SEPTEMBER 29- OCTOBER 1
ONLINE

LONDON imaging MEETING 2020

FUTURE COLOUR IMAGING

FINAL PROGRAM AND PROCEEDINGS

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WELCOME TO LIM 2020!

Thank you for joining us at this first edition of the London Imaging Meeting (LIM)! We would have loved to meet you all in person in London in April, but as with most other events in our lives this year, the pandemic had necessitated a move online. We have made our best efforts to provide you with the best possible experience given the current situation and hope that you will find the meeting interesting, informative, and even fun. Please remember that the courses, tutorial, and talks are all being recorded and you will have access to the materials until the end of 2020.

LIM's mandate is to bringing together experts from a particular imaging-related topic every year, with the first year's theme centered around "Future Color Imaging".

We have a thrilling program ahead of us. The Technical Program represents state-of-the-art in the field of Color Imaging in various topics including Color Science, Perception, Visibility, Image Reproduction and Computer Vision. On the first day, we have two very interesting short courses in Colorimetry and Chromatic Adaptation, plus a tutorial on understanding the color processing of the camera. The following two days are devoted to the technical program, and include two keynote talks, 5 focal talks, 14 oral presentations, 14 interactive presentations, and 9 work-in-progress posters.

I'd like to take a moment to highlight our two keynote speakers: Felix Heide (Princeton University) explains how to define cameras to see the "invisible" using computational imaging techniques and Lawrence Maloney (New York University) discusses the color perception of surfaces in real scenes. We hope these talks are very inspiring and a source of meaningful conversations among all attendees.

Even if this year we have an online conference and it is therefore less straightforward to foster informal interactions—when queuing for a coffee or touring around in the interactive session—we encourage you to attend our coffee breaks in which the interactive papers are presented and various spaces are available to join colleagues and discuss color-related topics.

Finally, I want to thank all the people who have helped to make this conference possible. These include Graham Finlayson (University of East Anglia), the LIM Series Chair; the Steering Committee composed of Michael Brown (York University), Susan Farnand (RIT), and Rafal Mantiuk (Cambridge University); all the great colleagues and researchers who volunteered to serve as the Program Committee and Reviewers; and the staff at IS&T. I also want to thank the Institute of Physics in which our Meeting was originally going to be held.

I hope you enjoy your time at LIM2020! And please send us ideas for improving LIM in the future.

—Javier Vazquez-Corral, LIM 2020 General Chair-

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LIM 2020: SCHEDULE AND TECHNICAL PAPERS

TUESDAY 29 SEPTEMBER 2020

SHORT COURSE PROGRAM

8:00-10:15 (LONDON) / 15:00 - 17:15 (BEIJING)
SC01: Comprehensive Colour Appearance Modelling (CCAM)
Instructor: Ming Ronnier Luo, Zhejiang University (China)

10:45-13:00 (LONDON) / 17:45 - 20:00 (BEIJING)
SC02: Chromatic Adaptation and Its Application in Imaging Systems
Instructor: Minchen (Tommy) Wei, The Hong Kong Polytechnic University (Hong Kong)

COMPLIMENTARY TUTORIAL

13:30-15:30 (LONDON) / 20:30 - 22:30 (BEIJING)
Understanding Color and Your Camera
Instructor: Michael Brown, York University (Canada)

WEDNESDAY 30 SEPTEMBER 2020

WELCOME/INTRO REMARKS

Session Chairs: Graham Finlayson, University of East Anglia (UK), and Javier Vázquez Corral, Universitat Pompeu Fabra (Spain)
9:00 - 9:15 (LONDON) / 16:00 - 16:15 (BEIJING)

SESSION I: COLOR SCIENCE AND APPLICATIONS

Session Chairs: Javier Vázquez Corral, Universitat Pompeu Fabra (Spain), and Ming Ronnie Luo, Zheijiang University (China) and University of Leeds (UK)
9:15 - 10:45 (LONDON) / 16:15 - 17:45 (BEIJING)

9:15 (London) / 16:15 (Beijing)
FOCAL TALK Recent Development of Colour Science, *Ming Ronnie Luo, Zheijiang University (China) and University of Leeds (UK)* *
This talk begins with an overview of the recent published CIE 15 Colormetry—the standards fourth edition—which covers the most up-to-date CIE colour metrics, including CIEDE2000, CIECAM02, and CAM02-UCS. This is followed by a review of CIE new models, including CAM16, CAT16, and CAM16-UCS, as well as colour metrics for HDR and WCG applications, include colour difference prediction under HDR and WCG conditions such as $J_z a_z b_z$ and ZCAM.

Other recent developments are also reviewed, including colour contrast modelling, chromatic adaptation transformation, 2D colour appearance scales, and chromatic spatial contrast sensitivity functions.

9:45 (London) / 16:45 (Beijing)

The goal of this research work is to generate high quality chromatic contrast sensitivity (CCS) data over a large range, especially at low spatial frequencies surrounding 5 colour centres, e.g. white, red, yellow, green, and blue. An experiment was carried out using forced-choice stair-case method to investigate the visible colour difference thresholds in different colour changing directions at different spatial frequencies. The just noticeable difference (JND) ellipses at different spatial frequencies were used to represent the data.

10:05 (London) / 17:05 (Beijing)

In this paper, skin tone heterogeneity in five facial areas (forehead, right cheekbone, left cheekbone, nose tip, and chin) was investigated under six light sources with correlated color temperature (CCT) of 2850 K, 3500 K, 5000 K, 5500 K, 6500 K, and 9000 K. Firstly, a facial image capturing protocol was developed and applied to five female participants, and their facial skin tone was analyzed based on the captured images. Through color characterization of the camera, XYZ values in each facial area were converted by a matrix from the extracted RGB data and then transformed to CAM02-UCS color space. MCDM with CAM02-UCS color difference was used to quantify skin tone heterogeneity in each facial area. The results under different light sources indicated that larger heterogeneity exists under the light source with lower CCT, and when the CCT of the light source ranges from 5000 K to 9000 K, there was smaller skin tone heterogeneity in each facial area.

10:25 (London) / 17:25 (Beijing)

This experiment was aimed to study the preference of mobile phone facial images captured under different simulated ambient lightings. The experiment was carried out by assessing the preference of images for two facial images under 11 lightings (5 correlated colour temperature levels at 2 illuminances plus a dark condition). Forty-five images were processed via CAT02 chromatic adaptation transform to simulate the pictures captured under different light environments. The results revealed that the preferred capture region was between 6500 and 8000K around -0.05 Duv. Furthermore, it was found that the preferred skin tones of all the 45 rendered had good agreement under all the ambient lightings of viewing, i.e. to have mean values of L*, Cab*, hab of [76.3 25.1, 46.4°] units under D65/10° conditions.

*Abstract only; no proceedings paper.

TWO-MINUTE INTERACTIVE PAPER (POSTER) PREVIEWS I FOLLOWED BY COFFEE BREAK/INTERACTIVE SESSION I

Session Chair: Sophie Triantaphillidou, University of Westminster (UK)

10:45 - 11:40 (LONDON) / 17:45 - 18:40 (BEIJING)

Interactive (Poster) Paper authors provide a brief overview of their work, followed by talks with authors in individual Zoom rooms. Posters may also be visited via Perusall (see directions within the conference portal) at any time.

How and to what extent the increase of Cab* affects on various subjective evaluations for congenital red-green color deficiency (CVD) and normal color vision (NCV) observers was investigated using scenery, food, and graph images. Results of "Pale vs Deep" evaluation indicate similar tendency for all color vision types in all test images, indicating that CVDs recognize the saturation change of images similar to NCVs using some kind of strategy. Individual differences of the CVDs in the results of other adjective pairs such as "Unnatural vs Natural" are generally larger than those of NCVs. Some color combinations in the graph images are indiscriminable for either protan or deutan, and thus are not recommended to be used.

We exploit evolutionary computation to optimize the hand-crafted Structural Similarity method (SSIM) through a data-driven approach. We estimate the best combination of luminance, contrast and structure components, as well as the sliding window size used for processing, with the objective of optimizing the similarity correlation with human-expressed mean opinion score on a standard dataset. We experimentally observe that better results can be obtained by penalizing the overall similarity only for very low levels of luminance similarity. Finally, we report a comparison of SSIM with the optimized parameters against other metrics for full reference quality assessment, showing superior performance on a different dataset.

In texture analysis, stationarity is a fundamental property. There are various ways to evaluate if a texture image is stationary or not. One of the most recent and effective of these is a standard test based on non-decimated stationary wavelet transform. This method permits to evaluate how stationary is an image depending on the scale considered. We propose to use this feature to characterize an image and we discuss the implication of such approach.

Experiments were carried out to investigate the simultaneous lightness contrast effect on a self-luminous display using simultaneous colour matching method. The Albers' contrast pattern named 'double-crosses' was used. The goals of this study were to model lightness contrast effect and modify it in the CAM16 colour appearance model. Five coloured targets were studied, and 41 test/background combinations were displayed on a calibrated display. Twenty normal colour vision observers performed colour matching in the experiment. In total, 820 matches were accumulated. The result shows present CAM16 has an unsatisfactory prediction for the effect, especially in the positive region which means the background is brighter than the target. Two models were established based on the visual data, i.e., with and without modification to the lightness difference in CAM16 space. Both of the models predict the effect with high accuracy and reliability.

SESSION II: PERCEPTION

Session Chairs: Javier Vázquez Corral, Universitat Pompeu Fabra (Spain), and Hannah Smithson, Oxford University (UK)

11:40 - 13:10 (LONDON) / 18:40 - 20:10 (BEIJING)

11:40 (London) / 18:40 (Beijing)

Objects in real three-dimensional environments receive illumination from all directions, characterized in computer graphics by an environmental illumination map. The spectral content of this illumination can vary widely with direction, which means that the computational task of recovering surface color under environmental illumination cannot be reduced to correction for a single illuminant. We report the performance of human observers in selecting a target surface color from three distractors, one rendered under the same environmental illumination as the target, and two rendered under a different environmental illumination. Surface colors were selected such that, in the vast majority of trials, observers could identify the environment that contained non-identical surface colors, and color constancy performance was analyzed as the percentage of correct choices between the remaining two surfaces. The target and distractor objects were either matte or glossy and presented either with surrounding context or in a dark void. Mean performance ranged from 70% to 80%. There was a significant improvement in the presence of context, but no difference for matte and glossy stimuli, and no interaction between gloss and context. Analysis of trial-by-trial responses showed a dependence on the statistical properties of previously viewed images. Such analyses provide a means of investigating mechanisms that depend on environmental features, and not only on the properties of the instantaneous proximal image.

12:10 (London) / 19:10 (Beijing)

Chromatic adaptation considering competing influences from emissive displays and ambient illumination is a little studied topic in the context of color management in proportion to its influence on displayed image appearance. An experiment was conducted to identify the degree to which observers adapt to the white point of natural images on an emissive display versus the color of ambient illumination in the room. The responses of observers had no significant difference from those of a previous experiment which was conducted with roughly the same procedure and conditions on a mobile display with a significantly smaller viewing angle. A model is proposed to predict the degree of adaptation values reported by observers. This model has a form such that it can be re-optimized to fit additional data sets for different viewing scenarios and can be used in conjunction with a number of chromatic adaptation transforms.

12:30 (London) / 19:30 (Beijing)

Contrast Sensitivity Functions for HDR Displays, *Minjung Kim[1], Maliha Ashraf[2], Maria Perez-Ortiz[1,3], Jasna Martinovic[4], Sophie Wuerger[2], and Rafal Mantiuk[1] ; [1]University of Cambridge, [2]University of Liverpool, [3]University College London, and [4]University of Aberdeen (UK)* **44**

Contrast sensitivity functions (CSFs) characterize the sensitivity of the human visual system at different spatial frequencies. However, little is known about CSFs at luminances above 1000 nits, especially for color. Here, we measured contrast sensitivities at background luminances from 0.02cd/m^2 to 7000cd/m^2 and for three color directions (black-white or achromatic, red-green, and yellow-violet). Stimuli were Gabor patches of various spatial frequencies (0.125 to 6 cpd), displayed on a high dynamic range display (peak luminance: 15000cd/m^2). We found that achromatic contrast sensitivity has an inverted U-shape as a function of background luminance, with peak sensitivity at 200cd/m^2, while red-green and yellow-violet contrast sensitivities were monotonic functions of background luminance, saturating at 200cd/m^2. Based on these measurements, we developed a model that predicts contrast sensitivity for the average observer. This model is intended for applications in high dynamic range imaging.

12:50 (London) / 19:50 (Beijing)

Fast Chromatic Adaptation Transform Utilizing Wpt (Waypoint) based Spectral Reconstruction, *Maxim Derhak, Onyx Graphics Inc. (US); Eric Lin Luo, OmniVision Technologies, Inc. (US); and Phillip Green, Norwegian University of Science and Technology (Norway)*. **49**

Burns previously showed that a chromatic adaptation transform (CAT) implemented using spectral reconstruction with lightness preserving produces comparable predictive results of corresponding color data sets as optimized linear CATs. A fast spectral reconstruction CAT based on Wpt (Waypoint) spectral reconstruction is proposed that is optimized to take advantage of spectral reconstruction improvements without incurring the performance cost of using spectral reflectance. Comparisons are made, and an implementation using iccMAX profiles is demonstrated.

TWO-MINUTE INTERACTIVE PAPER (POSTER) PREVIEWS II AND INTERACTIVE SESSION II

Session Chair: Sophie Triantaphillidou, University of Westminster (UK)

13:10 - 14:00 (LONDON) / 20:10 - 21:00 (BEIJING)

Interactive (Poster) Paper authors provide a brief overview of their work, followed by talks with authors in individual Zoom rooms. Posters may also be visited via Perusall (see directions within the conference portal) at any time.

Physics-based Modeling of a Light Booth to Improve Color Accuracy of 3D Rendering, *Khalil Huraibat and Esther Perales, Universidad de Alicante (Spain); Alejandro Ferrero and Joaquín Campos, Instituto de Óptica (Spain); and Ivo van der Lans and Eric Kirchner, AkzoNobel (the Netherlands)*. **54**

Computer Aided Design (CAD) is increasingly used as a tool in industries varying from automotive to interior design. Digital visualization allows users to design their working and living spaces, and to select materials and colors for future products.

The rendering software that is currently available often suggests photorealistic quality. However, visual comparisons of these images with the physical objects they represent reveal that the color accuracy of these methods is not good enough for critical applications such as automotive design.

Therefore, we recently developed a spectral pipeline for rendering gonio-apparent materials such as effect coatings. In order to accurately render objects as they appear in a physical environment, this new approach requires a physics-based representation of the illumination surrounding the objects. In the present article we investigate how to physically represent one, well-defined lighting environment.

Therefore, we investigated the lighting inside a recent, commercially available light booth that is widely used in the paint and graphical industry. We determined the spatial dimensions of the X-Rite SpectraLight QC light booth, and built a digital geometrical model of this light booth in the Open Source software Blender. We then measured the spectral radiance emitted by the various light sources that are integrated in the luminaire of this light booth, as well as the illuminance on a grid of measurement spots on the platform below the luminaire. Using these measurement data, we were able to develop an accurate physical simulation of the light field inside the light booth.

We plan to use the physics-based model of the lighting inside the light booth to set up visual tests in which physical objects inside the physical light booth are visually compared to images showing virtual objects inside the virtual light booth. These visual tests will form the basis for developing improved models for displaying the color and texture of gonio-apparent materials.

Evaluation of the Human Visual System in Cosmetics Foundation Colour Selection, *Altynay Kadyrova and Majid Ansari-Asl, Norwegian University of Science and Technology (Norway); and Eva M. Valero Benito, University of Granada (Spain)* **60**

Colour is one of the most important appearance attributes in a variety of fields including both science and industry. The focus of this work is on cosmetics field and specifically on the performance of the human visual system on the selection of foundation makeup colour that best matches with the human skin colour. In many cases, colour evaluations tend to be subjective and vary from person to person thereby producing challenging problems to quantify colour for objective evaluations and measurements. Although many researches have been done on colour quantification in last few decades, to the best of our knowledge, this is the first study to evaluate objectively a consumer's visual system in skin colour matching through a psychophysical experiment under different illuminations exploiting spectral measurements.

In this paper, the experiment setup is discussed and the results from the experiment are presented. The correlation between observers' skin colour evaluations by using PANTONE Skin Tone Guide samples and spectroradiometer is assessed. Moreover, inter and intra observer variability are considered and commented.

The results reveal differences between nine ethnic groups, between two genders, and between the measurements under two illuminants (i.e. D65 and F (fluorescent)). The results further show that skin colour assessment was done better under D65 than under F illuminant. The human visual system was three times worse than instrument in colour matching in terms of colour difference between skin and PANTONE Skin Tone Guide samples. The observers tend to choose lighter, less reddish, and consequently paler colours as the best match to their skin colour. These results have practical applications. They can be used to design, for example, an application for foundation colour selection based on correlation between colour measurements and human visual system based subjective evaluations.

Linear Histogram Adjustment for Image Enhancement, *Jake McVey, University of East Anglia (UK)*. **65**

Tone curves are one of the simplest techniques for image enhancement. Specified as a function, a tone curve is a transformation that maps pixel levels of an input image to new output levels. Tone curves are the basis of many contrast enhancement algorithms, including Contrast Limited Histogram Equalisation (CLHE), which derives a tone curve from a modification of the image histogram. While these methods can provide good enhancement, they are generally non-linear.

In this paper we show the surprising result that a tone curve generated by the non-linear CLHE method (and HE) can be calculated by applying a linear transform to the histogram of the input image. Experiments validate our method.

Solar Limb Darkening Color Imaging of the Sun with the Extreme Brightness Capability CAOS Camera, *Nabeel A. Riza, Mohsin A. Mazhar, and Nazim Ashraf, University College Cork (Ireland)*. **69**

Experimentally demonstrated for the first time is Coded Access Optical Sensor (CAOS) camera-based imaging of the Sun. Only by using both the shortest 0.029 ms integration time of the scientific CMOS sensor and a very large factor of 10,000 optical attenuation at the entrance of the CMOS camera, one is able to produce the desired unsaturated image of the Sun. In sharp contrast, a small factor of 3.2 optical attenuation is required over a much smaller single photo-detector zone of the CAOS camera to capture the unsaturated Sun image, including color images obtained using red, green, and blue filters. Image data processing shows that both the CMOS camera and CAOS camera show similar Sun limb darkening measurements consistent with prior-art works. The CAOS camera empowers optically and operationally efficient full spectrum (e.g., 350 nm to 2700 nm) imaging of bright heavenly bodies in space, with the potential for creating impact for solar energy farms, space navigation, space exploration, and astronomical science.

SESSION III: VISIBILITY

Session Chairs: Javier Vázquez Corral, Universitat Pompeu Fabra (Spain), and Jon Hardeberg, NTNU (Norway)

14:00 - 15:30 (LONDON) / 21:00 - 22:30 (BEIJING)

14:00 (London) / 21:00 (Beijing)

FOCAL TALK Imaging the Visible Beyond RGB, *Jon Hardeberg, Norwegian University of Science and Technology (Norway)* *****

Colour imaging is now an established and mature field of research and development. Digital RGB imaging devices and systems have been proven successful for a multitude of applications, including but not limited to consumer applications (digital photography), cultural heritage, medical, industrial process control, and automotive. Recently, computational approaches including deep learning has taken performances to new levels, nevertheless many challenges remain.

Even without venturing into non-visible imaging modalities such as infrared, thermal, ultrasound, and x-ray imaging, we see much promise for further developments in imaging of the visible world beyond the conventional RGB domain. In this presentation we introduce and discuss current research challenges and opportunities within the fields of spectral imaging and material appearance.

14:30 (London) / 21:30 (Beijing)

Single Image Dehazing by Predicting Atmospheric Scattering Parameters, *Simone Bianco, Luigi Celona, and Flavio Piccoli, University of Milano – Bicocca (Italy)* **74**

In this work we propose a method for single image dehazing that exploits a physical model to recover the haze-free image by estimating the atmospheric scattering parameters. Cycle consistency is used to further improve the reconstruction quality of local structures and objects in the scene as well. Experimental results on four real and synthetic hazy image datasets show the effectiveness of the proposed method in terms of two commonly used full-reference image quality metrics.

14:50 (London) / 21:50 (Beijing)

CNN-based Rain Reduction in Street View Images, *Simone Zini, Simone Bianco, and Raimondo Schettini, University of Milano – Bicocca (Italy)*. **78**

Rain removal from pictures taken under bad weather conditions is a challenging task that aims to improve the overall quality and visibility of a scene. The enhanced images usually constitute the input for subsequent Computer Vision tasks such as detection and classification. In this paper, we present a Convolutional Neural Network, based on the Pix2Pix model, for rain streaks removal from images, with specific interest in evaluating the results of the processing operation with respect to the Optical Character Recognition (OCR) task. In particular, we present a way to generate a rainy version of the Street View Text Dataset (R-SVTD) for text detection and recognition evaluation in bad weather conditions. Experimental results on this dataset show that our model is able to outperform the state of the art in terms of two commonly used image quality metrics, and that it is capable to improve the performances of an OCR model to detect and recognise text in the wild.

**Abstract only; no proceedings paper.*

15:10 (London) / 22:10 (Beijing)

Illumination-Invariant Image from 4-Channel Images: The Effect of Near-infrared Data in Shadow Removal, *Sorour Mohajerani, Mark Drew, and Parvaneh Saeedi, Simon Fraser University (Canada)*. **82**

Removing the effect of illumination variation in images has been proved to be beneficial in many computer vision applications such as object recognition and semantic segmentation. Although generating illumination-invariant images has been studied in the literature before, it has not been investigated on real 4-channel (4D) data. In this study, we examine the quality of illumination-invariant images generated from red, green, blue, and near-infrared (RGBN) data. Our experiments show that the near-infrared channel substantively contributes toward removing illumination. As shown in our numerical and visual results, the illumination-invariant image obtained by RGBN data is superior compared to that obtained by RGB alone.

15:30-15:45 (LONDON) / 22:30-22:45 (BEIJING) STRETCH BREAK

CONFERENCE KEYNOTE I

Session Chair: Graham Finlayson, University of East Anglia (UK)

15:45 - 16:45 (LONDON) / 22:45 - 23:45 (BEIJING)

Designing Cameras to Detect the "Invisible": Towards Domain-Specific Computational Imaging, *Felix Heide, Princeton University (US)**

Imaging has become an essential part of how we communicate with each other, how autonomous agents sense the world and act independently, and how we research chemical reactions and biological processes. Today's imaging and computer vision systems, however, often fail in the "edge cases'', for example in low light, fog, snow, or highly dynamic scenes. These edge cases are a result of ambiguity present in the scene or signal itself, and ambiguity introduced by imperfect capture systems. This talk presents several examples of computational imaging methods that resolve this ambiguity by jointly designing sensing and computation for domain-specific applications. Instead of relying on intermediate image representations, which are often optimized for human viewing, these cameras are designed end-to-end for a domain-specific task. In particular, the talk shows how to co-design automotive HDR ISPs, detection, and tracking (beating Tesla's latest OTA Model S Autopilot); how to optimize thin freeform lenses for wide field of view applications; and how to extract accurate dense depth from three gated images (beating scanning lidar, such as Velodyne's HDL64). It ends by presenting computational imaging systems that extract domain-specific information from faint measurement noise using domain-specific priors, allowing us to use conventional intensity cameras or conventional Doppler radar to image "hidden" objects outside the direct line of sight at long ranges.

**Abstract only; no proceedings paper.*

THURSDAY, 1 OCTOBER 2020

WELCOME/INTRO REMARKS

Session Chairs: Graham Finlayson, University of East Anglia (UK), and Javier Vázquez Corral, Universitat Pompeu Fabra (Spain)

9:00 - 9:15 (LONDON) / 16:00 - 16:15 (BEIJING)

SESSION IV: IMAGE REPRODUCTION

Session Chairs: Javier Vázquez Corral, Universitat Pompeu Fabra (Spain), and Philipp Urban, Fraunhofer Institute for Computer Graphics Research IGD (Germany)

9:15 - 10:45 (LONDON) / 16:15 - 17:45 (BEIJING)

9:15 (London) / 16:15 (Beijing)

FOCAL TALK Graphical 3D Printing: Challenges, Solutions, and Applications, *Philipp Urban, Fraunhofer Institute for Computer Graphic Research IGD, Norwegian University of Science and Technology NTNU (Germany)*. **87**

Graphical 3D printing is a relatively novel field of 3D printing focusing on reproducing the visual material appearance of an object in addition to its shape. Applications can be found in traditional prototyping, patient-individual surgery planning, fabricating prosthetic eyes, movie and entertainment industry as well as creating replicas in the field of cultural heritage. This paper gives a rough overview on the major challenges as well as solutions in graphical 3D printing focusing on imaging and computational aspects. It also gives an outlook to future research directions and new applications.

9:45 (London) / 16:45 (Beijing)

A Practical Approach on Non-regular Sampling and Universal Demosaicing of Raw Image Sensor Data, *Philipp Backes and Jan Fröhlich, Stuttgart Media University (Germany)*. **91**

Non-regular sampling is a well-known method to avoid aliasing in digital images. However, the vast majority of single sensor cameras use regular organized color filter arrays (CFAs), that require an optical-lowpass filter (OLPF) and sophisticated demosaicing algorithms to suppress sampling errors. In this paper a variety of non-regular sampling patterns are evaluated, and a new universal demosaicing algorithm based on the frequency selective reconstruction is presented. By simulating such sensors it is shown that images acquired with non-regular CFAs and no OLPF can lead to a similar image quality compared to their filtered and regular sampled counterparts. The MATLAB source code and results are available at: http://github.com/PhilippBackes/dFSR

10:05 (London) / 17:05 (Beijing)

Designing a Physically-feasible Colour Filter to Make a Camera more Colorimetric, *Yuteng Zhu, University of East Anglia (UK)*. **96**

Previously, a method has been developed to find the best colour filter for a given camera which results in the new effective camera sensitivities that best meet the Luther condition. That is, the new sensitivities are approximately linearly related to the XYZ colour matching functions. However, with no constraint, the filter derived from this Luther-condition based optimisation can be rather non-smooth and transmit very little light which are impractical for fabrication.

In this paper, we extend the Luther-condition filter optimisation method to allow us to incorporate both the smoothness and transmittance bounds of the recovered filter which are key practical concerns. Experiments demonstrate that we can find physically realisable filters which are smooth and reasonably transmissive with which the effective 'camera+filter' becomes significantly more colorimetric.

10:25 (London) / 17:25 (Beijing)

Colorimetric calibration computes the necessary color space transformation to map a camera's device-specific color space to a device-independent perceptual color space. Color calibration is most commonly performed by imaging a color rendition chart with a fixed number of color patches with known colorimetric values (e.g., CIE XYZ values). The color space transformation is estimated based on the correspondences between the camera's image and the chart's colors. We present a new approach to colorimetric calibration that does not require explicit color correspondences. Our approach computes a color space transformation by aligning the color distributions of the captured image to the known distribution of a calibration chart containing thousands of colors. We show that a histogram-based colorimetric calibration approach provides results that are on-par with the traditional patch-based method without the need to establish correspondences.

TWO-MINUTE INTERACTIVE PAPER (POSTER) PREVIEWS III AND INTERACTIVE SESSION III

Session Chair: Vien Cheung, University of Leeds (UK)

10:45 - 11:50 (LONDON) / 17:45 - 18:50 (BEIJING)

Interactive (Poster) Paper authors provide a brief overview of their work, followed by talks with authors in individual Zoom rooms. Posters may also be visited via Perusall (see directions within the conference portal) at any time.

Vision is the science that informs us about the biological and evolutionary algorithms that our eyes, optic-nerves and brains have chosen over time to see. This article is an attempt to solve the problem of colour to grey conversion, by borrowing ideas from vision science. We introduce an algorithm that measures contrast along the opponent colour directions and use the results to combine a three dimensional colour space into a grey. The results indicate that the proposed algorithm competes with the state of art algorithms.

Stained-glass windows are very particular artifacts; they not only have an intrinsic artistic and historical meanings, but also a functional role, strictly connected to the buildings where they were originally placed. The investigation of these artifacts is a challenging research opportunity, due to their optical, chemical, and physical characteristics. However, these properties could change with time, depending on the raw materials used, or due to exposure in a very aggressive environment. For this reason, developing imaging techniques that could both digitize and document the morphological/chemical changes of these object, would solve two important issues: first, it would be possible to obtain a digital model of the object, ensuring the preservation of the objects for the future; second, it would be possible to get information on the materials employed, the ways they change with time, and how these changes modify the final appearance of the artwork. In this paper, a proposal for a more systematic application of spectral imaging to stained glass is presented, discussing challenges and potentials of the technique.

A lot of image processing tasks requires key-point detection. If grey-level approach are numerous, colour and hyper-spectral ones are scarce. In this paper, we propose a generic key-point detection for colour, multi and hyper-spectral images. A new synthetic database is created to compare key-point detection approaches. Our method improves detection when the image complexity increases.

This paper implements an appearance rendering workflow using the iccMAX architecture with the aim of reproducing the directional appearance of surface colours on a display. In previous work, the prints were measured bidirectionally using an image-based measurement setup, and the bidirectional reflectance distribution function of the materials was estimated using the well-established Ward reflectance model. This function was applied in a colour managed workflow using the ICC.2 architecture to render the appearance of the prints on a display. The seven used as samples to the renderings.

The purpose of this article is to review the fabrication process of physical patient simulators for surgical training and describes current research areas.

Medical image acquisition and analysis are tools to reproduce human anatomy in 3D models. Data acquisition techniques include CT scans, MRI, and ultrasound. Postprocessing of this data is necessary to obtain a file for 3D printing.

Two available fabrication methods are direct 3D printing of an organ model and 3D printing a mould to cast an organ replica. Direct 3D printing presents several limitations. Therefore, casting techniques with silicones and hydrogels are better suited for the fabrication of softer tissue models.

Surgeons qualitatively evaluate the simulators and their ability to train students. It is also possible to make a quantitative evaluation to compare the properties of the simulators to the physical properties of organs. Different methods exist to measure the physical properties of soft tissues, mainly to find the Young modulus of the soft tissue. The tests can be *in vivo*, *in situ* or *in vitro*. Researchers perform tests on human tissues or animal tissues.

The use of surgical simulators has shown satisfactory results in surgical training. Nonetheless, limitations remain, simulators lack realism and are not available for some pathologies. Future work in this area could be of benefit to surgical training.

SESSION V: COMPUTER VISION

Session Chairs: Javier Vázquez Corral, Universitat Pompeu Fabra (Spain), and Raimondo Schettini, University of Milano-Bicocca (Italy)

11:50 - 13:20 (LONDON) / 18:50 - 20:20 (BEIJING)

11:50 (London) / 18:50 (Beijing)

Convolutional neural networks (CNNs) are used in an increasingly systematic way in a great variety of computer vision applications, including image quality assessment. However, their application to evaluate the perceived quality of images is strongly limited by the lack of adequate and consistent training data. A CNN-based framework for evaluating image quality of consumer photographs is made up of several building blocks that can be implemented in different ways. In this article, we schematically illustrate how these building blocks have been implemented and combined so far to create feasible solutions that take the most positive characteristics of CNNs while mitigating their intrinsic limitations. Some experimental results are reported to show the effectiveness of CNN-based solutions on real-world image quality datasets

12:20 (London) / 19:20 (Beijing)

Spectral recovery from measured camera signals based on deep learning lead to significant advancements of the potential reconstruction quality. However, most deep learning based approaches only consider RGB cameras and are targeting object classification in particular or remote sensing in general as their final application.

Within this work, we analyze the influence of a joint filter optimization and spectral recovery for multi-spectral image acquisition with the underlying goal of capturing high-fidelity color images. An evaluation on the influence of the total camera channel count on the reproduction quality is provided. Finally, a possible normalization of spectral data is discussed.

12:40 (London) / 19:40 (Beijing)

We present a method to estimate the direction and color of a scene light source from a single image. Our method is based on two main ideas: (a) we use a new synthetic dataset with strong shadow effects with similar constraints to SID dataset; (b) we define a deep architecture trained on the mentioned dataset to estimate direction and color of the scene light source. Apart from showing a good performance on synthetic images, we additionally propose a preliminary procedure to obtain light positions of the Multi-Illumination dataset, and, in this way, we also prove that our trained model achieves a good performance when it is applied to real scenes.

13:00 (London) / 20:00 (Beijing)

Spectral reconstruction (SR) aims to recover high resolution spectra from RGB images. Recent developments - leading by Convolutional Neural Networks (CNN) - can already solve this problem with low errors. However, those leading methods do not explicitly ensure the predicted spectra will re-integrate (with the underlying camera response functions) into the same RGB colours as the ones they are recovered from, namely the 'colour fidelity' problem. The purpose of this paper is to show, visually and quantitatively, how well (or bad) the existing SR models maintain colour fidelity. Three main approaches are evaluated - regression, sparse coding and CNN. Furthermore, aiming for a more realistic setting, the evaluations are done on real RGB images and the 'end-of-pipe' images (i.e. rendered images shown to the end users) are provided for visual comparisons. It is shown that the state-of-the-art CNN-based model, despite of the superior performance in spectral recovery, introduces significant colour shifts in the final images. Interestingly, the leading sparse coding and the simple linear regression model, both of which are based on linear mapping, best preserve the colour fidelity in SR.

TWO-MINUTE WORK-IN-PROGRESS POSTER PREVIEWS AND VIEWING SESSION

Session Chair: Vien Cheung, University of Leeds (UK)

13:20 - 14:20 (LONDON) / 20:20 - 21:20 (BEIJING)

Work in Progress Poster presenters provide a brief overview of their work, followed by talks with them in individual Zoom rooms. Posters may also be visited via Perusall (see directions within the conference portal) at any time. PLEASE NOTE: There are only abstracts associated with these posters, not papers.

Adversarially Constrained Camera Model Anonymisation,
Jerone Andrews, Yidan Zhang, and Lewis Griffin, University College London (UK)

Photographic images can be attributed to the specific camera model used for capture by inferring model-specific artefacts based on the noise-like photo-response nonuniformity (PRNU). PRNU is caused by slight stochastic variations in the sensitivity of individual pixel sensors, however when estimated from images in viewable formats it encodes systematic details of model-specific artefacts such as colour interpolation, on-sensor signal transfer, sensor design, and compression.

Consequently, model anonymisation methods have focused on attenuating or misaligning this fingerprint. However, a principal issue with such approaches is the detectable absence of model-specific artefacts within the anonymised images. In contrast, we focus on transforming the underlying model-specific artefacts of images such that their apparent capture model is changed.

Through conditional generative adversarial nets, we present an approach for learning these transformations. Our objective contains three types of terms: an adversarial loss for matching the distribution of transformed images to the conditional data distribution; a content loss to incentivise the preservation of image content; and negative log-likelihood losses from pre-trained model attribution classifiers to further constrain the transformation process to synthesise the necessary discriminative artefacts of the target camera model.

Since artefacts related to acquisition processes are contained in the image micro-patterns and not the image content, previous anonymisation approaches suppress the latter when estimating the PRNU. However, the estimation process is not an absolute operation, and not all artefacts are of a high-frequency nature (e.g. vignetting). Unlike previous anonymisation works, we constrain the generative network to not only synthesise salient high-frequency PRNU-based artefacts, but also image-based artefacts lost during PRNU estimation.

We successfully perform anonymisation on images derived from the Dresden database of natural images, achieving on average a targeted anonymisation success rate of 94%.Furthermore, through an ablation analysis, we demonstrate that anonymisation necessitates the transformation of both low- and high-frequency artefacts.

Acknowledgements: JTAA is supported by the Royal Academy of Engineering (RAEng) and the Office of the Chief Science Adviser for National Security under the UK Intelligence Community Postdoctoral Fellowship Programme; and acknowledges further research funding from the European Union's Horizon2020 research and innovation programme under the Marie Skłodows-Curie ENCASE project, Grant Agreement No.691025.

NOTE: This work was published in Andrews, J. T. A., Zhang, Y, and Griffin, L. D., Conditional Adversarial Camera Model Anonymization, Proc. European Conf. Computer Vision (ECCV), 2020, arXiv:2002.07798v2

A Color Preserving Chroma Processing Technique for HDR Video Compression, *Maryam Azimi, University of Cambridge (UK)*

To represent High Dynamic Range (HDR) and Wide Color Gamut (WCG) color pixels for video compression, several color spaces and encodings have been proposed. What all these color encodings have in common is their common separation of color into luma and chroma components. In this work, we evaluate these luma/chroma color encodings namely Y'CbCr, ICTCP, Jzazbzand Yu'v' in terms of how well they preserve the HDR and WCG colors after bit-depth quantization. To evaluate that, we employ CIE DE2000 as a color difference metric. Sampling colors from BT.2020 RGB, we transform them to the luma/chroma color encodings followed by 10-bit quantization (current standard HDR video compression). The results show that ICTCP outperforms the other color encodings in preserving color information in terms of DE2000. Yet, colors around the white point (WP) at higher luminance levels are represented with visible errors (DE2000 > 1) even using ICTCP. To further understand the distribution of color errors in ICTCP, we reduce the quantization bit-depth of the chroma channels to 9 and observe that while more colors are represented with visible errors in terms of DE2000, they are concentrated around the WP and the colors at the border of gamut are still represented with no visible differences. Based on these findings, a re-distribution function is proposed for ICTCP such that more codewords are allocated to the colors around the WP while fewer codewords are allocated to the colors at the gamut border. We evaluate the proposed chroma transfer function by applying it on real video sequences after ICTCP transformation, then compressing them using High Efficiency Video Coding (HEVC) standard and assessing the compressed videos objectively and subjectively. These performance evaluations show that the proposed scheme works well with compression resulting in comparable performance to the original ICTCP while preserving colors through quantization.

Novel Metrics for the Calibration and Characterization of a Multi-primary High Dynamic Range Display, *Allie Hexle[1], Takuma Morimoto[1], Manuel Spitschan[1], Rafal Mantiuk[2], and Hannah Smithson[1]; [1]University of Oxford and [2]University of Cambridge (UK)*

In previous work we demonstrate a novel multi-primary high dynamic range (MPHDR) display (Hexley et al., 2020, *JOSA A*, in prep.) that is suitable for photoreceptor isolating vision experiments via the method of silent substitution (Spitschan & Woelders, 2018 *Front. Neurol.* 9 941). The MPHDR display system allows the delivery of spatially controllable, high-dynamic range, multiple primary stimuli. To achieve an HDR configuration a DLP projector is used to replace the static backlight of an LCD monitor such that the backlight is dynamically controlled (Seetzen et al., 2004, *ACM Trans. Graph* 3 760-768). The MPHDR can be thought of as two HDR configurations stacked on top of each other. Through the placement of spectrally-selective filters in front of each DLP aperture, we can extend the number of primaries available in the display system. In our case, filters were chosen to produce maximum melanopsin contrast in photoreceptor isolating conditions. There are many methods for characterising the colour gamut of displays, but these methods are typically based on the signals from the three classes of cone photoreceptoror tranformations thereof. Here, we discuss possible frameworks for considering the gamut with reference to signals from all five photoreceptor classes (L, M, and S cones, rods, and melanopsin) in the human visual system. We also discuss new metrics for characterizing the maximum luminance output of the MPHDR display as the signal from the display is heavily viewpoint dependent due to the differences in the "sweet spots" of the two HDR configurations that constitute the display. We discuss how one may characterize the optimal viewpoint and the viewpoint tolerance of the display. Our primary contribution is the optimisation of display technologies for vision science experiments, which has demanded the development of novel metrics.

Online versus Offline Colour Naming Experiments, *Dimitris Mylonas, Lewis D. Griffin, and Andrew Stockman, University College London (UK)* . . . . **Appendix, page xii**

Online colour naming experiments are often criticised for the uncalibrated colour reproduction of different displays and the uncontrolled viewing environment. In contrast, laboratory-based (offline) experiments are criticised for not reproducing "real-world" monitor settings. In this study, we compare the performance of online and offline colour naming experiments in estimating colour naming functions.

Spectroradiometric Measurements of the Reflectance of the Human Sclera *In Vivo*, *Miranda Nixon, Felix Outlaw, Lindsay W. MacDonald, and Terence S. Leung, University College London (UK)* . . . . **Appendix, page xiii**

The color of the human sclera, or white of the eye, is known to be largely stable amongst healthy people. However, there is a dependence on age, and the color is also strongly affected by jaundice, caused by elevated bilirubin levels associated with, for example, pancreatic cancer. A contact measurement using a spectrophotometer is clearly not appropriate, whereas a conventional camera cannot provide spectral information. Use of a spectroradiometer provides an attractive alternative, with the ability to obtain spectral reflectance of the sclera from a distance.

Measurements are obtained under filtered tungsten light, which provides a continuous spectrum across the visible range, with no ambient light. The subject's head is stabilized using a head and chin rest, and he/she is directed to look to the side in order to expose a large scleral region. APR-650SpectraScan measurement (4nm intervals over range 380-780nm) is then taken with the measuring spot located over a purely scleral region. Care is required to avoid including any non-sclera data such as iris, eyelid or specular reflection from the light sources. Immediately after the scleral measurement, a second measurement is obtained using a white tile positioned directly in front of the eye. Division of the sclera measurement data by this white measurement data provides the scleral reflectance factor.

We present the first known *in vivo* reflectance measurements of the human sclera, and have carried out preliminary work investigating differences between healthy individuals. Interestingly, a strong haemoglobin signature is observed in the data, owing to the presence of small blood vessels on the sclera. Current work is focused on gathering data from a volunteer cohort to investigate the effect of age on scleral color, as well as a separate study with a patient cohort to look at the influence of bilirubin on the reflectance spectrum.

Discrimination of Temporal Illumination Changes, *Ruben Pastilha, Gaurav Gupta, Naomi Gross, and Anya Hurlbert, Newcastle University (UK)* *
We have been interested in the temporal dynamics and speed limits of illumination change perception. However, relatively little is known about human sensitivity to changes in illumination spectra over time, partly because illumination changes are usually represented as simplified stimuli with non-natural abrupt changes, and the few studies using naturalistic changes without discontinuities (e.g. Kong et al., 2019; Linnell & Foster, 1996) are not specifically concerned with measuring perceptual sensitivity to these. From an ecological standpoint, non-abrupt changes are more relevant, because of their ubiquity in the natural environments where primate vision evolved. In addition, the temporal dynamics of illumination perception have become especially relevant today, because of the rising technological development of dynamic lighting, and further study is needed.

Previously, we have shown that discrimination of abrupt discontinuous changes in illumination chromaticity depends on the chromaticity of the reference (adapting) illumination; for more extreme chromaticities, changes towards neutral chromaticities are less easily discriminated than changes away from neutral (Aston et al., 2019).

Here we describe new psychophysical measurements of discrimination of smooth temporal changes in illumination spectra using a spectrally tuneable light system in a naturalistic immersive environment. For 22 participants, the minimum detectable speed of chromaticity change is on average about 20 times larger than the fastest changes usually occurring in natural daylight. In addition, we found that changes in illumination chromaticity towards a neutral reference are hardest to detect, for non-neutral adaptation lights. These results are consistent with our previous findings for abrupt stimuli (Aston et al., 2019) and support the notion that the brain encodes a neutral-daylight illumination prior. Extensions of the paradigm to other illumination conditions and contexts are currently underway.

Acknowledgement: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 765121.

Development of a Large Gamut Equalization Experiment Setup, *Emilie Robert[1], Magali Estribeau[1], Rémi Barbier[1], Greggory Swiathy[2], Justin Plantier[3], and Pierre Magnan[1]; [1]ISAE SUPAERO, [2]DGA TA, and [3]IRBA (France)* . . . . **Appendix, page xiv**
Characterizition of human color vision allow the development of individual imaging systems or conversely imaging systems that presents the same colors to anyone. Although the colorimetry is now a day driven by CIE's standard observers Color Matching Functions (CMFs) [1], this work aims to get individual CMFs from the developed equalization experiment. This setup provides an extremely large interchangeable gamut compared to what is commonly seen in the literature.

Thin Film Structures for Colour-shift Effects, *Riley Shurvinton, Antonin Moreau, Fabien Lemarchand, and Julien Lumeau, Institut Fresnel (France)* *
The colour of an object greatly influences its impact upon the viewer. The control of surface colour is therefore of great interest in many applications, from the design of everyday objects to eye-catching and moving pieces of art, to precision applications such as security features.

Most reproductions of colour rely on pigments. However, thin-film coatings present an alternative and highly versatile method of generating colour. Coatings made of precisely controlled nanometer-thick layers of dielectric or metallic materials can create bright, attractive colours difficult or impossible to achieve with pigments, while using easily obtained and well-studied materials such as silicon dioxide.

As the colour is created via interference, the appearance of these thin-film coatings typically displays a strong angular dependence, with a visible colour shift between normal and oblique incidence. Much current research in the field of thin-film coatings seeks to suppress this colour shift effect to create angular-invariant coatings. However, the colour shift characteristic exhibited by these coatings is a unique property of thin films that could provide novel effects if controlled.

We present our progress on the development of colour-controlled multilayer structures. These structures combine metallic layers (e.g. copper, aluminium, titanium...) and dielectric layers (e.g. silica). Using 3 or 4 layers is enough to produce, at normal incidence, any colour within the visible range. This colour can then be easily changed and controlled by tilting the surface with respect to illuminating light. Several such structures were designed using a MATLAB script by constructing the characteristic matrices of each layer and multiplying them to obtain the stack. The layer thicknesses were iteratively optimized to give the desired colour shift. These coatings were then fabricated using an e-beam deposition machine. These coatings present an experimental demonstration of the possible effects that can be achieved both on glass substrates and non-optical surfaces.

Spatial and Angular Variations of Colour Rendition due to Inter-reflections, *Cehao Yu and Sylvia Pont, Delft University of Technology (the Netherlands)* . . . . **Appendix, page xv**
The effective illuminance in a real-world scene is a geometrically weighted sum of direct and indirect components, and varies spatially and directionally, which is captured by the so-called light field. The spectral power distribution (SPD) of the indirect illuminance is dependent on that of the direct illuminance and the surface spectral reflectance (SSR) of the scene materials. The SPD of the indirect illuminance was derived to show systematic brightness, saturation and hue shifts due to inter-reflections. Differences between the spectral shapes of the direct and indirect illuminance induce colour rendition variations over the light fields, which we here investigate for uni-chromatic spaces.

CONFERENCE KEYNOTE II

Session Chair: Graham Finlayson, University of East Anglia (UK)
14:20 - 15:20 (LONDON) / 21:20 - 22:20 (BEIJING)

Surface Color Perception in Realistic Scenes: Previews of a Future Color Science, *Laurence Maloney, New York University (US)* *
Research in the past two decades has shown that surface color perception in natural scenes is profoundly connected with perception of the spatial layout of the scene. This talk describes the spatial information human observers get from scenes that affects their perception of surface color and material and what it would mean to match human performance.

CLOSING REMARKS

Session Chairs: Graham Finlayson, University of East Anglia (UK), and Javier Vázquez Corral, Universitat Pompeu Fabra (Spain)
15:20 - 15:30 (LONDON) / 22:20 - 22:30 (BEIJING)

**Abstract only; no proceedings paper.*

LIM 2020 APPENDIX: WORK-IN-PROGRESS

The Appendix contains the full submission for the some of the Work-in-Progress posters, as noted in the Program/Table of Contents.
Those not found here consisted solely of the abstract found in the Program/Table of Contents.

WORK-IN-PROGRESS ABSTRACT

Online versus Offline Colour Naming Experiments

Dimitris Mylonas[1,2], Lewis D. Griffin[1], Andrew Stockman[2]

[1]Dept. Computer Science, [2]Institute of Ophthalmology, University College London

Introduction

Online colour naming experiments are often criticised for the necessarily uncalibrated colour reproduction of different displays and the uncontrolled viewing environment. In contrast, laboratory-based (offline) experiments are criticised for not reproducing “real-world” monitor settings. In this study, we compare the performance of online and offline colour naming experiments in estimating colour naming functions.

Methods

Test stimuli subtended approximately 2 degrees of visual diameter and were presented against a neutral grey background. The set of stimuli comprised 589 simulated samples from the Munsell Renotation Dataset plus 11 achromatic samples (Mylonas & MacDonald, 2010). In the online experiment, 447 English observers provided 7405 responses and each observer named only 3.3% of the stimuli. In the offline experiment, 10 English observers offered 4812 responses but each observer named all 600 stimuli. In both experiments, we considered only those distinct responses given by two or more observers with normal colour vision (Mylonas, PhD Thesis, 2019).

Results

We found a good correspondence between the paired centroids of the 11 Basic Colour Terms (BCTs; Berlin & Kay, 1969) in the online and offline experiments with a mean $\Delta E_{00} = 4.58$, $SD = 2.83$. The mean colour difference between BCTs among individuals in the offline experiment was $\Delta E_{00} = 7.91$, $SD = 3.22$. There was a significant effect in inter-experimental differences and intra-experimental differences of the offline experiment $t(10) = 2.58$, $p > 0.02$.

Conclusions

Our findings suggest that online and offline experimental methodologies produce consistent results and support the validity of both methods in estimating colour naming functions in laboratory and real-world monitor settings. The inter-experimental variability between online and offline experiments is significantly lower than intra-experimental variability among individuals in the offline experiment.

Acknowledgements

This study was funded by the Engineering and Physical Sciences Research Council (UK), Grant/Award Number: EP/M506448/1-1573073.

WORK-IN-PROGRESS ABSTRACT

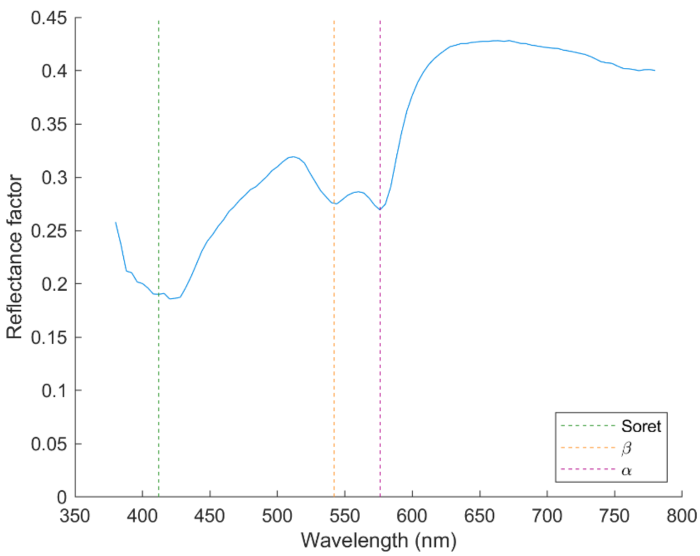
Spectroradiometric measurements of the reflectance of the human sclera *in vivo*

Miranda Nixon [1], Felix Outlaw [1], Lindsay W. MacDonald [2], Terence S. Leung [1]
[1]Department of Medical Physics and Biomedical Engineering, University College London, UK;
[2]Department of Civil, Environmental & Geomatic Engineering, University College London, UK

The color of the human sclera, or white of the eye, is known to be largely stable amongst healthy people. However, there is a dependence on age, and the color is also strongly affected by jaundice, caused by elevated bilirubin levels associated with, for example, pancreatic cancer. A contact measurement using a spectrophotometer is clearly not appropriate, whereas a conventional camera cannot provide spectral information. Use of a spectroradiometer provides an attractive alternative, with the ability to obtain spectral reflectance of the sclera from a distance.

Measurements are obtained under filtered tungsten light, which provides a continuous spectrum across the visible range, with no ambient light. The subject's head is stabilized using a head and chin rest, and he/she is directed to look to the side in order to expose a large scleral region. A PR-650 SpectraScan measurement (4nm intervals over range 380-780nm) is then taken with the measuring spot located over a purely scleral region. Care is required to avoid including any non-sclera data such as iris, eyelid or specular reflection from the light sources. Immediately after the scleral measurement, a second measurement is obtained using a white tile positioned directly in front of the eye. Division of the sclera measurement data by this white measurement data provides the scleral reflectance factor.

We present the first known *in vivo* reflectance measurements of the human sclera, and have carried out preliminary work investigating differences between healthy individuals. Interestingly, a strong haemoglobin signature is observed in the data, owing to the presence of small blood vessels on the sclera. Current work is focused on gathering data from a volunteer cohort to investigate the effect of age on scleral color, as well as a separate study with a patient cohort to look at the influence of bilirubin on the reflectance spectrum.



Supporting figure: A reflectance spectrum measured for a healthy human volunteer. Wavelengths of oxygenated haemoglobin features have been marked using dashed lines.

WORK-IN-PROGRESS ABSTRACT

Development of a large gamut equalization experiment setup

Emilie Robert[1,*], Magali Estribeau[1], Rémi Barbier[1], Greggory Swiathy[2], Justin Plantier[3], and Pierre Magnan[1]

[1]Institut Supérieur de l'Aéronautique et de l'Espace, Toulouse, France
[2]Direction Générale de l'Armement - Techniques Aéronautiques, Balma, France
[3]Institut de Recherche Biomédicale des Armées, Brétigny sur Orge,France
[*]Correspondance : emilie.robert@isae-supaero.fr

Introduction

Characterizition of human color vision allow the development of individual imaging systems or conversely imaging systems that presents the same colors to anyone. Although the colorimetry is nowaday driven by CIE's standard observers Color Matching Functions (CMFs) [1], this work aims to get individual CMFs from the developed equalization experiment. This setup provides an extremely large interchangeable gamut compared to what is commonly seen in the litterature.

Method

The four light sources used for the setup are Quartz Tungsten Halogen (QTH) lamps of 100W. The variations of each of the three primaries are made through a doublet of linear/Glan – Thompson polarizers. The stimuli are created by the addition of interferometric filters in front of the reference lamp through two rotating wheels. The size of the output field is controlled by a diaphragm inserted in the optical path of the projection channel, making the results comparable with 10degrees and 2degrees CIE standards. The participant mixes the RGB primaries through three corresponding cursors allowing the rotation of the GT polarizers independently. This setup provides an extremely large interchangeable gamut compared to what is commonly seen in the litterature. The primaries can be replaced for each part of the chromaticity diagram to be investigated. Fig. 1 gives an example of the large achievable gamut with primaries at 440nm, 520nm and 620nm. Accordingly, stimuli presentation system allow any filter to be proposed for equalization.

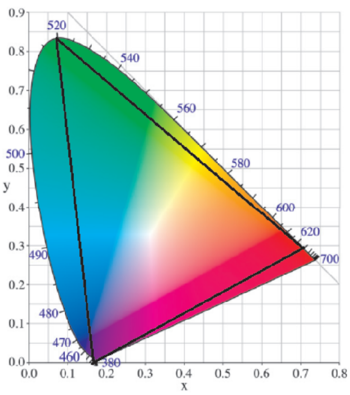


FIGURE 1: On this chromaticity diagram is represented the large gamut (black triangle) of our equalization experiment. Due to interchangeable primaries, this gamut is variable allowing the investigation of different parts of the chromaticity diagram.

Results

The relative quantities R, G and B of each of the primaries and their radiometric spectrums $S_R(\lambda)$, $S_G(\lambda)$ and $S_B(\lambda)$ measured with the CS-1000 KONICA MINOLTA spectroradiometer allow the comparison of the participant's equalizations. The tristimulus values of the equalized stimuli are computed as shown in equations (1), (2) and (3) below with $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ the CMFs of a strandard observer.

$$X_{EQ} = K \int_{\lambda} [(R \times S_R(\lambda) + G \times S_G(\lambda) + B \times S_B(\lambda)) \times \bar{x}(\lambda)] d\lambda \quad (1)$$

$$Y_{EQ} = K \int_{\lambda} [(R \times S_R(\lambda) + G \times S_G(\lambda) + B \times S_B(\lambda)) \times \bar{y}(\lambda)] d\lambda \quad (2)$$

$$Z_{EQ} = K \int_{\lambda} [(R \times S_R(\lambda) + G \times S_G(\lambda) + B \times S_B(\lambda)) \times \bar{z}(\lambda)] d\lambda \quad (3)$$

The tristimulus values are compared through DeltaE2000 [2] color difference formulae. Key works of Sarkar et al. and Asano et al. allowed the development of the Individual Colorimetric Observer Model (ICOM) [3], an augmented version of the CIE 2006 Physiological Observer (CIEPO06) [4]. In our work, ICOM is used to deduct individual CMFs from equalizations performed in a larger gamut experiment, allowing to work on the development of a fidele personalized imaging system.

Conclusion

Our equalization experiment is still under development and is about to give promising results. The main challenge is due to the optical process but this choice allows interchangeable primaries and stimuli, leading to a larger gamut than those commonly seen in the litterature. From the equalization results and future derived CMFs, the objective is to outline a possible improvment of a personalized imaging systems.

Références

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WORK-IN-PROGRESS ABSTRACT

Spatial and Angular Variations of Colour Rendition due to Inter-reflections

Cehao Yu[1], Sylvia Pont[1]

[1]Perceptual Intelligence lab (π–Lab), Faculty of Industrial Design Engineering, Delft University of Technology

Abstract (300/300)

Introduction: The effective illuminance in a real-world scene is a geometrically weighted sum of direct and indirect components, and varies spatially and directionally, which is captured by the so-called light field. The spectral power distribution (SPD) of the indirect illuminance is dependent on that of the direct illuminance and the surface spectral reflectance (SSR) of the scene materials. The SPD of the indirect illuminance was derived to show systematic brightness, saturation and hue shifts due to inter-reflections. Differences between the spectral shapes of the direct and indirect illuminance induce colour rendition variations over the light fields, which we here investigate for uni-chromatic spaces.

Methods: The SPDs of the direct and indirect light field components were measured in four physical uni-chromatic spaces each furnished with one of four sample colours. We used CIE CRI and IES TM-30 colour metrics to quantify their spatially varying colour rendition properties. With computer simulations of a colour swatch containing CIE specified test colour samples in the uni-chromatic spaces, we numerically analysed colour distortions as a function of scene material SSRs.

Results: We found that the effective colour rendition differed up to 20% between direct and indirect illumination. The effective colour rendition of the light vector was more consistent with the illuminant specifications, but still deviated up to 10% in the corner. The colour appearances of 3D objects in the scene showed systematic shifts determined by the chromatic variations over the scene.

Conclusions: The spectral shape of the indirect light field component depends predominantly on scene material SSRs, whereas the major determinant of the direct component is the illuminant. Treating the indirect and direct illumination in a linear model allows capturing and understanding the influences of illuminant and scene separately, and analysing the variation of SPD throughout a scene (or light field) in a systematic manner.

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