6th European Conference on Colour in Graphics, Imaging, and Vision 2012

(CGIV 2012)

Amsterdam, Netherlands
6-9 May 2012

Technical Papers Program: Schedule and Contents*

SUNDAY MAY 6, 2012

SC2: Understanding and Handling the Quality of Experience (QoE) for Multimedia Applications
15.15 – 17.15 (2 hours)
Instructor: Mohamed-Chaker Larabi, Univ. of Poitiers

SC3: General-purpose Gamut Mapping Workshop
13.15 – 17.15 (4 hours)
Instructors: Roger D. Hersch and Romain Rossier, Ecole Polytechnique Fédérale de Lausanne (EPFL)

Welcome Reception
18:00 – 20:00
Krasnapolsky Hotel, Dam Square

MONDAY MAY 7, 2012

Keynote
Session Chair: Marcel Lucassen, University of Amsterdam (the Netherlands)
8:15 – 9:00

8:15 **Example-based image manipulation,** *Erik Reinhard, Max-Planck-Institute for Informatics (Germany)* **1**
Many color-related image adjustments can be conveniently executed by exposing at most a small number of parameters to the user. Examples are tone reproduction, contrast enhancements, gamma correction, and white balancing. Others require manual touch-ups, applied by means of brush strokes. More recently, a new class of algorithms has emerged, which transfers specific image attributes from one or more example images to a target. These attributes do not have to be well-defined and concepts that are difficult to quantify with a small set of parameters, such as the "mood" of an image, can be instilled upon a target image simply through the mechanism of selecting appropriate examples. This makes example-based image manipulation a particularly suitable paradigm in creative applications, but also finds uses in more technical tasks such as stereo pair correction, video compression, image colorization, panorama stitching and creating night-time images out of day-light shots.

Colour Capture/Reproduction A
Session Chair: Peter Zolliker, Empa (Switzerland)
9:10 – 10:10

9:10 **Natural color profile adjustment for professionals,** *Peter Morovic, Ján Morovic, Jordi Vilar, Jordi Arnabat, and Ángel Albarrán, Hewlett-Packard Company (Spain)* . . **5**
While there may be no point in arguing about taste, creative professionals make a living from sharing theirs. Making specific, individual color preferences that a creative professional knows how to achieve when creating content on a display also propagate into print is a significant challenge since it lacks real-time feedback. The present paper introduces a method for allowing creative professionals to use the tools they know and love to also personalize the color behavior of their devices. This is achieved by analyzing color changes applied to images and applying them to a device's ICC profile. As a result the personalized device results in customized color behavior regardless of the workflow used. The paper describes the ICC profile transformation algorithm in detail and provides a color error analysis of its performance.

* Please note: Page numbers listed after paper titles refer to the page on which the paper begins in the compiled version of the proceedings, which is found digitally on the CD that accompanies this book.

9:30 **Color appearance control for color vision deficiency by projector-camera system,**
Yoshiki Koshikizawa, Takahiko Horiuchi, and Shoji Tominaga, Chiba University
(Japan) **11**
Color vision deficiency is the decreased ability to perceive color differences. To over-
come this deficiency, supporting techniques for realizing barrier-free color environments
are required. This paper proposes a color appearance control system to enable peo-
ple afflicted with color vision deficiency to easily distinguish between confusing colors
on any printed images using a projector-camera system. The proposed system captures
a printed image using a video camera and shifts the lightness components of each
pixel by super-imposing a compensation image obtained from the projector device
onto the printed image. The compensation image is produced in the CIEL*a*b* color
space for iteratively adjusting the desired lightness components toward the target light-
ness. The feasibility of the proposed system is verified experimentally using real printed
images.

9:50 **Accurate apperance-based visualization of car paints,** *Ivo van der Lans,*
Eric Kirchner, and André Half, AkzoNobel Automative & Aerospace Coatings
(the Netherlands) **17**
We propose a new method to generate images with a given color and texture, in
order to visualize the appearance of car paints. Unlike current methods, the new
method is based on visual comparisons of rendered paints with actual physical sam-
ples. Thus, we optimized the method to maximize the appearance match between ren-
dered image and the corresponding car paint. In the new method it is possible to set
accurate numerical values for not only color properties, but also for well-defined texture
parameters.
       The new method is able to accurately render car paints under various light condi-
tions, ranging from purely unidirectional, intense spot light to purely diffuse light. We
show that the latter type of lighting conditions, which is often encountered in practical
situations, is not well covered by existing rendering techniques that are based on BRDF
and BTF measurements. Compared to existing methods for rendering, the proposed
method is much faster regarding measurement and calculation, it has lower instrument
costs and requires less data storage.

10:10 – 10:40   Coffee Break

Image Quality
Session Chair: Ivar Farup, Gjøvik University College (Norway)
10:40 – 12:00

10:40 **Learning image similarity measures from choice data,** *Matthias Scheller-Lichtenauer,*[1,3]
Peter Zolliker,[1] *Ingmar Lissner,*[2] *Jens Preiss,*[2] *and Philipp Urban*[2]*; *[1]*Empa (Switzerland),*
[2]*Technische Universität Darmstadt (Germany), and* [3]*Friedrich-Schiller-Universität Jena*
(Germany) **24**
We present a corpus of experimental data from psychometric studies on gamut map-
ping and demonstrate its use to develop image similarity measures. We investigate
whether similarity measures based on luminance (SSIM) can be improved when features
based on chroma and hue are added. Image similarity measures can be applied to
automatically select a good image from a sample of transformed images.

11:00 **Acceptability ratings for simulated image distortions of static images corresponding**
to different viewing angles for a flat panel display, *Mahalakshmi Ramamurthy,*[1]
Jeff Hovis,[1] *and Vasudevan Lakshminarayanan*[1,2]*; *[1]*University of Waterloo (Canada)*
and [2]*University of Michigan (USA)* **31**
Subjective ratings of image quality have always played an important role in the field of
display industries in order to help understand the observer tolerance of a product. This
paper focuses on establishing tolerance levels in terms of acceptability ratings for the
distortions produced by viewing the display at different angles away from normal.
The objective of this study was to simulate the shift in luminance and hue that occurs
when viewing a flat panel display at different angles using complex static scenes (car,
landscape and portrait). Observers rated the images both in terms of acceptability/
unacceptability. All simulations were carried out using the Visual Stimulus Generator
(ViSaGe, Cambridge Research System) controlled by Matlab on a Sony Trinitron CRT
monitor. A total of 20 subjects participated in this study. All subjects were between the

age group of 15 to 35 years of age and had average to superior color discrimination categorized based on the FM-100 Hue color vision test. Results from the rating experiments showed that, irrespective of the complexities in the images, average ΔE_{Lab} greater than five times thresholds (average discrimination threshold of vectors that change in both hue and luminance for different uniform CRT colors) were less than 50% acceptable. This corresponds to viewing angles greater than 10° for a given flat panel display. The car was rated more acceptable at lower ΔEs and more unacceptable at higher ΔEs compared with the other two scenes. Thus, for flat panel displays, observers were more tolerant to color distortions on natural scenes and were less tolerant to manufactured objects like car.

11:20 **A machine learning regression scheme to design a FR-Image quality assessment algorithm,** *Christophe Charrier, Olivier Lézoray, and Gilles Lebrun, Université de Caen Basse-Normandie (France)* **35**
A crucial step in image compression is the evaluation of its performance, and more precisely available ways to measure the quality of compressed images. In this paper, a machine learning expert, providing a quality score is proposed. This quality measure is based on a learned classification process in order to respect that of human observers. The proposed method namely Machine Learning-based Image Quality Measurment (MLIQM) first classifies the quality using multi Support Vector Machine (SVM) classification according to the quality scale recommended by the ITU. This quality scale contains 5 ranks ordered from 1 (the worst quality) to 5 (the best quality). To evaluate the quality of images, a feature vector containing visual attributes describing images content is constructed. Then, a classification process is performed to provide the final quality class of the considered image. Finally, once a quality class is associated to the considered image, a specific SVM regression is performed to score its quality. Obtained results are compared to the one obtained applying classical Full-Reference Image Quality Assessment (FRIQA) algorithms to judge the efficiency of the proposed method.

11:40 **The impact of image-difference features on perceived image differences,**
Jens Preiss,[1] Ingmar Lissner,[1] Philipp Urban,[1] Matthias Scheller-Lichtenauer,[2,3] and Peter Zolliker[2]; [1]Technische Universität Darmstadt (Germany), [2]Empa (Switzerland), and [3]Friedrich-Schiller-Universität Jena (Germany) **43**
We discuss a few selected hypotheses on how the visual system judges differences of color images. We then derive five image-difference features from these hypotheses and address their relation to the visual processing. Three models are proposed to combine these features for the prediction of perceived image differences. The parameters of the image-difference features are optimized on human image-difference assessments.

For each model, we investigate the impact of individual features on the overall prediction performance. If chromatic features are combined with lightness-based features, the prediction accuracy on a test dataset is significantly higher than that of the SSIM index, which only operates on the achromatic component.

12:00 – 13:30   Lunch on own

Colour Science/Appearance A
Session Chair: Reiner Lenz, Linköping University (Sweden)
13:30 – 14:30

13:30 **Why we don't know how many colors there are,** *Ján Morovic,[1] Vien Cheung,[2] and Peter Morovic[1]; [1]Hewlett-Packard Company (Spain) and [2]University of Leeds (UK)* **49**
There have been many attempts to answer the question of how many distinct colors there are, with widely varying answers. Here we present an analysis of what it would take to arrive at a reliable answer and show how currently available models fail to make predictions under the wide range of conditions that needs to be considered. Gamut volumes are reported for a number of light sources and viewing modes and the conclusion is drawn that the only reliable data we have comes from psychophysical work. The color gamut of the LUTCHI data in CIECAM02 is therefore shown as an alternative to the gamut of all possible colors.

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A new algorithm for evaluating metamer mismatch volumes is introduced. Unlike previous methods, the proposed method places no restrictions on the set of possible object reflectance spectra. Such restrictions lead to approximate solutions for the mismatch volume. The new method precisely characterizes the volume in all circumstances.

Color harmony patterns are relationships between coexisting colors where human psycho-perceptual visual pleasantness is the judging criterion. They play pivotal role in visualization, digital imaging and computer graphics. As a reference we assumed Itten model where harmony is expressed in terms of hue. The paper demonstrate investigation on color harmony patterns using clustering techniques.

Our source data was Adobe Kuler database consisting of hundreds of thousands of color palettes prepared for creative purposes. For the color palettes dissimilarity measurement we propose to use Jaccard distance additionally treating colors as the elements of a fuzzy set. Then, in the next step, separate colors are grouped within each group of palettes to specify each scheme of relations. The results are schemes of relationships between color within palettes.

Interactive Paper Session 1 and Coffee Break
14:30 – 16:00

Short-run sampling and customized production with digital textile printing is an attractive option for creative professionals to market their designs in a cost-effective way. The accuracy of color reproduction on the digitally printed textile is crucial for designers. The main objective of this study is to evaluate color reproduction capability of digitally printed silk fabrics based on color gamut and optical density. In addition, color management with ICC profiles was used to investigate the color matching capability of specific spot colors, which were selected from the Pantone® Fashion + Home digital color library. The accuracy of color matching of digitally printed silk fabrics was evaluated in terms of color difference ($\Delta E_{CMC\ 2:1}$). Three different silk fabrics—silk chiffon, silk crepe de chine, and spun silk taffeta, were tested and compared. The choice of textile substrate significantly influences image quality. It was found that Crepe De Chine is capable of yielding a wider color gamut and higher optical densities, resulting in better color reproduction capability and color matching. Chiffon has a relatively small color gamut and only can reproduce lighter colors.

Chromagenic color constancy is one of the promising solutions to the color constancy problem. However, this technique requires two shots of a scene: a conventional RGB image and an additional image that is optically pre-filtered using a chromagenic filter. This severely limits the usefulness of chromagenic based color constancy algorithms to static scenes only. In this paper we propose a solution to this with the use of a digital stereo camera, where we place the chromagenic filter in front of one of the lenses of the stereo camera. This allows capturing two images of a scene, one unfiltered and one filtered, in one shot. An illuminant can then be estimated using chromagenic based illumination estimation methods. Since more and more digital stereo cameras are being commercially available, the system can be built quite easily, and being a one shot solution, it is a practical computational color constancy method that could be useful in many applications. Experiments with a modern commercial digital stereo camera show promising results.

Modern printers allow printing on different paper types with many different coloured inks. Therefore, predicting the reflectances of paper printed with solid inks and ink superpositions (Neugebauer primaries) is of high importance. Given the separately measured transmittance of

an ink and the reflectance of a white diffusing background, we try to predict the reflectance of the inked white diffusing background by relying on a modified Saunderson formula accounting for the differences in the measurement geometries when performing transmittance and reflectance measurements. Accurate reflectance predictions are obtained for the cyan and magenta ink patches as well as for their ink superpositions. Less accurate predictions are obtained for the yellow ink patches or for ink superpositions incorporating the yellow ink. We suspect that the yellow ink layer is at the origin of optical phenomena which behave differently in reflectance and transmittance modes, and therefore allow less accurate predictions.

An important aspect of image and print quality is the existence of artifacts, such as compression or print artifacts. A general perceptual masking model, that describes the perceptual severity of artifacts on general background, could have been used to extract specific artifact detectors. However, currently general models are not mature enough to provide print artifact detectors for commercial print quality control application. Consequently we propose to employ machine learning techniques to learn a specific model for each print artifact based on a relevant set of features. We used the approach to develop two print artifact detectors. While the proposed approach was developed for print quality purpose, the method is general and can be used for learning automatic evaluators for image defects and quality degradation as well.

Successful cure of a burn injury depends highly on the first treatment. Burn depth is traditionally defined in three degrees. Estimation of depth degree is carried out by visual evaluation of the wound by the specialized dermatological experts. This type of evaluation includes a high degree of subjectivity. In the literature it can found objective methods for determining the depth of the burn by processing of digital photographic images. However, these methods estimate only one degree per burn wound despite the fact that it is common to find all three types within the same burn wound. In this paper a classification system to estimate the different depth degrees that a burn wound can present, is proposed. A color characterization algorithm is initially applied to the photographic images. A color and texture features extraction based on the L*a*b* color space and the chromatic opponent channels is carried out. The classifier used is a Fuzzy-ARTMAP neural network. This neural network performs a pixel-based classification to estimate the different depth degrees present in burn wound image. The system has been tested with 60 images. A success rate of around 80% has been achieved.

We have been attempting to digitize murals at the royal tomb of Amenophis III. When photographing the murals, two strobe lights with an umbrella were used to provide uniform illumination. Nonetheless, the illumination was still somewhat non-uniform. We corrected for this non-uniform illumination by applying an illumination model, which we evaluated using images with white patches and images of the model mural without white patches. The illumination model was then extended to two light sources and applied to images of the actual mural. The corrected images were observed to be more uniformly illuminated.

A main issue in the archaeological research is to deal with colors of soils and artefacts, especially pottery. Since, in many cases, color information are crucial for the interpretation of cultural products, to avoid risks of a too subjective autoptic recognition Munsell system is commonly used in archaeology.

This method widely used in other fields, like geology and anthropology, is based on the matching between the real color and its standardized version on Munsell Charts. But it has significant limitations, due to the influence of cultural background, color sensibility and education, that can mislead archaeologists in their daily work.

In this paper a semi-automatic method of color detection on selected regions of digital images of ancient pottery is presented. This tool, whose encouraging experimental results are widely discussed in the contribute, is aimed to prevent eventual subjective errors during color

identification and to speed up the process of identification itself. In order to emphasize the relativity of Munsell system, a statistical analysis was carried out on a group of potsherds selected for this research, pointing out the range of different colors identified on a single specimen by different observers.

The starting point of the experiment was to take digital pictures of specimens together with the Gretag-Macbeth Color Checker Chart, whose chromatic values have been objectively established. The digital image is processed with color balancing techniques aimed to restore the original value of Macbeth patches, in order to eliminate distortions coming from acquisition process. After the color correction, several regions of interest are selected via 'point and click' for the identification of surface color, the algorithm converts RGB values in Munsell data. The reliability of our tool is also verified comparing this chromatic values with the color specification of pottery sherds performed with a spectrocolometer using the CIELAB space to evaluate the differences.

The results obtained and percentages of successful matching with Munsell color identification coming from the statistical analysis, seem to open new perspectives for the development of a full automatic system with a GUI interface aimed to facilitate significantly some aspects of the archaeologist's work.

Labial teeth and gingiva color image segmentation for gingival health-state assessment,

Gingival health state assessment has always been considered of great importance in the field of dentistry. A major concern in this area is the subjectivity that commonly applied assessment methods inherit. Most of the previous approaches that aim at introducing objectivity in the assessment are based on data from photographic images of the gingival area. Nevertheless, they generally lack applicability in the clinical environment because of the requirement of expertise in image processing to perform the analysis. In this work, an enhanced teeth region segmentation scheme is proposed, based on the Self-Organizing Map algorithm. The segmentation task is the basis for further objective assessment of gingival health that can entirely be performed automatically. By introducing a novel training image selection approach, the segmentation performance of this task was increased significantly, compared to previous work. Apart from that, a newly developed spatial segmentation feature in addition to color is investigated and evaluated. The novel *Labial Teeth and Gingiva Image Database* of the University of Granada is used as benchmark for the segmentation scheme.

Can you see what others see—A defect detection model for patterned backgrounds,

No one wants defects on their products – neither manufacturers nor consumers. For manufacturers, a series of quality inspection processes is always required to ensure qualities of all their products are under control. For consumers of liquid crystal displays (LCDs), however, they may only concern whether they can see defects on their displays. In this sense, visibility of defects is more important than whether they really exist. Mura is such type of detects on LCDs that most people might have neither heard about it nor been aware of (existence of) them on their panels but some professional users do concern them a lot. This reflects that Mura defects are visually hard to notice and thus tend to be easily overlooked by most users; but in certain circumstances they are really an issue to image quality. In this research, a Mura detection model based on human visual perception was established particularly for visibility prediction of Mura on patterned backgrounds. It is also a model different from current industrial standards which suggest, and therefore are limited to, inspections of Mura defects to be carried out on uniform neutral grey backgrounds. Our analysis showed that colour did not have as much influence on the visibility as previous studies reported when Mura defects are viewed against patterned backgrounds. For a given Mura size and special frequency of a patterned background, there existed a linear relationship between the model outputs (dR, in terms of ΔE^*_{ab}) and the lightness (L*) of the background. An interesting phenomenon was also found that the 1st derivative of the slopes (i.e. slope variation across different experimental conditions) of the linear functions representing the relationships mentioned above can represent the special frequency effect whilst the 2nd derivative of the slopes represents the Mura size effect on the visibility of Mura patterns. Apparently this model provides more reliable predictions of visibility to situations closer to the reality that it is usually complex images, rather than uniform colour patches, are displayed on LCDs. Preliminary analysis also shows that the proposed model can deliver more reliable results for patterned backgrounds than S-CIELAB does.

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Colour Science/Appearance B

Session Chair: Maria Vanrell, Universitat Autònoma de Barcelona (Spain)
16:00 – 17:00

16:00 **Colour laser scanner characterisation by enhanced LUT,** *Lindsay W. MacDonald, University College London (UK)* **137**
This study investigated how to improve the accuracy of colour characterisation for a three-colour laser scanner, implemented by a lookup table (LUT) with interpolation. The transfer function was trained on a huge number of real and synthetic reflectance spectra, refined through statistical analysis. The lookup table enabled a 'baseline' matrix fitting to be enhanced through local deformations of 3D colour space to give optimal colorimetric performance.

16:20 **Colour based image retrieval with embedded chromatic contrast,**
Xiaohong Gao, Yu Qian, Yuanlei Wang, and Anthony White, Middlesex University (UK). **143**
Due to the over-whelming amount of digital images available in the internet, content-based image retrieval (CBIR) has been developed to complement with the current text-based approach. As such, colour has played a key role in representing image features and has been employed widely in such a development. However a colour appears differently to human eyes when it is viewed against different coloured back-grounds and surroundings, whereas none of existing colour spaces and models has taken this effect of colour contrast into account, leading to a number of unsatisfied retrieved results to a certain extent. This study aims to develop a colour appearance model/space to predict simultaneous colour contrast, which is in turn to be suitable on course to retrieve a collection of museum wallpaper papers. In doing so, a 2-field paradigm is maintained instead of traditionally 3-field one in an effort to model chromatic contrast, which has led to the extension of CIECAM02 into CIECAMcc. Colour based image retrieval is subsequently evaluated using 4 popular colour models and spaces, including CIECAMcc, CIECAM02, HSI, and RGB. Although it is unlikely to judge which method performs better purely based on colour content due to the nature of subjectivity in interpreting images, it can be said that in terms of both brightness and colourfulness contrast between foreground and background, CIECAMcc outperforms the others. In addition, CIECAMcc exhibits potentials in retrieving back images that constitute two shaded patterns the similar way as those depicted in a query image. However this phenomenon can not be simply explained away. Further investigation will be carried out in this regard in the future by including larger collections.

16:40 **A new version of CIECAM02 with the HPE primaries,** *Changjun Li, University of Science and Technology Liaoning (China); M. Ronnier Luo, University of Leeds (UK); and Pei-Li Sun, National Taiwan University of Science and Technology (Taiwan)* . **151**
CIECAM02 has been used to predict colour appearance under a wide range of view-ing conditions, to quantify colour differences, to provide a uniform colour space and to provide a profile connection space for colour management. However, several prob-lems have been identified with the CIECAM02. This talk is to present a new version of the CIECAM02 with the Hunt-Pointer-Estevez (HPE) matrix. The new version overcomes some problems and is simpler. The performance of the new version is verified.

Canal Boat Tour
17:30 – 19:30
Boats leave from the quay at Singel 359
followed by dinner on own

TUESDAY MAY 8, 2012

Keynote

Session Chair: Theo Gevers, University of Amsterdam (the Netherlands)
8:15 – 9:00

8:15 **Are *a priori* metrics in colorimetry meaningful?,** *Jan Koenderink, KU Leuven (Belgium) and Delft University of Technology (the Netherlands)* **155**
"Are *a priori* metrics in colorimetry meaningful?" is a question that is rarely asked. Yet the choice of metric in the form of an inner product is of crucial importance in basic colorimetry. Is there an *a priori* unique choice? The answer is no. One needs to opt for some choice of inner product on rational grounds that may differ from case to case. I discuss possible alternatives.

Colour Capture/Reproduction B

Session Chair: Carinna E. Parraman, University of the West of England (UK)
9:10 – 10:10

9:10 **An expanded Neugebauer formula, using varying micro-reflectance of the Neugebauer primaries,** *Daniel Nyström, Linköping University (Sweden)* **157**
Modeling color reproduction in halftone printing is difficult, mainly because of light scattering, causing optical dot gain. Most available models are limited to macroscopic color measurements, averaging the reflectance over an area that is large relative the halftone dot size. The reflectance values for the full tone ink and the unprinted paper are used as input, and these values are assumed to be constant. An experimental imaging system, combining the accuracy of color measurement instruments with a high spatial resolution, allows us to measure the individual halftone dots, as well as the paper between them. Microscopic reflectance measurements reveal that the micro-reflectance of the printed dots and the paper between them is not constant, but varies with the ink area coverage. By incorporating the varying micro-reflectance values of the ink and paper in an expanded Murray-Davies model, we have previously shown that the resulting prediction errors are smaller than for the commonly used Yule-Nielsen model. Moreover, unlike Yule-Nielsen, the expanded Murray-Davies model takes into account the varying micro-reflectance for the printed dots and the paper, thus providing a better physical description of optical dot gain in halftone prints.

In this study, we further extend the proposed methodology to handle color prints, predicting tristimulus values for prints with multiple and overlapping colorants. After converting the microscopic images of halftone prints into CIEXYZ color space, tristimulus values for the paper and the different combinations of ink are computed from CIEEXYZ histograms. From the microscopic images we can also compute the physical ink area coverage for each of the Neugebauer primaries, which typically differ from the nominal one, due to physical dot gain. The result is an expanded Neugebauer model, taking into account how the tristimulus values of the paper, the primary inks and the overlapping secondary colors, vary with the total ink area coverage. Experimental results confirm the accuracy of the proposed methodology, when compared to measurements using a spectrophotometer. The results have shown that the variation of the micro-reflectance of the Neugebauer primaries is large, and depends on the total ink area coverage. The results further show that the way that the micro-reflectance vary is also strongly dependent on the surrounding inks, because of light scattering in the substrate.

9:30 **Investigating the possibility of using fewer training samples—in the color prediction model based on CIEXYZ using an effective coverage map,** *Yuanyuan Qu and Sasan Gooran, Linköping University (Sweden)* **163**
The goal of the present work is to reduce the number of the training samples used in our color prediction model based on CIEXYZ using an Effective Coverage Map while keeping satisfying prediction. A general approach is proposed in this paper to choose the best reference combination for the training samples. The approach is based on the dot gain behavior of each primary ink, which is characterized by three curves using CIEXYZ tri-stimulus values. The proposed approach is built in our model to predict the color values for the color prints using two different devices, i.e. a laser printer and an inkjet printer. For the laser printer the number of the training samples is reduced from 125 to 64 while still giving quite good result. The approach also shows that for the

test laser printer it is possible to further cut this number to 53 with a satisfying result. For the inkjet printer the number of training samples for our model is reduced from 125 to 79 or 64, both giving satisfying results.

9:50 **A gamut boundary metadata format,** *Jurgen Stauder, Corinne Porée, Patrick Morvan, and Laurent Blondé, Technicolor R&D France (France)* **169**
Recent display technologies (LCD backlight, OLED) allow watching images with more contrast and more saturated colors than even digital cinema. Unfortunately, today's video content and broadcast cannot convey such colors due to the currently used colorimetry standard (ITU-R.BT 709). Solutions exist for more contrast and wider color gamut, but they are different in the video and photography worlds. New standardization initiatives for video (IEC 61966-2-4, ITU-R) try to set up a new, extended but fixed colorimetry, while digital photography applies—since a decade—flexible color management (ICC). However, in all these approaches the color gamut of either devices or contents is not described explicitly. This paper presents the new international standard IEC 61966-12-1 "Metadata for identification of colour gamut (Gamut ID)". This standard allows the precise and flexible description of a color gamut. The metadata supports graphics hardware, scalability, memory footprint efficiency, convex handling of non-convex gamuts, handling of fuzzy color gamuts, and handling of gamut cusps. This standard may be used in future systems for video color management or for image-dependent gamut mapping.

10:10 – 10:40   Coffee Break

Colour Image/Video Processing A
Session Chair: Mohamed-Chaker Larabi, University of Poitiers (France)
10:40 – 12:00

10:40 **Spatio-temporal retinex-like envelope with total variation,** *Gabriele Simone and Ivar Farup, Gjøvik University College (Norway).* **176**
Many algorithms for spatial color correction of digital images have been proposed in the past. Some of the most recently developed algorithms use stochastic sampling of the image in order to obtain maximum and minimum envelope functions. The envelopes are in turn used to guide the color adjustment of the entire image. In this paper, we propose to use a variational method instead of the stochastic sampling to compute the envelopes. A numerical scheme for solving the variational equations is outlined, and we conclude that the variational approach is computationally more efficient than using stochastic sampling. A perceptual experiment with 20 observers and 13 images is carried out in order to evaluate the quality of the resulting images with the two approaches. There is no significant difference between the variational approach and the stochastic sampling when it comes to overall image quality as judged by the observers. However, the observed level of noise in the images is significantly reduced by the variational approach.

11:00 **Optimal global approximation to spatially varying tone mapping operators,**
Jakkarin Singnoo and Graham D. Finlayson, University of East Anglia (UK) **182**
Compared with spatially-varying tone-mapping operators, global tone maps have the advantage that the input is mapped to an output image without introducing spatial artifacts common to spatially-varying tone-mapping operators (e.g. halos and intensity inversions). However some local detail can be compressed (visually lost). In this work, we propose a global tone-mapping operator that optimally, in a sum of least-squares sense, approximates spatially-varying tone-mapping operators.

Our method is based on a modification of the simple but elegant constrained optimization technique called Pool-Adjacent-Violators-Algorithm (PAVA). In a second step, we show how any lost local detail can be brought back through copying, in an edge sensitive manner, detail from the original input (an approach already developed in the literature).

Our new global tone-curve approach has a specific advantage: we show it suffices to learn the tone-curve by processing a small thumbnail and then produce the final output by applying the tone-curve to the full resolution input. Not only does processing on thumbnails deliver excellent results we can, using this approach, significantly increase the speed of tone-mapping operators.

To evaluate our method we carried out a paired comparison psychophysical

experiment. Preference scores resulting from the experiment show that in general the perceived quality of our proposed operator is similar (equally preferred) to a range of spatially-varying tone-mapping operators.

11:20 **Towards a multivariate probabilistic morphology for colour images,**
Mihai Ivanovici and Alexandru Caliman, Transilvania University (Romania); and Noël Richard and Christine Fernandez-Maloigne, University of Poitiers (France) . . **189**
The mathematical morphology for colour images faces the delicate issue of defining a total order in a vectorial space. There are various approaches based on partial or total orders defined for color images. We propose a probabilistic approach, that uses principal component analysis (PCA), for the computation of the convergence colours, *i.e.,* the extrema of a set. Then we define two pseudo-morphological operations, the dilation and the erosion, applying the Chebyshev's inequality on the first eigenvector of the image colour data. As an application, we use our approach to extract the Beucher colour gradient. We discuss the advantages and disadvantages of our approach, we comment our results and then we conclude this paper.

11:40 **Dual-tree complex wavelet transform based denoising for random spray image enahcement methods,** *Massimo Fierro, Wang-Jun Kyung, and Yeong-Ho Ha, Kyungpook National University (Korea)* **194**
This work introduces a novel way to reduce point-wise noise introduced or exacerbated by image enhancement methods leveraging the Random Spray sampling approach. Due to the nature of the spray, the sampling structure used, output images for such methods tend to exhibit noise with unknown distribution. The proposed noise reduction method is based on the assumption that the non-enhanced image is either free of noise or contaminated by non-perceivable levels of noise. The dual-tree complex wavelet transform is applied to the luma channel of both the nonenhanced and enhanced image. The standard deviation of the energy for the non-ehanced image across the six orientations is computed and normalized. The normalized map obtained is used to shrink the real coefficients of the enhanced image decomposition. A noise reduced version of the enhanced version can then be computed via the inverse transform. A thorough numerical analysis of the results has been performed in order to confirm the validity of the proposed approach.

<p align="center">12:00 – 13:30   Lunch on own</p>

<p align="center">**Colour Image/Video Processing B**</p>
<p align="center">Session Chair: Sebastiano Battiato, Università di Catania (Italy)</p>
<p align="center">**13:30 – 14:50**</p>

13:30 **RGB filter design using the properties of the Weibull manifold,** *Reiner Lenz and Vasileios Zografos, Linköping University (Sweden)* **200**
Combining the channels of a multi-band image with the help of a pixelwise weighted sum is one of the basic operations in color and multispectral image processing. A typical example is the conversion of RGB- to intensity images. Usually the weights are given by some standard values or chosen heuristically. This does not take into account neither the statistical nature of the image source nor the intended further processing of the scalar image. In this paper we will present a framework in which we specify the statistical properties of the input data with the help of a representative collection of image patches. On the output side we specify the intended processing of the scalar image with the help of a filter kernel with zero-mean filter coefficients. Given the image patches and the filter kernel we use the Fisher information of the manifold of two-parameter Weibull distributions to introduce the trace of the Fisher information matrix as a cost function on the space of weight vectors of unit length. We will illustrate the properties of the method with the help of a database of scanned leaves and some color images from the internet. For the green leaves we find that the result of the mapping is similar to standard mappings like Matlab's RGB2Gray weights. We then change the colour of the leaf using a global shift in the HSV representation of the original image and show how the proposed mapping adapts to this color change. This is also confirmed with other natural images where the new mapping reveals much more subtle details in the processed image. In the last experiment we show that the mapping emphasizes visually salient points in the image whereas the standard mapping only emphasizes global intensity changes. The proposed approach to RGB filter

design provides thus a new methodology based only on the properties of the image statistics and the intended post-processing. It adapts to color changes of the input images and, due to its foundation in the statistics of extreme-value distributions, it is suitable for detecting salient regions in an image.

13:50 **The fractal estimator: A validation criterion for the colour mathematical morphology,** *Audrey Ledoux, Noël Richard, and Anne-Sophie Capelle-Laizé, University of Poitiers (France)* **206**
Mathematical Morphology relies on the notion of ordering. For colour image processing, this question is relative to the colour space choice, to the colour distance defined in the colour space, or to the importance of each colour axes in the colour representation or statistical colour organization. For twenty years, more than 60 different proposals have been developed to express such orders, but how to choose the right ordering form, on which criterion to ensure the stability of the morphological behavior? In this paper, we investigate one criterion and we apply it on some approaches in colour Mathematical Morphology.

14:10 **Toward a natural local color image enhancement,** *Jean-Michel Morel, CMLA ENS Cachan (France), and Ana Belén Petro and Catalina Sbert, Universitat Illes Balears (Spain).* **211**
There is no unique contrast enhancement method, but the existing methods seem to cover all needs for local or global enhancement. Nevertheless, experimental evidence shows that the two main algorithmic classes (histogram based and high pass filter based) have their own characteristic artifacts. This work intends to show that new and simple alternative algorithms in these classes are possible. The two proposed algorithms introduce bounds on the amount of contrast change, permitting to always deliver natural looking enhanced images. Comparison with six state-of the-art methods illustrate the competitiveness of a fast nonlinear local contrast enhancement method by partial differential equation, and of a very simple histogram modification method.

14:30 **Feature based no-reference continuous video quality prediction model for coded stereo video,** *Z. M. Parvez Sazzad, Rafik Bensalma, and Mohamed-Chaker Larabi, University of Poitiers (France)* **217**
In this paper, we propose a continuous no-reference video quality evaluation model for MPEG-2 MP@ML coded stereoscopic video based on spatial, temporal, and disparity features with the incorporation of human visual system characteristics. We believe edge distortion is a major concern to perceive spatial distortion throughout any image frame which is strongly dependent on smooth and non-smooth areas of the frame. We also claim that perceived depth of any image/video is mainly dependent on central objects/structures of the image/video contents. Thus, visibility of depth is firmly dependent on the objects' distance such as near, far, and very far. Subsequently, temporal perception is mostly based on jerkiness of video and it is dependent on motion as well as scene content of the video. Therefore, segmented local features such as smooth and non-smooth area based edge distortion, and the objects' distance based depth measures are evaluated in this method. Subsequently, video jerkiness is estimated based on segmented temporal information. Different weighting factors are then applied for the different edge distortion and depth features to measure the overall features of a temporal segment. All features are calculated separately for each temporal segment in this method. Subjective stereo video database, which considered both symmetric and asymmetric coded videos, is used to verify the performance of the model. The result indicates that our proposed model has sufficient prediction performance.

Interactive Paper Session 2 and Coffee Break
14:50 – 16:20

Enhancement of gloss perception by using binocular disparity, *Shoji Yamamoto, Tokyo Metropolitan College of Industrial Technology, and Masashi Sawabe, Mayu Yokoya, and Norimichi Tsumura, Chiba University (Japan).* **226**
In this paper, we quantified the gloss perception by using binocular stereoscopic display. In our experiment, we evaluated gloss perception changing the disparity angle of surface and highlight to investigate the relationship between glossy appearance and the disparity angle. The magnitude estimation method is used to evaluate the sensibility of gloss appearance subjectively. As the result, the score of subjective evaluation on stereo display is stronger than on

flat display, within the disparity angle range that is depth perceptible, and the score on stereo display and on flat display is same without the range. Additionally, we found that glossy contrast correlated highly with evaluation score regardless of the disparity angle and display method.

Accurate information vs. looks good: Scientific vs. preferred rendering,

Scientists use digital camera data as the input to their analysis of image processing algorithms. In this paper we measured the "engineered color errors" introduced by digital camera color processing. Camera manufactures build their color management systems using the sRGB design standard. Although that sRGB is a guideline in the beginning, the final firmware shows certain liberties taken to make the best preferred rendering of scenes. The ensemble of algorithms that perform the color balance, color enhancement, tone scale, and post-LUT for display and printing, create large discrepancies between the sRGB measurements of the light from the scene, and actual sRGB values in cameras. We measured these discrepancies. These modifications to scene information introduce large changes in spatial information and make computer vision algorithms less accurate. Camera firmware and software modify color separation data for better looking pictures. These modifications need to be removed for accurate scientific scene analysis. We describe a computer program that converts a RAW digital camera file to calibrated file, in which digit value is proportional to log scene radiances.

Spectral and colorimetric constancy and accuracy of multispectral stereo systems,

Stereo multispectral systems enable at the same time the acquisition of accurate spectral and depth information. The left and right cameras of the system can either present the same spectral sensitivities (e.g., a monochrome sensor with 7 different bandpass color filters sequentially placed in front of it for both cameras) or complementary sensitivities. The latter alternative can be accomplished by the utilization of two different filters or sets of filters for each camera of the stereo system. Even if each camera alone does not provide complete spectral information about the acquired scene, the estimation of the spectra becomes possible when both cameras are considered together. But since the reflectance spectrum of objects is a function of the wavelength, of the illumination angle and of the observation angle, the information from the left and the right cameras is generally different. This problem is already known from the RGB stereo imaging, and becomes even more relevant when it comes to multispectral stereo imaging, whose purpose is in addition an accurate color recording.

In this paper, we analyze this problem experimentally by acquiring different series of stereo data and comparing them for determined regions of interest. We acquire two scenes under different lighting conditions with a standard color chart and objects whose reflectance spectra have a limited observation angle dependence. We utilize real multispectral data as well as spectra measured with a spectrophotometer to verify camera acquisition and compare them for different observation angles. We then estimate the acquired spectra using several of the possible spectral compositions, given by all the color channels available for the left and for the right camera. These estimated spectra are compared to the ground truth data and we show that the stereo system with 7 channels cameras using only 3 color channels from one camera and the 4 complementary color channels from the other camera has a good colorimetric accuracy.

Evaluating the noise variance of an image acquisition system with various reconstruction

Estimation of the noise variance of image acquisition systems is very important to solve the inverse problems such as the recovery of spectral reflectances through the use of image data or to get a clear image from a blurred image, etc. In the color imaging community, the acquisition of accurate spectral reflectances of objects at the resolution of pixels is important to reproduce realistic color images under a variety of viewing illuminants. The accuracy of recovered spectral reflectances is usually evaluated by the mean square errors (MSE) between the measured and the recovered reflectances. The MSE is dependent on the noise present in an image acquisition system, which is called as the system noise below, and estimating the noise level is important to increase the estimation accuracies. In the evaluation of the influence of the noise, dividing the MSE into two terms, i.e., the noise independent MSE (MSEfree) and noise dependent MSE (MSEnoise), is essential to estimate the noise variance and to analyze the influence of the noise on the MSE. A model separating the MSE into the two terms and estimating the noise variance was already proposed based on the Wiener estimation by one of the authors. Later the model was modified to a comprehensive model based on an arbitrary reflectance reconstruction

matrix and was also applied to the noise estimates by two spectral estimation models such as the Wiener and the linear model.

In the previous paper, it was not possible to apply the comprehensive model to the regression model or the Imai-Berns model, which are the models to estimate spectral reflectances, because their reconstruction matrices are derived from the sensor responses which include the system noise in it.

In this paper, a new method is proposed to extend the comprehensive model to four reconstruction models (Wiener, linear, regression and Imai-Berns models), since it is very interesting whether the influence of the noise on the recovery performance is dependent on the model used or not. By defining the theoretical estimates of the sensor responses and by estimating the reconstruction matrices without the system noise for the regression model and the Imai-Berns model, it is shown that the increasing in the MSE by the noise present in an image acquisition system can be evaluated by a simple formulation for the four models. From the experimental results it is shown that the comprehensive model analyzes the effect of the system noise on the increase in the MSE on the reflectance recovery.

This study investigates preference for, and perception of, blackness using psychophysical experiments. A total of 29 black samples (varying in value and chroma) were evaluated for colour perception (which of two black samples observers considered to be closest to a pure black) and colour preference (which of two black samples observers preferred). For colour perception there was no statistical difference between UK and Chinese observers nor between male and female observers. However, for colour preference there were effects of culture; Chinese observers preferred darker samples and UK observers preferred lighter samples.

Hybrid-resolution multispectral imaging has been proposed for reconstructing multispectral images from two types of data with different spatial and spectral resolutions. This paper proposes a new scheme for hybrid-resolution multispectral imaging based on image sensors with a multispectral filter array (MSFA). The proposed method reconstructs multispectral images from a high-resolution RGB image and image data from an MSFA with narrow-band color filters. The MSFA samples each band of a multispectral image sparsely in space, while RGB images are obtained at high spatial resolution; i.e., this dataset is regarded as a hybrid-resolution measurement. In the multispectral image reconstruction, each band of a multispectral image is reconstructed as a linear combination of high-resolution RGB images. The weighting coefficients of the linear combination are determined on the basis of MSFA data. By determining the weighting coefficients for each appropriate small area, overall multispectral images can be reconstructed with high accuracy. In this paper, typical configurations of image sensors for the hybrid-resolution multispectral imaging are also proposed. The effectiveness of the proposed method was verified for 16-band images through computer simulations in the case of a single-panel image sensor with an MSFA. As a result, it was confirmed that the proposed method reconstructed 16-band images at higher spatial resolution and with lower normalized root mean squared error than did a simple linear interpolation of the data from an equidensity-sampling MSFA.

Colour constancy algorithms range from image statistics-based pixel intensity manipulation to gamut-mapping methods, and are generally independent of specific image contents. In previous work, we have demonstrated that natural polychromatic surfaces possess distinct chromatic signatures in cone-contrast space that may be exploited for colour constancy, and that in human vision, colour constancy is improved for such objects. Here we set out to use the specific, recognisable, and ubiquitous content of human skin in colour images to drive a gamut mapping method for colour constancy. We characterise variations in the chromaticity gamut of varying types of, pre recognised, human skin (male, female; Caucasian, African, Asian) under varying illumination. We use a custom-built LED illuminator to produce daylight metamers, and a spectroradiometrically calibrated hyperspectral camera (Specim V10E) to acquire images and create a novel hyperspectral skin image database. We demonstrate that human skin gamuts in cone-contrast space are characterised by a set of features that can be used to differentiate between similar illuminations, whose estimate can then be used to colour correct an image.

Psychophysical estimation of the best lighting for commercial counters of fruits and vegetables, *Osamu Masuda,[1] Hélder Tiago Correia,[1] João Manuel Maciel Linhares,[2] and Sérgio Miguel Cardoso Nascimento[1]; [1]University of Minho (Portugal) and [2]Anglia Ruskin University (UK)* **272**

Naturalness and aesthetic preference are two important aspects of color rendering that are difficult to capture with rendering indices. Several factors may influence observer's choices in complex ways, e.g. color memory and the composition of the scenes, and the best illumination for specific conditions may be difficult to predict from existing indices.

The aim of this work was to estimate psychophysically the spectral composition of the best lighting for commercial food counters. Stimuli were monitor simulations of commercial food counters containing fruits and vegetables derived from hyperspectral data obtained in a local supermarket. Illuminants were synthetized from Judd's daylight spectral basis functions with variable coefficients such that their color defined a chromaticity grid over and around Planckian locus with correlated color temperature (CCT) in the range 2,222—20,000 K. Two conditions were tested: in one, the naturalness condition, observers selected the illuminant producing the most natural colors; in the other, the preference condition, observers selected the illuminant producing the most pleasant appearance.

The average CCT in the preference condition was significantly lower than that obtained in the naturalness condition, by about 2,400 K. The average chromaticity of each condition was closer to the Planckian locus than to the daylight locus.

Scene recognition by hyperspectral ratio indexing: How many channels are necessary?, *Nsikak Ekpenyong and David H. Foster, University of Manchester (UK)* **279**

The problem of object or scene recognition is often addressed by seeking geometric image properties that are invariant under changes in viewing conditions. An alternative, non-geometric, ratio method was described by Funt and Finlayson (IEEE Trans. Pattern Anal. Mach. Intell. 17,522, 1995) in which histograms of spatial ratios of colour RGB triplets from neighbouring image regions were used to recognise objects under changes in viewpoint and illumination. In this study, ratio indexing was extended from RGB images to hyperspectral images with a variable number of sensor channels distributed over 400-720 nm. Fifty natural scenes were used to generate test and reference images. For each number of sensors, independent random samples were drawn from each test image of a scene under either a daylight of correlated colour temperature of 25000 K or of 4000 K and matched against independent random samples drawn from each reference image of the scenes under a daylight of correlated colour temperature 6500 K. Matching was based on the intersection of multi-dimensional histograms of ratios of sensor signals in these samples Differences between match hit and false-alarm rates provided a measure of recognition performance. Results suggest that for small samples, indexing with five sensor channels has advantages over indexing with three sensor channels for the recognition of natural scenes.

Studying and modeling the binocular energy for stereoscopic images, *Rafik Bensalma and Mohamed-Chaker Larabi, Université de Poitiers (France)* **283**

Stereovision is a research field attracting people from various fields such as psychology, physiology, mathematics and recently computer vision. Physiological and psychological studies allowed to understand, in a significant way, the behavior of the visual cortex. Plenty of these results have been modeled but never implemented in imaging applications for various reasons. However, this step is very important in order to take advantage of the advances in the aforementioned fields. This paper tries to formulate analytically the binocular behavior of the HVS by applying the binocular fusion made by the complex cells to merge the retinal information provided by the simple cells. This allows to study the evolution of the binocular energy with regards to different impairments on one or both of the stereo pairs. Results demonstrate and important correlation between the binocular energy and the quality of the 3D reconstruction.

The effect of experimental instructions on the number of areas identified as important in photographic images, *Susan Farnand and Mark Fairchild, Rochester Institute of Technology (USA)* **290**

A study is currently underway that is aimed at increasing understanding of the optimal design of pictorial stimuli in perceptual experiments. Evaluating the impact of image complexity on visual attention is of particular interest. Since this work centers on pictorial scenes, a variety of such scenes must be selected as stimuli. The experiments planned require scenes that are perceived to have at least five key areas of interest. Further, each of these must be able to be cropped to versions perceived to have three or four key areas of interest and one or two key areas of interest. The objective of the present experiment is to evaluate the impact of the experimental instructions on the number of key interest areas identified in each of the potential

scenes and its cropped versions. The results of this experiment indicate that observer instructions have an impact on the number of areas observers determined to be important in the test images. These results have been used to select the scenes for subsequent work being conducted to evaluate the impact of scene complexity on how people look at images in perceptual experiments. In these experiments, fixation patterns will be evaluated with respect to the areas identified as important in the present study.

The purpose of this study is to get a color perception model of dichromat. We construct a color perception model of dichromat, and analyze the mechanism. Then we have prospect of find human color perception mechanism. We expect it when we understand mechanism of the color perception of the human beings by construct and analysis a dichromat's color perception model. We construct a color perception model of color defects based on the results of psychophysical experiments with optimizes the strucutre of neural network using genetic algorithm (GA). The neural network used in this paper is real flexibly connected neural network (RFCN). RFCN , the evolutionary neural network we previously proposed, is a model that can have high performance in various fields. In RFCN, the structure of the network and parameter are optimized automatically and fleibly with GA according to tasks we give. So we can obtain the network that has desirable performance without special knowledge about the task. We developed a model that can operate similarly to dichromat's catergorical color perception. The results showed that the obtained neural network has similar characterisitcs to those of dichromat's vision system.

Glossiness is one of the important qualities for printing paper. Glossiness is a specular reflection phenomenon in aspect of optics. Therefore, there are various methods of evaluating specular reflection phenomenon. When a person is evaluating the glossiness of paper, it is quite popular to visually inspect the glossiness by the sharpness of the reflected light image. In this paper, it is shown that this visual inspection can be expressed by a transfer function of specular reflection image.

First, we discuss the possible use of point spread function of specular reflection (SR-PSF). A technique for measuring SR-PSF of paper is proposed. The measurement principle is a collimator method. This method has been used for the PSF measurement of typical transmittance optical system. We have developed the apparatus to measure SR-PSF. The SR-PSFs were measured for paper samples. The experimental results showed that the measured SR-PSF works as a transfer function for specular reflection image.

Second, we show that the apparatus used for measuring SR-PSF also works as a gonio-photometer within a narrow solid angle. It is shown that the reflection angle calculated theoretically meets well with that experimentally obtained. That is, a distribution of reflection angle can be calculated using SR-PSF data.

It is thought that the spreading of specular reflection observed on paper samples is caused by the distribution of surface normals. Our results showed that SR-PSF and gonio-reflectance distribution are one phenomenon expressed in two different physical concepts. Our future study will be focused on new reflection model for computer graphics.

We studied the utilization of illumination and observer spectral characteristics in clustering based color image segmentation. Segmentation was based on k-means algorithm, spectral clustering algorithm and non-local spatial constraint spectral clustering algorithm both with the Nyström method. The image segmentations were performed for four different representations derived from a set of spectral images: 1) simulated sRGB images using D65 illumination, 2) six band images based on sRGB images under the D65 and A illuminations, 3) estimated spectral reflectance images, and 4) true spectral reflectance images. The spectral reflectance estimation was based on Wiener estimation model, reflectance of Macbeth Color Checker (24 samples) and CIE XYZ tristimulus values under the D65 and A illuminations. The experimental results showed that the segmentation results via reflectance estimation model were improved when compared to the segmentation with sRGB images. These results suggest that it is useful to include the knowledge from illumination and observer spectral characteristics in order to increase the clustering based color image segmentation accuracy.

Extraction of emotional impact in colour images, *Syntyche Gbèhounou, François Lecellier, and Christine Fernandez-Maloigne, Université de Poitiers (France)* **314**
This paper proposes a method to extract the emotional impact of images. Emotions are often associated with facial expressions, but we decided consider other features as first emotional characteristic of natural images, which, in general, does not contain faces. For a seek of generally we have built a new image database composed of a large variety of low semantic images. We used colour images because often colours and emotions are supposed to be linked.

For the modelling of the emotions, we considered colours features completed with other recent and efficient descriptors. We supposed that different features used could also implicitly encode high-level information about emotions. The concept of emotion is not easy to model. The perception of emotion is not only influenced by the content and the colour of the images. It is also modified by some personal experiences like cultural aspects and personal semantic associated to some colours or objects.

The complexity of emotion modelling was considered in classification process through psycho-visual tests. The twenty-five observers assessed the nature and the power of emotions they felt. These tests allowed us to distinguish three classes of emotions, which are "Negative", "Neutral" and "Positive" emotions.

We used a Support Vector Machine for classification and the average success rate is 51,75%; that is really relevant regarding the equivalent results in the literature.

Conference Banquet
19:00 – 23:00
Marble Hall, Royal Tropical Institute

WEDNESDAY MAY 9, 2012

Keynote
Session Chair: Alessandro Rizzi, Università Degli Studi di Milano (Italy)
8:15 – 9:00

8:15 **What makes a good picture? Reflections on image quality research,**
Geoff Woolfe, Canon Information Systems Research Australia Pty. Ltd. (Australia) . **320**
Image quality is a complex and multi-disciplinary field of research. Its applications cover a broad gamut including image engineering, photography, display technology and printing. Image quality is frequently an important consideration in optimizing technologies such as imaging device design, image compression, image encoding, colour management and broadcast transmission. In display and printing image quality plays an important role in design factors such as colour gamut, tone scale, resolution and spatial uniformity.

The paper begins by reviewing the development of image quality concepts from simple engineering measures of fidelity, through attempts to improve these measures by accounting for low level features of the human visual system.

In the case of photographic capture and rendering, the issue of fidelity of the image to the original scene is discussed, taking account of the consequences of colour appearance phenomena and colour preference.

Finally, the relationship between image quality and higher order cognitive factors including naturalness, composition and region of salience are examined.

Colour Vision/Cognition A
Session Chair: David H. Foster, University of Manchester (UK)
9:10 – 10:10

9:10 **Judgments about the intensity of the illumination are influenced by the association between colour and luminance in the scene,** *Eli Brenner, VU University (the Netherlands), and Sérgio Nascimento, University of Minho (Portugal)* **321**
In order to judge whether a surface that one is looking at is white or grey, one needs to consider the intensity of the illumination. We here show that people do not simply use the maximal luminance in the light from the scene as a measure for the intensity of the illumination but also consider how luminance and chromaticity are associated. We

suggest that they take into account that there are physical limitations to the luminance that reflecting surfaces can achieve at high chromatic saturation. These limitations arise because chromaticity is the result of surfaces selectively reflecting light of different wavelengths, so that the luminance of the illumination must be higher than that of the brightest patch in the scene if that patch is not white.

Color constancy involves correctly attributing a bias in the color of the light reaching your eyes to the illumination, and therefore compensating for it when judging surface reflectance. But not all biases are caused by the illumination, and surface colors will be misjudged if a bias is incorrectly attributed to the illumination. Evidence from within a scene (highlights, shadows, gradients, mutual reflections, etc.) could help determine whether a bias is likely to be due to the illumination. To examine whether the human visual system considers such evidence we asked subjects to match two surfaces on differently colored textured backgrounds. When the backgrounds were visibly rendered on screens in an otherwise dark room, the influence of the difference in background color was modest, indicating that subjects did not attribute much of the difference in color to the illumination. When the simulation of a change in illumination was more realistic, the results were very similar. We conclude that the visual system does not seem to use a sophisticated analysis of the possible illumination in order to obtain color constancy.

The enhancement of faded color on old pictures, printings, and paintings is one of important issue in color image processing. Several techniques have been introduced to enhance the faded images. Almost techniques are performed with global illuminant estimation algorithms such as the gray world assumption and white patch Retinex methods, since the phenomenon of color fading is regarded as an illuminant effect. However, fading effect is shown up differently according to the ink property, temperature, humidity, illuminants, and so on. Therefore simple global operators to eliminate the illuminant effects are not suitable for enhancing faded images. This paper presents a color enhancement algorithm based on multi-scale gray world algorithm for faded images. First, the proposed method adopts local process by using multi-scale mask. The coefficients for each multi-scale mask are obtained to apply the gray world algorithm. Then, integrating the coefficients with weights is performed to calculate correction ratio for red and blue channels in the gray world assumption. Finally, the enhanced image is obtained by applying the integrated coefficients to the gray world algorithm. In the experimental results, the proposed method reproduces better colors for both wholly and partially faded images compared with the previous methods.

10:10 – 10:40   Coffee Break

Colour Vision/Cognition B

Session Chair: Alessandro Rizzi, Università Degli Studi di Milano (Italy)
10:40 AM – 12:00

Color constancy refers to the ability of the human visual system to stabilize the color appearance of surfaces under an illuminant change. In this work we studied how the interrelations among nine colors are perceived under illuminant changes, particularly whether they remain stable across 10 different conditions (5 illuminants and 2 backgrounds). To do so we have used a paradigm that measures several colors under an immersive state of adaptation. From our measures we defined a perceptual structure descriptor that is up to 87% stable over all conditions, suggesting that color category features could be used to predict color constancy. This is in agreement with previous results on the stability of border categories and with computational color constancy algorithmsfor estimating the scene illuminant.

Local scene colour can influence the visual detectability of an object or target, but so can the familiarity, meaning, and global organisation of the scene. The aim of this study was to test whether the effects of local scene colour on target detectability are secondary to global effects. A target-detection task was undertaken by human observers with coloured images of natural scenes that were cut into quarters, randomly rearranged, and then reassembled. The target was a small, shaded, neutral grey sphere located randomly within the scene and matched in mean luminance to its local surround. It was found that observers' target-detection performance with the rearranged images was about as good as with the original images. The combination of local colour properties, namely, lightness and the red-green and yellow-blue components of chroma, accounted, respectively, for 55% and 50% of observers' detection performance with the original and rearranged images. Despite the disruption of global organisation, local scene colour continued to influence target detection.

To be able to score the aesthetic and emotional appealing of digital pictures through the usage of ad-hoc computational frameworks is now affordable. It is possible to combine low-level features and composition rule to extract semantic issues devoted to isolate the degree of emotional appealing of the involved subject. We propose to assess the aesthetic quality assessment on a general set of photos focusing on consumer photos with faces. Taking into account local spatial relation between involved faces and coupling such information with simple composition rule an effective aesthetic scoring is obtained. A further contribution of the proposed solution is the novel usage of the involved facial expressions and relative pose to derive additional insights to the overall procedure. Preliminary experiments and comparisons with recent solution in the field confirm the effectiveness of the proposed tool.

We present a statistical framework to automatically determine an associated color for a given arbitrary semantic expression. The expression can not only be a color name but any word or character string. In addition to the color value, we are also able to compute the result's significance, which determines how meaningful defining the color is for the expression. To demonstrate the framework's strength we apply it to two well known tasks: assessing memory colors and finding the color values for a given color name (color naming). We emphasize that we solve these tasks fully automatic without any psychophysical experiment or human intervention. Further, we outline the potential of our automatic framework and in particular the significance for the imaging community.

Spectral Colour Science

Session Chair: Markku Hauta-Kasari, University of Eastern Finland (Finland)
13:30 – 14:50 PM

This paper evaluated four conventional methods for reflectance recovery: smoothness method, principle component analysis, basis functions with smoothness constraint and Wiener estimation. Most of these methods adopt a "learning-based" procedure with a training set. Modifications based on the training set were applied for improving the reflectance recovery performance. This paper described combined methods involving the application of localised training data and localised training data with a weighted matrix to the four recovery methods. All these methods were applied to recover reflectance from XYZ values for two datasets. Both the training and testing performance were evaluated in terms of CIEDE2000 colour differences. The results showed that the

performance of the methods with localised training data significantly improved. There are also limited improvements by applying the weighted matrix. Overall, the localised weighted method (using a local training set with a weighted matrix) with Weiner estimation method performed the best.

13:50 **Representing outliers for improved multi-spectral data reduction,** *Farnaz Agahian and Brian Funt, Simon Fraser University (Canada); and Seyed Hossein Amirshahi, Amirkabir University of Technology (Iran)* **367**
Large multi-spectral datasets such as those created by multi-spectral images require a lot of data storage. Compression of these data is therefore an important problem. A common approach is to use principal components analysis (PCA) as a way of reducing the data requirements as part of a lossy compression strategy. In this paper, we employ the fast MCD (Minimum Covariance Determinant) algorithm, as a highly robust estimator of multivariate mean and covariance, to detect outlier spectra in a multi-spectral image. We then show that by removing the outliers from the main dataset, the performance of PCA in spectral compression significantly increases. However, since outlier spectra are a part of the image, they cannot simply be ignored. Our strategy is to cluster the outliers into a small number of groups and then compress each group separately using its own cluster-specific PCA-derived bases. Overall, we show that significantly better compression can be achieved with this approach.

14:10 **Spectrally tunable LED illuminator for vision research,** *Michal Mackiewicz,[1] Stuart Crichton,[2] Steve Newsome,[3] Robert Gazerro,[4] Graham D. Finlayson,[1] and Anya Hurlbert[2]; [1]University of East Anglia (UK), [2]Newcastle University (UK), [3]Gamma Scientific (USA), and [4]Digital Optics Corporation (USA)* **372**
Solid state lighting (SSL) is expected to become a popular light source for colour vision experiments. One of the advantages of the light emitting diodes (LEDs) is the possibility to shape the target light spectrum according to the experimenters' needs. In this paper we present the LED based tunable illuminator designed specifically for colour vision research. The equipment we use consists of six Gamma Scientific RS-5B lamps, each containing 9 different LEDs and the 1 m integrating sphere. We describe the specification of the system and the preliminary work that we carried out in order to set the system up. Finally, we describe the spectral and colorimetric matching algorithms we developed to produce target light spectra.

14:30 **Spectral reflectance estimation from transverse field detectors responses,**
Miguel A. Martinez, Eva M. Valero, and Javier Hernandez-Andres, University of Granada (Spain); and Giacomo Langfelder, Politecnico di Milano (Italy) **378**
The main aim of this study is to investigate which would be the best algorithm for spectral estimation from Transverse Field Detectors (TFD) sensor responses. We perform a quality check of the estimation accuracy of five different algorithms, most of which are recent proposals. Some modifications are introduced as well in their implementation to simplify calculations or to increase the performance (see subsection Spectral estimation algorithms for details). The results obtained have allowed us to introduce relevant suggestions for enhancing the TFD sensor performance for their use in multispectral capture devices. This work paves the way for the practical development of a fully automatic multispectral device based on sensors with reconfigurable responsivities.