choice of other state-of-the-art characterization methods and the results show that our method consistently gives high colorimetric accuracy for both synthetic and real camera data.

12:00 **Analyzing the Individual Relationship between Habit of UV Protection and Melanin Pigmentation based on the Change of Facial Images for 7 Years,** *Yuri Tatsuzawa[1], Misa Hirose[1], Nobutoshi Ojima[2], Keiko Ogawa-Ochiai[3], and Norimichi Tsumura[1]; [1]Chiba University, [2]Kao Corporation, and [3]Kanazawa University Hospital (Japan)* **24**

In this paper, we obtain individual difference on variation of melanin component which greatly affect apparent age. We consider frequency of use for UV protection as the factor causing individual difference in aging. It is known that the exposure of UV rays produces melanin pigment in our skin, which promotes aging of a skin such as darkening and unevenness of a skin color. In our previous work, we applied principal component analysis (PCA) to skin color pigmentation distribution and obtained feature values. By changing feature values, we simulated the appearance of human face in arbitrary age. According to this, it is revealed that melanin component in around cheeks especially tends to increase with aging. However, in the previous method, averaged feature values are used for each ages in analysis, and individual difference should be considered at the next step of research. In this paper, we constructed database that have facial image taken in 2003 and 2010 where the same 77 people were subjective. The frequency of use for UV protection was also recorded as lifestyle habit. By applying the same analysis in the previous method, we obtained score shift from the data in 2003 and 2010. From these trends of the shift, we found that one-fourth people can get light-skinned face after 7 years if they use UV protection throughout the year.

12:20 **Hierarchical Integrated Color Matching in a Stereoscopic Image based on Image Decomposition (JIST-first Paper),** *Ho-Gun Ha, Shibudas Kattakkalil Subhashdas, Bong-Seok Choi, and Yeong-Ho Ha, Kyungpook National University (Korea)* **29**

Color discrepancies between the left and right image in a stereoscopic image cause many problems, including a reduction of the three-dimensional effect and increased visual fatigue. Thus, color matching in a stereoscopic image is very important for three-dimensional display systems. Therefore, a hierarchical integrated color matching method based on image decomposition is proposed for stereoscopic images. In the proposed method, global and local color discrepancies generated in a stereoscopic image are effectively reduced by histogram matching and illuminant estimation using image decomposition. The stereoscopic image is first decomposed into a base layer and several texture layers. Each decomposed layer is then matched using cumulative histogram matching and a multi-scale retinex algorithm. Lastly, inverse decomposition is applied to each layer to reconstruct the corrected stereoscopic image. Experimental results show that the proposed method has a better color matching performance in comparison with previous methods.

12:40 – 14:00 — Lunch Break

Beyond the Rainbow

Session Chair: Pei-Li Sun,
National Taiwan University of Science and Technology
14:00 – 15:40

14:00 **An Experimental Study of Fast Multispectral Imaging Using LED Illumination and an RGB Camera,** *Raju Shrestha and Jon Yngve Hardeberg, Gjøvik University College (Norway)* **36**

Active illumination based multispectral imaging using LED light sources has got much attention in recent years due to the availability of wide range of narrow band color LEDs spreading across the visible as well as infrared regions. We proposed a fast multispectral imaging using LED illumination and an RGB camera (RGB-LEDMSI) along with a novel LED selection method. In this paper, we present and analyze the results from real world experiments on the proposed RGB-LEDMSI. We built a prototype 9-band RGB-LEDMSI system using commercial iQ-LED panels and a Nikon D600 camera. The experimental results from the prototype system confirm the effectiveness of the proposed system.

14:20 **Iterative Spectral Edge Image Fusion,** *Graham D. Finlayson and Alex E. Hayes, University of East Anglia (UK)* **41**

The Spectral Edge method of image fusion fuses input image details, while maintaining natural color. It is a derivative-based technique, based on the structure tensor, and lookup-table-based gradient field reconstruction. It has many applications, including RGB-NIR image fusion and remote sensing.

In this paper, we propose adding an iterative step to the method. We use the output Spectral Edge image as the putative color image for another fusion step, and repeat this for several iterations. We show that this creates an output image with a structure tensor field closer to that of the high-dimensional input than the output of the original method. We perform a psychophysical experiment using the iterative Spectral Edge method for RGB-NIR image fusion, which shows that the result of multiple iterations is preferred.

14:40 **Scene-Adaptive Registration of Line-Scan Multi-Spectral Image Data for Non-Planar Scanning Objects,** *Timo Eckhard, Jia Eckhard, Eva M. Valero, and Javier Hernández-Andrés, University of Granada (Spain)* **46**

Limitations of conventional RGB cameras with respect to color and spectral measurements are widely known and motivated the development of multi-spectral camera systems, which extend the amount of spectral information captured from an imaging scene. With the camera response data captured by such a system, machine learning techniques can be used to recover surface reflectance factor data of the scene on a pixel-by-pixel basis. The 12-channel line-scan multi-spectral camera system considered in this work is an example of this technology. Currently, a drawback of this system is that spectral measurements are limited to planar surfaces. Non-planar surface structure of the scanning objects results in image channel misalignment and corrupted recovery of the spectral data. We overcome this limitation by using a scene-adaptive registration scheme for the multi-channel image data. The proposed approach incorporates an invariant feature matching, a sum of squared difference based block matching algorithm and bi-linear image resampling to accomplish this task with sub-pixel accuracy. We show that the adaptively registered image data increases the spectral image quality markedly and gives rise to using this imaging principle for simultaneous spectral measurements and 2.5D geometrical measurement, ie. 2D surface measurement with height profiles.

15:00 **Reproduction of Reflective and Fluorescent Components Using Eight-Band Imaging,** *Masaru Tsuchida, Minoru Mori, Kunio Kashino, and Junji Yamato, NTT Communication Science Laboratories (Japan)* **52**

We propose a method for relighting fluorescent objects using a multiband image system. Fluorescence is often present in everyday articles and its optical properties make it harder to reproduce than pure reflectance. Decomposing colors into separate fluorescent and reflective components is required for accurate color reproduction. In our method, bi-spectral images are captured using an eight-band camera and an eight-band lighting system for the decomposition. First, spectral reflectance of the object is estimated. Next, the multiband image of the fluorescent components under relighting illumination is generated from the weighted linear combination of the captured fluorescent images. The weight of each band is calculated from the spectral transmittance of each band-pass filter attached to the lighting system, and the spectral power distributions (SPD) of the illumination during image capturing and relighting. Finally, a relighted image is reproduced by composing reflective and fluorescent component images. Experimental evaluations show that the spectral reflectance and SPD of fluorescent components are accurately estimated and relighting images are well reproduced.

15:20 **Spatio-Spectral Gamut Mapping and Separation (JIST-first Paper),** *Sepideh Samadzadegan, Technische Universität Darmstadt, and Philipp Urban, Fraunhofer Institute for Computer Graphics Research IGD (Germany)* **58**

Spectral printing aims to achieve an illuminant-invariant match between the original and the reproduction. Due to limited printer spectral gamuts, an errorless spectral reproduction is mostly impossible, and spectral gamut mapping is required to reduce perceptual errors. The recently proposed paramer-mismatch-based spectral gamut mapping (PMSGM) strategy minimizes such errors. However, due to its pixel-wise processing, it may result in severely different tonal values for spectrally similar adjacent pixels, causing unwanted edges (banding) in the final printout. While the addition of some noise to the a* and b* channels of the colorimetric (e.g., CIELAB) image—rendered for the first illuminant—prior to gamut mapping solves the banding problem, it adversely increases the image graininess. In this article, the authors combine the PMSGM strategy with subsequent spectral separation, considering the spatial neighborhood within the tonal-value space and the illuminant-dependent perceptual spaces to directly compute tonal values. Their results show significant improvements to the PMSGM method in terms of avoiding banding artifacts.

15:40 – 16:20
Coffee Break

Picture Perfect

Session Chair: Marius Pedersen, Gjøvik University College
16:20 – 17:20

16:20 **Distinct Contrast in CIECAM02 for Mobile Display,** *Wang-Jun Kyung, Ji-Hoon Yoo, Shibudas Kattakkalil Subhashdas, and Yeong-Ho Ha, Kyungpook National University (Korea)* **70**

The absolute contrast ratio of a display is a distinctive measure of the display contrast. However, this contrast ratio does not match the perceived contrast as it only uses the physical characteristic of the display. Therefore, this paper proposes a contrast measure that considers the perceptually discriminable brightness within the display brightness ranges. First, the Weber-Fechner ratio is applied to determine the brightness ranges of the display gamut in CIECAM02. Thereafter, the number of brightness values for each brightness range is computed and the perceptually discriminable brightness is then estimated based on the sum of the ratio between the number of brightness values in each brightness range and the brightness length in the display gamut. A preference test was conducted on various displays using random brightness patches to evaluate the perceived contrast. Experimental results showed that the proposed measure is more consistent with human perception than previous contrast measures.

16:40 **Robust Chroma and Lightness Descriptors,** *Hamidreza Mirzaei and Brian Funt, Simon Fraser University (Canada)* **75**

New descriptors for lightness and chroma are presented that are based on properties of a wraparound Gaussian metameric to the given XYZ tristimulus coordinates. For the 1600 samples of the Munsell glossy set, both descriptors are found to correlate to Munsell value and chroma at least as well as the corresponding CIECAM02 descriptors when the Munsell samples are under the CIE C illuminant. However, when the illuminant is changed the new descriptors were found to be considerably more consistent under the second illuminant than those of CIECAM02.

17:00 **Measuring Relative Image Contrast of Projection Displays (JIST-first Paper),** *Ping Zhao, Marius Pedersen, and Jon Yngve Hardeberg, Gjøvik University College (Norway), and Jean-Baptiste Thomas, Université de Bourgogne (France)* **79**

Projection displays, compared to other modern display technologies, have many unique advantages. However, the image quality assessment of projection displays has not been well studied so far. In this paper, we propose an objective approach to measure the relative contrast of projection displays based on the pictures taken with a calibrated digital camera in a dark room where the projector is the only light source. A set of carefully selected natural images is modified to generate multiple levels of image contrast. In order to enhance the validity, reliability, and robustness of our research, we performed the experiments in similar viewing conditions at two separate geographical locations with different projection displays. In each location, we had a group of observers to give perceptual ratings. Further, we adopted state-of-art contrast measures to evaluate the relative contrast of the acquired images. The experimental results suggest that the Michelson contrast measure performs the worst, as expected, while other global contrast measures perform relatively better, but they have less correlation with the perceptual ratings than local contrast measures. The local contrast measures perform better than global contrast measures for all test images, but all contrast measures failed on the test images with low luminance or dominant colors and without texture areas. In addition, the high correlations between the experimental results for the two projections displays indicate that our proposed assessment approach is valid, reliable, and consistent.

19:30 – 21:30
Conference Reception
Burg Frankenstein Restaurant
Located within the ruins of the famous 10th century Frankenstein Castle

Buses will pick up attendees at the Maritim Konferenzhotel Darmstadt at 18:30 and return to the hotel by 22:00.

THURSDAY OCTOBER 22, 2015

Thursday Keynote and IS&T Awards

Session Chair: Vien Cheung, University of Leeds
9:00 – 10:00

9:00 **Quantum Dots: New and Exciting Coloured Materials—Their Properties and Structures,** *Paul O'Brien, University of Manchester (UK)* **92**

The origin of colour in quantum dots will be discussed in simple and more complicated systems. The history of the area will be briefly surveyed as will their potential for technological application.

Colorful Matter

Session Chair: Marcel Lucassen, Philips Research Eindhoven
10:00 – 12:20

10:00 **A Computer Aided Color Appearance Design System for Metallic Car Paint (JIST-first Paper),** *Clement Shimizu and Gary Meyer, University of Minnesota (USA)* **93**

A computer aided design system for determining the color appearance of metallic automotive coatings has been developed. A sketch based bidirectional reflectance distribution function design interface allows simple concept art to be used to style new metallic car colors. The final design is specified using industrial measurement standards for metallic color appearance, and paint formulations are determined by employing an automotive refinish system. A virtual collection of existing automotive paints, specified using the measurement standard, is provided, and tools for searching this database, for both design and manufacturing purposes, are described. The system is assessed by using it in industrial and educational design studios.

10:20 **Yarn Color Measurement and Reproduction by a Multispectral Imaging System (JIST-first Paper),** *Isabella W. S. Tang and John H. Xin, Hong Kong Polytechnic University (Hong Kong, China)* **103**

Conventionally, measuring and thus reproducing yarn color is mainly done in an indirect way, involving the preparation of yarns in card or even fabric forms, which consumes both time and labor. A direct yarn color measurement and reproduction method based on a multispectral imaging system would be one solution to avoid this problem. In this research, 100% raw cotton yarn hanks dyed using several reactive colorants, being different sample sets, were measured by both a spectrophotometer in yarn card form and a multispectral imaging system innovatively in yarn form itself, for back-prediction and fore-prediction matching comparisons. Experimental results showed that the multispectral imaging system can perform closed-loop color reproduction satisfactorily by yarn form color measurements, with color difference means all within industrial tolerance. This new method is capable of shortening the yarn specimen handling time and, more importantly, giving more accurate yarn color measurements without the influence of neighboring colors, so as to give improved coloration accuracy.

10:40 – 11:20
Coffee Break and CIC Paper Demonstrations

11:20 **Bispectral Interreflection Estmation of Fluorescent Objects,** *Shoji Tominaga, Keiji Kato, Keita Hirai, and Takahiko Horiuchi, Chiba University (Japan)* **111**

If multiple objects are located closely, we often observe interreflection on the object surfaces. The interreflection is accompanied by a change in the appearance of the object surfaces. In this paper, we propose a method to estimate the spectral image components from the captured images of two closely apposed objects. A spectral imaging system is used for image capturing of both objects under uniform illumination. First, we describe the basis bispectral characteristics of a fluorescent object. Second, we model the interreflection of two objects with the bispectral characteristics. The surface appearance of each object was based on both reflected component and luminescent component. We show that the spectral composition of interreflection is determined by a series of multiplication of the Donaldson matrices of the two objects. The spectral components of one bounce interreflection can be limited to only four spectral functions. Third, an algorithm is developed to estimate the spectral image components from the observed spectral radiance images that are influenced by the interreflection. The algorithm is based on a two-step estimation procedure in which the spectral components are estimated separately in the outside and inside of the emission wavelength range. The feasibility of the proposed method is investigated using fluorescent samples in details.

11:40 **Multi-Color Properties of Silver Glaze Images Photo-Engraved on Glass Plates,** *Juan Martínez-García, Mathieu Hébert, Alain Trémeau, Nicolas Crespo-Monteiro, and Nathalie Destouches, Université Jean-Monnet (France)* **116**

Recent progresses in nanotechnologies enabled the coloration of glass plates coated with silver and titanium dioxide by laser irradiation. The colored samples display very different colors according to whether they are obtained by reflection or transmission of light; in specular or diffuse directions; and with or without polarizing filters. This printing technology, that we call PICSLUP, enables the production of gonio-apparent color images. In this paper, we recall the physical principles that allow the appearance of these multi-coloration effects, show the color variations under various illumination and observation configurations, and present the first color images that we could print. We also analyze the possibility of extending the color gamut with halftoning and show some preliminary spectral reflectance and transmittance predictions done with the Yule-Nielsen modified Spectral Neugebauer model.

12:00 **Colour Contrast Occurrence Matrix: A Vector and Perceptual Texture Feature,** *Armando Martínez Ríos[1,2], Noël Richard[1], and Christine Fernandez-Maloigne[1]; [1]University of Poitiers (France) and [2]Instituto Politécnico Nacional (Mexico)* **121**

Texture discrimination was the second more important task studied after colour perception and measurement. A lot of works have explored it using a separated channel processing and very few have addressed the vector aspect of this spatio-chromatic information. In this paper we propose a novel vector processing for colour texture characterization: the Colour Contrast Occurrence matrix (C_2O). The C_2O is expressed using a perceptual distance in the CIELab colour space and two angles characterizing the chromaticity, and darker or lighter direction of local differences. The set of local differences, the contrast occurrences, is represented in a 3D representation, offering an understandable representation of the texture variations. In this work, we analyze also the feature invariance to changes in illumination, viewpoint and spectrum of the light source. Performances in classification tasks on several texture databases show the added-value of the C_2O for texture discrimination especially when the texture content becomes complex.

12:20 – 14:00 — Lunch Break

Do You See What I See?

Session Chair: Maria Vanrell, Universitat Autònoma de Barcelona
14:00 – 15:00

14:00 **A Spectral-based Color Vision Deficiency Model Compatible with Dichromacy and Anomalous Trichromacy,** *Hiroaki Kotera; Kotera Imaging Laboratory (Japan)* **127**

This paper proposes a spectral-based CVD (Color Vision Deficiency) model compatible with both of dichromacy and anomalous trichromacy. The spectral projection model based on Matrix-**R** extracts the lost spectra as a difference in the fundamentals between the normal and the color deficient. The lost spectra are re-used for image daltonization by an optimal spectral shift to maximize the spectral visibility or minimize the visual gap from the normal. The model rationally improves the scene visibility after daltonization. The proposed algorithm is designed based on the original key ideas of

1. Acquisition of fundamental l **C***$_{LMS}$ (spectra visible to the normal) from sRGB camera image by a pseudo-inverse projection without expensive spectral image.
2. Foundation of projection matrix-**R**$_{CVD}$ onto dichromatic and anomalous trichromatic spectral spaces by combining the cone responses in the table by DeMarco & Pokorny & Smith.
3. Extraction of fundamental **C***$_{CVD}$ (spectra visible to the dichromat or anomalous trichromat) by operating the matrix-**R**$_{CVD}$ on the fundamental **C***$_{LMS}$.
4. Introduction of complete OCS (Opponent-Color Space) to keep the perfect achromatic grayness in the opponent-color stage.
5. Estimation of lost spectra **ΔC***$_{CVD}$ as the difference between visible spectra **C***$_{LMS}$ to the normal and **C***$_{CVD}$ to the dichromacy or anomalous trichromacy.
6. Color blindness correction (daltonization) by reviving the lost spectra **ΔC***$_{CVD}$ with the optimal spectral shift into the visible waveband.

14:20 **Investigation of Memory Colours across Cultures,** *Yuteng Zhu[1], M. Ronnier Luo[1, 2], Lihao Xu[1], Xiaoyu Liu[1, 3], Guihua Cui[4], Sebastian Fischer[5], Peter Bodrogi[5], and Tran Quoc Khanh[5]; [1]Zhejiang University (China), [2]University of Leeds (UK), [3]Harbin Engineering University (China), [4]Wenzhou University (China), and [5]Technische Universität Darmstadt (Germany)* . . **133**

Memory colours have been extensively investigated. They are important for different image applications, such as colour image reproduction. However, it is possible memory colours vary according to different cultures. The present experiments were conducted to investigate 22

memory colours, which are divided into three types: 12 common colours such as vegetables, fruits and flowers, 6 natural colours such as sky blue, grass, and skin colours, and 4 culture specific colours. Each colour was assessed by 25 Chinese observers and 30 German observers in each country. The inter-observer variations between two groups were compared in terms of mean of CIELAB colour differences in terms of MCDM measure and tolerance ellipses. Also, the colour centers are plotted in CIELAB a*b* diagram to show the culture differences. The intention here is to establish a methodology to study memory colours across different countries based on homogeneous colour patches.

14:40 **A Meta-Analysis of Color Palettes for Protans and Deutans: The Problems with Using Dichromatic Simulations,** *Takashi Sakamoto, National Institute of Advanced Industrial Science and Technology (AIST) (Japan)* **138**

This study describes a meta-analysis of three color palettes for protans and deutans, respectively proposed by Tol (2012), Krzywinski et al. (2012), and Ito et al. (2013). Their three color palettes were defined using standard red-green-blue (sRGB) tristimulus values, and they were designed to help color-deficient people distinguish the colors of graphs, maps, and other visual representations. However, color differences between the component colors of their palettes and the chromatic distribution of the component colors were unspecified by these researchers. Without comparative studies, it is difficult to compare the performance of these palettes and their visual effectiveness for color-deficient people. Hence, this study provides a meta-analysis of their color palettes. Protanopic and deuteranopic color perception and color differences were used for this analysis, along with a combination of a dichromatic simulation method and a uniform color space, such as CIELAB and CIELUV. This study elucidates a problem for analyses that rely on dichromatic simulation methods calculated using the reduced stimuli planes in the RGB color space, and proposes a way around such simulations. The results of the meta-analysis reveal that the three color palettes have problems in terms of the uniformity of color difference and the chromatic distribution of the component colors.

Interactive Paper Previews

Session Chair: Adrià Forés Herranz, Apple Inc., and Juan Lin, Ricoh Americas Corp.
15:00 – 15:40

Color Reproduction of Digital Camera Systems Using LED Spotlight Illumination, *Sebastian Fischer and Tran Q. Khanh, Technical University Darmstadt (Germany)* **143**

The use of LED spotlights has become more and more common in today's digital film and television production. In this context, the flexibility that comes along with the new LED technology offers a unique possibility to optimize the color reproduction of digital camera systems. In the following paper, an appropriate evaluation model should be proposed. It compares the reproduced image of a scene, depending on the spectra of the illuminating LED spotlights, to its direct perception under a reference illuminant and tries to minimize the perceived color differences by finding an optimal LED spectrum for each specific scene. The performance of this model will be tested using a set of 143 different surface colors and a measure for the quality of the color reproduction will be introduced.

Study of Perceived Bit-Depth on TV with High Dynamic Range, *Yuhoon Kim, Sungjin Bang, and Jang-Un Kwon, LG Display (Korea)* **148**

One of important objectives on display market is to provide natural and realistic images. Specifications which are high dynamic range, high bit-depth, large gamut size, efficient data compression, etc. are demand-

ed for achieving this objective. For high dynamic range (HDR), increase of maximum luminance is needed to present the brilliant sun realistically. Lower minimum luminance is better for complete darkness. As dynamic range is increased, discontinuous perception of luminance difference between adjacent gray levels can be presented in display. Bit-depth is related to luminance difference between adjacent gray levels. Discontinuous perception due to HDR can be reduced by high bit-depth. But, high bit-depth is caused of high cost for manufacturing display. Therefore, minimally required bit-depth should be determined for prohibiting contour. The objective of this paper is to present perceived bit-depth on display for TV with HDR. To achieve the objective, methods for visual test are proposed in this paper. As experimental results, bit-depth of 12 bit is enough to prohibit contour perceptually in OLED TV which has dynamic range over 100000 : 1.

The color of automotive coatings varies with illumination and detection angles. For 3D rendering of these coatings currently two categories of methods exist, aiming at either color accuracy or at computational speed. Current methods that aim for color accuracy are based on measurement data from BRDF instruments. Since many hundreds of measurement geometries are needed to capture the color variation with angles, these methods require time-expensive interpolation of large three-dimensional Look-Up Tables. Current methods that aim for computational speed use physically crude approximations, usually taking into account color variations with respect to only one of the four angular dimensions.

Here, we derive a new approach for 3D rendering of automotive and other gonio-apparent coatings, which is a dedicated form of microfacet models. It aims at improved color accuracy as compared to the current computationally inexpensive methods, combined with higher computational speed and lower cost as compared to current color-accurate rendering techniques. The new approach utilizes a recently developed physical analysis method, introducing flake-based parameters and isochromatic lines, for the reflection properties of automotive coatings. This makes it more accurate than current fast rendering methods. The new method naturally leads to two- rather than three-dimensional Look-Up Tables, which explains the small computation time it needs. We show that when applied to 3D rendering, this method indeed leads to accurate 3D rendering of automotive coatings while requiring reduced computation times. For numerical errors found in some special cases, solutions are found and tested.

In this research, we propose to estimate images of five components that are melanin, oxy-hemoglobin, deoxy-hemoglobin, shading and surface reflection from five band images at the same time. For this purpose, we build nonlinear estimation method by using Monte Carlo simulation of light transport in multi-layered tissue (MCML). The diffuse reflectance of MCML is converted to absorbance using logarithm and the absorbance for each wavelength is defined by a cubic function of chromophore concentration. By using the cubic function, chromophore concentration is determined to minimize residual sum of squares of reflectance. To evaluate the estimation accuracy, we generate numerical phantom of spectral reflectance map. In generating the numerical phantom, we acquire the distribution of chromophore by applying independent component analysis (ICA) to skin color image. The spectral reflectance of MCML is allocated to the obtained chromophore distribution and the reflectance map. As a result of evaluation, our proposed method improved the estimation accuracy significantly.

Most cameras resolve a color stimulus by three spectral sensitivity responses. Commonly, these do not satisfy the Luther-Ives condition. Hence, there is no linear mapping between the camera's RGB values and the CIE XYZ tristimulus values. Although more complex methods for camera characterization have been proposed, none can solve the issues caused by camera metamerism. While being different to the human eyes, certain stimuli will induce the same RGB response in the camera. To investigate color reproduction errors and the effects of device metamerism, metameric spectra must be found. Previously proposed methods generate metameric pairs artificially. We present a method for finding metameric pairs within a database of real-world measured spectra, which we believe has more practical utility than methods employing synthesized metameric pairs. By using measured camera sensitivities and reflectances from the SOCS database we can identify metamers with a real-world occurrence possibility. We characterize critical spectra by type of object and by hue, considering both CIE illuminants and real-world LED fixtures.

Color extrapolation is the estimation of color coordinates or transforms for values that lie beyond the sampled colors or training data. For example given a chart of measured color values and a digital image of that chart it is useful to be able to extrapolate values that are beyond the color samples provided by the chart. One option is to use linear multivariate regression based on a sampling of nearby points. This will result in a matrix transform which can be used for extrapolation. This abstract proposes the derivation of a median matrix based on a sampling of nearby points. That is given random triplets of points a closed form inverse of the first order polynomials is used to directly compute matrix elements. The final matrix is determined by the median of the individual elements. The median matrix extrapolation is shown to be more accurate than conventional multivariate regression, more robust to noise, does not require linear algebra, and can potentially be applied to streaming data.

In an effort to create more dynamic looking automobiles, there is an ever increasing trend among automobile manufacturers towards the use of gonio-apparent coatings in car bodies. These coatings consist of transparent pigments mixed with metallic or interference flakes. The flakes in the coating cause a change in color and brightness of the finish with viewing and illumination direction. This change in appearance accentuates the 3D shading of a car body, making it visually more attractive. Besides this angular dependence on viewing/illumination direction, the metallic finishes also exhibit a visually complex texture. Depending on the properties of the finish and the viewing and illumination conditions, the flakes exhibit a sparkle like texture, while the glossy clear coat may show a rough or smooth surface. As a result of these complex visual attributes, capturing the appearance and finding a perfect color match for an automotive coating is a non trivial task.

The main objective of this work is to evaluate the relationship between the special-effect pigments size, and the maximum distance which is detectable the sparkle texture effect. For this, two different sets of samples with different structural features were evaluated in a lighting booth specifically designed for the visual experiment. The booth allows to vary the lighting conditions, the viewing geometry and the distance at which the sample is perceived.

The visual experiment was applied to evaluate the high correlation between a structural parameter (i.e. pigment size) and the visual appearance attribute related with texture (sparkle detection distance). Under some fixed environmental conditions, as light intensity, color temperature and geometry of the light source, the sparkle detection distance was evaluated by applying the adjustment psychophysical method for two panel sets (metallic grays and blues), with known pigment sizes and colorimetry, with a small set of observers. The visual results show that a greater the pigment size, a greater the sparkle detection, but with some considerations.

In future, we will extend this method, even reinforced applying the statistical design of experiments (DOE), for understanding the relevance and interplay of structural (size, shape, concentration, orientation, etc.), environmental (illuminance level, color rendering, geometry, etc.) and colorimetric (dark vs. light background, chroma, etc.) factors on the sparkle detection distance.

Comparing Spectrophotometry and Photography with Hyperspectral Imaging for Pigments' Characterization on Paintings, *Anita Hayem-Ghez[1,2,3], Clotilde Boust[1], Elisabeth Ravaud[1], Gilles Bastian[1], Michel Menu[1], and Nancy Brodie-Linder[2]; [1]Centre de Recherche et de Restauration des Musées de France, [2]Université de Cergy Pontoise, and [3]Fondation des Sciences du Patrimoine (France)* **180**

Pigments characterization on paintings is usually made with X-ray fluorescence, traditional false color photography and optical microscopy. The use of optical techniques based on reflectance spectra, like reflectance spectrophotometry or hyperspectral imaging, is limited today to some case studies. We would like to improve these optical techniques for pigment characterization, because they are non-invasive and can give a lot of information. After comparing the ways to calibrate to reflectance spectrophotometry and hyperspectral imaging, we develop the two techniques for the specific study of pigments. We develop a Matlab program to analyze (identify and quantify) reflectance spectra given by spectrophotometry, and a new methodology based on false color composites to use hyperspectral images in a simple way. The choice of the spectral bands to identify pigments takes its roots in the maximization of spectral differences, and leads to the generation of 3 false color composites—called variable composites FC1, FC2 and FC3 —to distinguish the pigments of the four categories (blue, red, yellow and green). The results of spectrophotometry and variable composites on a painting of the 17th century by French painter Eustache Le Sueur are encouraging and consistent with other techniques' results. Our results should promote the use of spectrophotometry and hyperspectral imaging for pigment characterization in the future.

Interactive Illumination Invariance, *Han Gong and Graham Finlayson, University of East Anglia (UK)* **186**

Illumination effects cause problems for many computer vision algorithms. We present a user-friendly interactive system for robust illumination-invariant image generation. Compared with the previous automated illumination-invariant image derivation approaches, our system enables users to specify a particular kind of illumination variation for removal. The derivation of illumination-invariant image is guided by the user input. The input is a stroke that defines an area covering a set of pixels whose intensities are influenced predominately by the illumination variation. This additional flexibility enhances the robustness for processing non-linearly rendered images and the images of the scenes where their illumination variations are difficult to estimate automatically. Finally, we present some evaluation results of our method.

Gloss and Material Constancy in the Change of Light Source Size, *Masanori Maki[1], Ryota Domon[1], Shoji Yamamoto[2], and Norimichi Tsumura[1]; [1]Chiba University and [2]Tokyo Metropolitan College of Industrial Technology (Japan)* **191**

It is well-known that gloss appearances are observed as the results of association among various physical factors. In order to analysis this association, perception for constancy is very important characteristic features. In this paper, therefore, we verify the influence in gloss and material constancy under the artificial environment by changing the shape and size of light source. We performed two type observations in subjective evaluation, one is the "gloss appearance" which is mainly observed the distribution of specular reflection, and the other is "material appearance" which is mainly observed all distribution of specular and diffuse reflection influenced roughness as whole appearance of object. We prepared two kinds of object which has different roughness, and four kinds of light image generated by LCD projector. A paired comparative experiment was performed under different light source with real object. As the result, there was no obvious gloss constancy when we observed only the distribution of specular reflection, since the shape and size of light source gave a great influence to the gloss perception. On the other hand, an effect of material constancy appeared when we observed all distribution of specular and diffuse reflection influenced roughness as whole appearance of object.

The Correlation of Reproduction and Recovery Angular Errors for Similar and Diverse Scenes, *Roshanak Zakizadeh and Graham D. Finlayson, University of East Anglia (UK)* **196**

Illuminant estimation algorithms are usually evaluated by measuring the angular error between the RGB vectors of the estimated illuminant and the ground-truth illuminant (recovery angular error). However, the recovery angular error reports a wide range of errors for a given illuminant estimation algorithm and a given scene viewed under multiple lights (despite the fact that when the estimated lights are divided out the reproductions are similar). Following this observation, the reproduction angular error was proposed which instead measures the angle between the RGBs of a white surface being color corrected by dividing out the estimated illuminant RGB and R=1, G=1 and B=1 (i.e. white if the illuminant is correctly discounted). In this work we look at the correlation between the two metrics for each individual algorithm applied on a set of images. We observe that where the images are from the same scene under different illuminations the recovery and reproduction errors are often uncorrelated. Whereas when the same algorithm is applied on the images of diverse scenes the two errors are highly correlated.

Construction of Manga Materials Database for Analyzing Perception of Materials in Line Drawings, *Yuma Saito, Keita Hirai, and Takahiko Horiuchi, Chiba University (Japan)* **201**

Interest in the visual perception of the materials that objects are made of has been growing. Most past studies on visual material-category perception have used stimuli with rich information such as color, shape, and texture. However, we can distinguish material categories from even simple black-and-white line drawings. This paper presents a new attempt to analyze material perception from Japanese "manga" comics which are composed of line drawings typically printed in black and white. In this study, we first collected 400 material objects captured from manga comics, and created 400 corresponding patches that were close-up images of the objects and that excluded shape information. Through psychophysical experiments, 274 pairs of images giving consistent material impressions to observers were chosen. According to our experiments, observers could distinguish material categories from patches with on accuracy of 88.4%. Then for each material, we investigated the low-dimensional image features that contributed to the material perception of black-and-white drawings. In particular, we found image features that represented metals very well.

Non-Contact Video based Estimation for Heart Rate Variability Spectrogram Using Ambient Light by Extracting Hemoglobin Information, *Kouki Kurita, Taku Yonezawa, Mai Kuroshima, and Norimichi Tsumura, Chiba University (Japan)* **207**

Non-contact video based heart rate estimation has great various potential in areas such as medical, health care, and affective computing. Recently, the methods using a digital camera for remote heart rate (HR) measurement are widely spread. However, the accuracy of these methods are not

sufficient enough to calculate heart rate variability (HRV) accurately. If HRV are measured with high accuracy, we can visualize the sympathetic nerve system by calculating heart rate variability spectrogram (HRVS).

In this paper, we propose a method of HR and HRV spectrogram estimation by analyzing extracted hemoglobin concentration from facial color images. Our method does not require any special camera. Furthermore, it is possible to have a stable presumption even under the ambient light sources. As a result, we could obtain 99% accuracy of HR and HRV spectrogram with the same accuracy electrocardiogram. Therefore we succeeded to identify whether participants were relaxed or stressed using conventional DSLR camera.

Mutual Illumination Photometric Stereo without Calibration, *Christopher Powell and Graham D. Finlayson, University of East Anglia (UK)* **212**
Recovering three-dimensional shape from two-dimensional images is a long-standing problem in computer vision. First proposed in the 1980s, photometric stereo has matured to the point that accurate recovery of complex shapes and surfaces has become achievable. However, such methods typically demand multiple image captures, highly controlled scene conditions and elaborate experiment designs which require calibration. Building on previous work, we propose using a variant of photometric stereo which needs only a single image of an object in a colourful environment and we now remove the requirement of a calibration step. Instead we build an entirely synthetic graphics model of our capture environment (a colourful box) and carry out a synthetic calibration. The validity of this approach is demonstrated by bench-marking real world experiments against ground truth data and comparison with previous work.

Performance Evaluation of JPEG, JPEG2000, and New CSI-JPEG Algorithms by Incorporating Different Color Spaces,
Muhammad Safdar[1], M. Ronnier Luo[1,2], and Xiaoyu Liu[3]; [1]Zhejiang University (China), [2]University of Leeds (UK), and [3]Harbin Engineering University (China) **219**
In the current work, seven different color spaces were investigated including sRGB, YCbCr, YCoCg-R, RDgDb, CIELAB, IPT, and CAM02-UCS by incorporating into JPEG1992, JPEG2000 and new JPEG. The prime objective of this work was to compare the performance of CSI-JPEG with that of JPEG1992 and JPEG2000. Psychophysical experiments were also performed to examine visual appearance of the compressed and decompressed images. Compression performance was examined for different color spaces by using measures like SNR, PSNR, MSE, CIEDELAB and CIEDE2000. The results showed that CSI-JPEG algorithm provided about 20-30% more compression rate compared to JPEG1992 algorithm for same color difference. Moreover, CAM02-UCS was found to perform best in terms of compression rate and image quality for all three algorithms. The CAM02-UCS was found significantly better compared with linear color spaces but CIELAB, CIELUV, and IPT were insignificantly better. This also implies that it is visually more uniform than CIE uniform color spaces. Results also showed that performance difference of CSI-JPEG and JPEG2000 was not significant but both performed significantly better compared with JPEG1992.

A Pilot Study on Evaluating Common Appearance and a Color Naming Approach to Measure It, *Philipp Tröster, Robin Schwanse, and Andreas Kraushaar, Fogra Institute (Germany)* **224**
If an image, for example a company logo is shown on different devices the degree of colour consistency amongst this set of stimuli can be defined as common appearance (CA). Because of the expanding number of devices with high dynamic range of imaging and with highly varying colour gamuts this issue becomes more and more important. Unfortunately conventional and established colourimetry, where usually two patches or images are compared side by side or through a media relative approach, is not sufficient, because the used metrics are developed for small colour distances. Establishing a measurement-tool for large colour differences and multiple reproductions side by side requires approaches that go beyond classic colourimetry. In this paper we designed a psychophysical experiment to measure if CA can be measured and we show a first approach for establishing a metric for CA through colour naming.

Measuring Human Skin Colour, *Mengmeng Wang[1], Kaida Xiao[2], Sophie Wuerger[2], Vien Cheung[1], and Ming Ronnier Luo[1,3]; [1]University of Leeds (UK), [2]University of Liverpool (UK), and [3]Zhejiang University (China)* **230**
Human skin colour measurements from four ethnic groups including 188 subjects were accumulated. Five to ten locations of each subject were measured by using two different instruments, a tele-spectroradiometer and a spectrophotometer. Three repeated measurements were accumulated for each location. Repeatability of the measurements at different locations from different ethnicities was examined using the mean CIELAB colour difference from the mean (MCDM). The colour distribution between different locations of different ethnic groups was also studied by plotting the data in a*b* and $L^*C^*_{ab}$ planes. Systematic trends were found between different ethnicities and instruments.

Assessing the Quality of Two LED based CIE Illuminant Simulators,
Haiting Gu[1], Ming Ronnier Luo[1, 2], Xiaoyu Liu[1, 3], Yang Yang[1], and Binyu Wang[4]; [1]Zhejiang University (China), [2]University of Leeds (UK), [3]Harbin Engineering University (China), and [4]Thousand Lights Lighting Limited (China) **235**
CIE D50 and A simulators based on a multi-channel LED system were evaluated and compared with those based on conventional fluorescent and tungsten sources. A psychophysical experiment was carried out for critically evaluating the colour difference of 30 metameric pairs. The results showed that LED lighting based on 9 channels can successfully achieve the desired quality specified by ISO 3664:2008(E) viewing conditions for the applications of graphic technology and photography. In the visual experiment, it was found that LED simulator outperformed the conventional fluorescent simulator under D50 illuminant, and gave similar performance as the tungsten simulator under A illuminant.

Interactive Paper Session

Session Chair: Adrià Forés Herranz, Apple Inc., and Juan Lin, Ricoh Americas Corp.
15:40 – 17:00

FRIDAY OCTOBER 23, 2015

CIC Workshops

Session Chair: Jérémie Gerhardt, EyeEm Mobile GmbH, and Albrecht Lindner, Qualcomm Technologies, Inc.
times vary; see workshop

8:00 – 12:30
W1: Camera Color Characterization Workshop

Organized by Dietmar Wueller, Image Engineering GmbH & Co. KG (Germany); **Moderated by** Sabine Süsstrunk, EPFL (Switzerland)

This workshop covers the whole process of camera characterization in theory and practice; a talk is provided on all important aspects.

Many camera manufacturers stick to old test chart based color characterization methods because they reluctant to change a running system or have not fully understood what modern technology can do.

The goal of the workshop is to identify and demonstrate known issues in this process and provide potential solutions using the latest technology like multispectral LED light sources in combination with in situ measured spectral radiances of natural objects and modern implemen-

tations of color look up tables so that participants get all the information they need to implement advanced color correction in their cameras and software.

The following topics will be covered:

Why Cameras Need to be Characterized and Calibrated, *Kevin Matherson, Microsoft Corporation (USA)*

Target-based versus Spectral Camera Calibration, *Eric Walowit (USA)*

Target-based versus *In Situ* Spectral Training Data, *Dietmar Wueller, Image Engineering GmbH & Co. KG (Germany)*

Impact of Color Correction on General Image Quality

CCM versus Color Lookup Tables

Potential Rec2020 Impact on Color Correction in Cameras, *Nick Bulitka, Lumenera Corporation (Canada)*

Demonstration of Spectral Characterization and Implementation of the Data

9:00 – 12:30

W2: Multi-Disciplinary Challenges in the Measurement and Reproduction of Skin Colors Workshop

Chair: Kaida Xiao, University of Liverpool (UK)

The motivation behind this workshop is to bring together practitioners and academics from a range of disciplines to explore the outstanding issues in the measurement, reproduction, and perception of skin, with a particular emphasis on skin imaging. The overall goal is to understand more deeply what the most pressing challenges are in this area and stimulate cross-disciplinary collaborations that might help address these issues. The following speakers will present:

Fundamentals of Skin Color Reproduction for Tele-Medicine, *Francisco Imai, Canon USA (USA)*

This talk covers how to characterize and model imaging systems for accurately capturing ground truth skin imaging and reproducing the appearance on displays emphasizing the need for a perceptual metric to assess the performance of the reproduction. Applications for tele-medicine on appearance of facial skin, endoscopy and odontology will be discussed.

A Multispectral Imaging System for Dermatology Studies, *Wei-Chung Cheng, US Food and Drug Administration (USA)*

A multispectral imaging system was developed to obtain the spectral imagery in the d/0º lighting geometry. The system images skin in a Ø65 mm circle and reports the spectrum between 380 and 780 nm for each of the 113 thousand pixels. The sampling size of every pixel is approximately 113x113 μm2. The illumination is a tunable light source diffused by an integral sphere. The detector is a fully calibrated scientific camera set up at 0 degrees. The system is driven by computer software to capture an image in 4 seconds and then generate the spectra within 30 seconds. Compared with typical spectrophotometers, the multispectral imaging system provides per-pixel spectral data of a larger area, which enable researchers to study spectral properties of skin disease including melanoma and other pigmented lesions.

Uncertainty of Skin Colour Measurement and Database, *Mengmeng Wang, University of Leeds (UK)*

Skin colour is important for colour reproduction and skin disease diagnoses. For measuring skin colour, tele-spectroradiometers (TSRs) and spectrophotometers (SPs) are two widely used instruments for skin colour measurement. In this study, the short-term repeatability and skin colour distribution of ten and five locations of 188 subjects from four ethnic groups, including 86 Oriental, 79 Caucasian, 13 South Asian and 10 Africa, which measured by these two kinds of instrument were investigated. Each of the location was measured three times. The short-term repeatability was determined through the mean colour difference from the mean (MCDM), which is the mean colour difference (ΔE*ab) between each of the three repeat measurement and their mean CIELAB values. From the MCDM values of different instruments and ethnicities can see, the short-term repeatability of these two instruments is different. The MCDM value of TSR is about twice to the SP's. Apart from African group, the short-term repeatability of different ethnic groups is similar. The skin colour distribution of different ethnicities and instruments were investigated through plot the mean CIELAB value on a*b* and L*C*ab planes. Comparing the measurement results of two instruments can see, the TSR's is lower in lightness than the SP's. The hue angle and chroma of two instrument's measurement results agrees well. The distribution of two instruments measurement results is similar. They both showed a trend that lighter skin colour is higher in lightness and lower in chroma, except the African group.

Skin Colour Gamut for Different Ethnic Groups, *Changjun Li, University of Science and Technology Liaoning (China)*

The gamut of surface colour was considered by Mike Pointer in 1980 and was refined by ISO in 2007. However, the skin colour gamut is much smaller than that. In this talk, the skin gamut for all ethnic minorities such as Caucasian, Chinese and Thailand and so on, as a whole will be given and comparisons on gamuts from different ethnic minorities will be given as well.

Physics and Physiologically-based Skin Color Image Analysis and Synthesis, *Mai Sugawara and Norimichi Tsumura, Chiba University (Japan)*

Reproduced skin appearance such as color, texture and translucency depend on imaging devices, illuminants and environments. As a result of the recent progress of color management technology, imaging devices and the color of an illuminant can be calibrated by device profiles to achieve high-fidelity appearance reproduction. However, the high-fidelity reproduction is not always effective in the practical imaging systems used for facial imaging; therefore, additional functions for color, texture and translucency reproduction are required in high quality facial image reproduction. We named these functions as E-cosmetic functions, and we believe the E-cosmetic function should be physics based and physiologically based processing for high quality facial image reproduction. In this manuscript, therefore, physics and physiologically based image processing is introduced based on the extraction of specular, hemoglobin, melanin and shading information in the skin color image.

9:00 – 12:30

W3: High Dynamic Range Imaging & Digital Camera Workflow

Chairs: Nicolas Bonnier, Apple Inc. (USA), and Harald Brendel, ARRI (Germany)

Speakers: Nicolas Bonnier, Apple Inc. (USA); Jan Fröhlich, University of Stuttgart (Germany); Stefan Grandinetti, Stuttgart University (Germany); Timo Kunkel researcher, Dolby Laboratories (USA); and Erik Reinhard, Technicolor (USA)

As digital cinema workflows evolve, new technologies emerge bringing higher resolution, higher frame-rate, higher dynamic range, and wider gamut. In particular, cameras manufacturers are developing input devices capturing an always-higher dynamic range while projectors and monitors gradually improve and display higher and higher dynamic range. Different aspects of the digital cinema workflow such as the image rendering, the encoding range and format, the color space, the color sampling, the supported dynamic range, and the bandwidth will have to be reconsidered to adopt these emerging High Dynamic Range (HDR) technologies.

The workshop reviews emerging HDR technologies in digital cinema, evaluates the likelihood of their adoptions by the community, and discusses the impact of their adoptions on the digital cinema workflow. The aim is to bring together researchers from both the industry and academia to identify opportunities and challenges within this field. The workshop starts with a series of invited talks from established researchers from leading companies, organizations, and universities who will focus on particular aspects of the field.

The following stages of the digital cinema workflow are covered: camera capture, color grading and post-production, mastering, distribution and broadcasting, and display. The current state of standardization efforts by leading organizations such as the Academy of Motion Picture, Art and Science, SMPTE and MPEG is also discussed.

12:30 – 14:00 — Lunch Break

Closing Keynote and Best Paper Awards

Session Chair: Vien Cheung, University of Leeds

14:00 – 15:00

Keynote sponsored by Hewlett-Packard Company

14:00 **3D Printing: Building Rich and Seamless Workflows for Advanced Fabrication,** *Scott White, Hewlett-Packard Company (Spain)* **239**

3D Printing and Additive Manufacturing technologies are evolving rapidly. Materials and processes are being created and refined to fabricate compelling and useful objects for a wide array of industries. The digital pipeline from design to fabrication is evolving as well, but there are many challenges associated with matching designers' intent to fabricated objects, especially for advanced visual and mechanical properties. Meeting these challenges will require effort across the entire 3D printing ecosystem and, in some cases, require entirely new ways to specify and encode printing data.

Bright Ideas and Closing Remarks

Session Chair: Peter Bodrogi, Technische Universität Darmstadt

15:00 – 16:10

15:00 **Encoding Color Difference Signals for High Dynamic Range and Wide Gamut Imagery,** *Jan Froehlich[1, 2], Timo Kunkel[1], Robin Atkins[1], Jaclyn Pytlarz[1], Scott Daly[1], Andreas Schilling[3], and Bernd Eberhardt[4]; [1]Dolby Laboratories Inc. (USA), [2]University of Stuttgart, [3]University of Tübingen, and [4]Stuttgart Media University (Germany)* **240**

High dynamic range and wide color gamut are currently being introduced to television and cinema. This extended information requires not only more efficient signal encodings, but also improved color spaces. Due to the increasing variation in display capabilities, it is desirable to have a color signal encoding that is not only suitable for efficient quantization but also for color volume mapping.

While an efficient method for high dynamic range luminance encoding has been put forward, a similar encoding scheme for color difference signals is not yet available. We address this with a novel color space representation that can be used for both efficient encoding of high dynamic range and wide gamut color difference signals as well as color volume mapping. We compare the performance, robustness and complexity against other color spaces in a variety of usage scenarios.

15:20 **A Spectral Database of Commonly Used Cine Lighting,** *Andreas Karge, Jan Fröhlich, and Bernd Eberhardt, Stuttgart Media University (Germany)* **248**

In recent years, multiple methods have been published that describe how to estimate the spectral response of a camera system or object reflectance spectrum. These methods are becoming increasingly important for the color processing pipeline in movie productions. Knowing the spectral power distribution of light sources used in a movie production is essential for a spectral based approach to ensure a correct color reproduction in movie data creation. We present a thoroughly documented data set of spectral power distributions of typical film and TV lighting. The data set can be used to create more precise camera characterizations and help to develop spectral color processing pipelines. Furthermore, the spectral power distribution data set can be employed to detect and validate overaged or damaged lighting, by comparing their spectra to our reference measurement.

15:40 **Theoretical Implementation of the Color Inconstancy Index for Gonio-Apparent Automotive Coatings,** *Francisco M. Martínez-Verdú, Esther Perales, Elísabet Chorro, Valentín Viqueira, Bárbara Micó-Vicent, and Omar Gómez, University of Alicante (Spain)* **255**

Color inconstancy index (CON), well stablished and recommended by the ISO 105-J05 normative, is usually applied on textile solid colors, and not on gonio-apparent ones. In this work we propose a fast and easy implementation and virtual color assessment of this colorimetric index for these innovative colors, often used in many industries as automotive, cosmetics, computer graphics, plastics for electronic consumers, printing inks, etc.

Instead using the ΔE CMC(1:1) color difference formula, the ΔE AUDI2000 formula for the six measurement geometries recommended by the ASTM E2194 normative was used simulating the theoretical visual assessment in a directional lighting booth, and applied on some different panel sets, as the official AUDI palette composed by 117 colors, both solid, metallic and pearlescent. The theoretical directional lighting booth can select different standard illuminants (A, D65 as reference, and F11), daylight fluorescent simulators (D50, etc.) and light sources (as wLED, etc.).

The results showed that spectral reflectances with low chroma and lightness lead to minimum CON index. But, spectral reflectances with high chroma and middle lightness lead to maximum CON index. Additional interesting conclusions were also derived. For instance, for near-specular geometries the CON index is maximum due the high variability or contrast in the photometric scale of the spectral reflectance (higher to the conventional 100 %). Although the spectral content of the light source clearly influences on the CON index of a color panel, different relative spectra can provide different color travels in the same panel, and then high CON index, as for instance A vs. D65, or F11 and D65, or wLED vs. D65.

16:00 **Closing Remarks**