

# IS&T REPORTER

"THE WINDOW ON IMAGING"

Vol. 25, No. 5 September/October 2010

## HIGHLIGHTED PAPERS: CGIV 2010

### Best Interactive Paper Award Session I

#### Estimation of an Individual's Human Cone Fundamentals from Their Color Matching Functions"

Casper F. Andersen, *Mediehøjskolen (Denmark)*, and  
Graham D. Finlayson, *University of East Anglia (UK)*

**Abstract:** Estimating individual cone sensitivities on the basis of their corresponding individual color matching functions is a classic problem of color vision. To solve the problem one has, in effect, to postulate constraints on the shape of the cone sensitivities. For example, Logvinenko applied a linear matching method (originally proposed by Bongard and Smirnov) which excludes all but one primary to which each of the sensitivities of the visual system is supposedly sensitive and, mathematically, if this constraint is met reasonable estimates should result. However, when applied to color matching functions in general, it turns out that the method estimates middle and especially long wave sensitivity quite poorly. We propose a new method based on linear optimization, in which it is assumed only that the photo-pigment spectral absorbance functions are known a priori. In an iterative scheme, the method works by simultaneously estimating the coefficients of the linear relation between the known individual color matching functions and estimated cone sensitivities and estimating the ocular and macular filtering that multiplied by the absorbances yield the estimated cone sensitivities. The ocular and macular pre-filtration is treated as a single spectral function

(i.e. a combined ocular and macular filtration). We are also able to predict the cone sensitivities proposed by Stockman and Sharpe in recent research. The method is tested on a selection of individual 1959 10 degree Color Matching Functions, with the assumption that they have the Stockman and Sharpe 10 degree photo-pigment spectral absorbance in common. The results for the estimated cone sensitivities look very plausible. Finally we have applied the method to the CIE1964 10 degree observer and get very reasonable result as well.

### Best Interactive Paper Award Session II

#### Estimating Melatonin Suppression and Photosynthesis Activity in Real-World Scenes from Computer Generated Images

David Geisler-Moroder and Arne Dür,  
*University of Innsbruck (Austria)*

**Abstract:** In lighting design and architectural illumination planning simulations of luminance and illuminance distributions within scenes are performed using rendering tools such as RADIANCE. In this paper we focus on the evaluation by two action spectra other than the luminous efficiency function – the circadian action function describing the melatonin suppression and the photosynthesis action function. We show how indices that are derived from these action spectra can be calculated from spectrally rendered images of a real-world scene. For both action

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To view the full papers of these abstracts for no fee go to  
[www.imaging.org/ist/publications/reporter/index.cfm](http://www.imaging.org/ist/publications/reporter/index.cfm)

You can also view a video of all of these talks, as well as most others from the conference, at  
<http://river-valley.tv/conferences/cgiv-2010>

\* These papers were presented at the CGIV 2010 conference, held June 14-17, 2010, in Joensuu, Finland.

spectra we derive approximations based on the CIE color matching functions that allow estimations of the corresponding index from RGB rendered images. We evaluate the differences between the spectral results and the RGB approximations for an office room with three different types of illumination.

## Visual Attention Simulation in RGB and HSV Color Spaces

Frédérique Robert-Inacio<sup>1,2</sup>, Quentin Stainer<sup>2</sup>, Rémy Scaramuzzino<sup>2</sup>, and Edith Kussener-Combier<sup>1,2</sup>; <sup>1</sup>Institut Matériaux Microélectronique et Nanosciences de Provence and <sup>2</sup>Institut Supérieur de l'Électronique et du Numérique (France)

**Abstract:** In computer vision several methods are directly inspired by the human visual system. Visual attention is one of the main abilities a human eye uses to discover a new scene. This ability is based on the focus of attention principle, which enables to look at a particular point. The works presented in this paper describe how to simulate such an ability in computer vision. Color images are resampled according to this principle, in order to considerably decrease the amount of data to be processed. This resampling is done by using a concentric distribution of hexagonal cells instead of the rectangular cell grid generally provided by uniform sensors such as CCD cameras. Such a distribution is derived from the cone distribution on the retina and the result is encoded by using polar coordinates. In this way the information is more and more blurred in an isotropic way, when getting far and far from the focusing point. This resampling method then allows decreasing data number while it globally keeps all the information included in the image. In this way a new scene can be explored by focusing successively at a sequence of focusing points. This allows reproducing the human eye behavior that explores a new scene by saccades. Furthermore the resampled images can be used in order to set up image preprocessing. For example this resampling can be achieved before a preliminary step of segmentation. The resampled image is segmented in order to coarsely determine regions. Afterwards the segmentation step can be refined by combining the segmented resampled image and the original image. A comparison between results obtained in RGB and HSV spaces is also given on a set of images.

## Color Edge Saliency Boosting using Natural Image Statistics

David Rojas Vigo, Joost van de Weijer, and Theo Gevers,  
Universitat Autònoma de Barcelona (Spain)

**Abstract:** State of the art methods for image matching, content-based retrieval and recognition use local features. Most of these still

exploit only the luminance information for detection. The color saliency boosting algorithm has provided an efficient method to exploit the saliency of color edges based on information theory. However, during the design of this algorithm, some issues were not addressed in depth: (1) The method has ignored the underlying distribution of derivatives in natural images. (2) The dependence of information content in color-boosted edges on its spatial derivatives has not been quantitatively established. (3) To evaluate luminance and color contributions to saliency of edges, a parameter gradually balancing both contributions is required. We introduce a novel algorithm, based on the principles of independent component analysis, which models the first order derivatives of color natural images by a generalized Gaussian distribution. Furthermore, using this probability model we show that for images with a Laplacian distribution, which is a particular case of generalized Gaussian distribution, the magnitudes of color-boosted edges reflect their corresponding information content. In order to evaluate the impact of color edge saliency in real world applications, we introduce an extension of the Laplacian-of-Gaussian detector to color, and the performance for image matching is evaluated. Our experiments show that our approach provides more discriminative regions in comparison with the original detector.

## Digital Reproduction of Small Gamut Objects: A Profiling Procedure based on Custom Color Targets

Giorgio Trumpy, Institute of Applied Physics "N. Carrara" (Italy)

**Abstract:** In this paper the optimization of color accuracy of digital reproductions is approached. Standard color targets currently available on the market, are constituted of colors spread uniformly in the color space, therefore, these targets are usable in any situation, i.e. for any chromatic content of the images to be profiled. The usage of standard color targets becomes an issue when the object that has to be reproduced is characterized by a small gamut of colors. In this case the ICC profile that can be obtained with a standard color target may miss to match with sufficient accuracy the dominating color due to two different causes. First, with reference to the colors of the standard target, the software used to create an ICC profile attempts to optimize all colors, including those which are not present in the object. Secondly, the color of the object can be colorimetrically distant from the patches of the target and therefore the interpolation process required results in a low level of precision. Hence the profiling process would work better if the color of the patches of the target were chosen with reference to the palette of the object that has to be reproduced. Here this problem is approached empirically by developing a new profiling procedure. A custom-made color target has been created in order to optimize the color accuracy of the digital reproduction of a small gamut object. Selection of colors has been carried out from a color catalogue, choosing a set with colorimetric values uniformly distributed in the volume of the color space took up by the gamut of

*continued on page 5*

# Industry and Academia Meet at CVGIV2010

by Alain Trémeau, Program Chair

CGIV2010, the fifth European Conference on Colour in Graphics, Imaging, and Vision, was held June 14-17, in Joensuu, at the University of Eastern Finland (UEF). Collocated, and making up the Thursday technical papers program, was MCS'10, the 12th International Symposium on Multispectral Colour Science.

Organized by General Chairs Jussi Parkkinen and Timo Jääskeläinen (UEF), UEF Joensuu Color Group staff, and Program Chairs Theo Gevers (University of Amsterdam, Netherlands) and Alain Trémeau (Université Jean Monnet, Saint-Etienne, France), the conference welcomed 144 participants. UEF, the city of Joensuu, the Infotonics Center Joensuu, and Specim provided financial or in-kind support to the conference.

## Breadth of Program

With attendees hailing from 21 countries from as far away as Japan, Taiwan, and the USA, CGIV 2010 was truly an international meeting. The breadth of the papers program shows that the field of color science is robust in Europe, as well as increasing in importance in education, research, and industry. It is essential to keep this progress moving forward as a combined effort within the entire European color science community. As an international event, CGIV 2010 provides a unique opportunity to foster and support such co-

CGIV 2010 STATS	
Attendees:	144
Oral Papers:	51
Interactive Papers:	36
Workshops:	2
Exhibitors:	1
Dates:	June 14-17, 2010
Location:	Joensuu, Finland



The city of Joensuu hosted a delicious dinner of local delicacies in the lovely, Art Deco-inspired City Hall.

operation within the community, as well as offers those attending the chance to learn, exchange viewpoints, and seek out interesting and new collaborations from around the globe.



Held in the Infotonics Park at the University of Eastern Finland in Joensuu, complementary workshops offered the first day of the conference provided attendees with hands-on opportunities to learn about various aspects of color measurement.

## VÄRITUTKIMUS

# Spektristä apua lääketieteeseen

Itä-Suomen yliopisto isännöi kansainvälistä väritutkimuskonferenssia tällä viikolla.

JANUARI  
Juoni Hiltunen

Tutkimuslaitos kehittää haastavien värien tutkimusta varten värien tutkimusta ja värien tutkimusta.



Spektriä tutkivat professori Karl Gegenfurtner ja dosentti Markku Hauta-Kasari.

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Photos: Jouni Hiltunen



## Technical Program

In order to continue to strengthen the overall quality of the conference, authors were asked to submit a full-length paper; next a robust reviewing process was employed. Each paper was reviewed by at least two experts as part of the technical program acceptance process. The conference encompassed technical areas that were a balance between academic and industrial topics, providing plenty of opportunities for professional networking. The 87 paper strong technical program emphasized color science technology with presentations focusing on color vision and color psychophysics, color reproduction,

color image processing and color analysis, color image and video processing, and color difference equations, and through two half-day Workshops, three keynote presentations, 49 oral talks, and 36 interactive papers. Most of talks were captured for future viewing and can be found at <http://river-valley.tv/conferences/cgiv-2010>.

## Workshops Offer Hands-on Learning

Breaking from the tradition of short courses, CGIV2010 offered two complementary workshops, which were very well attended. The first workshop, given by Roger D. Hersch (EPFL), assisted by

Romain Rossier, discussed “Modeling the Interaction of Light, Paper, and Ink Halftones.” The workshop was comprised of a lecture and hands-on laboratory session. The second workshop—“Spectral Color Measurements”—was taught by several members of the UEF Joensuu Color Group, including Jukka Antikainen, Ville Heikkinen, Jouni Hiltunen, Tuija Jetsu, Jussi Kinnunen, and Pertti Silfsten. In this workshop, after an overview lecture on color measurement, participants were divided into three groups that rotating between three labs where hands-on practicums were given: measuring with integrating spheres and bidirectional

Traditional Finnish folk dances performed and then taught to attendees by professionals entertained attendees at the Conference Banquet Wednesday night.



Top row, middle and far right: A color matching game, lakeside conversations, local grilled meat dinner, and the chance to enjoy a traditional sauna (followed by dip in the lake) were highlights of the CGIV Reception, held at the “Home of the Polar Bears” swim club.

Photos: Jouni Hiltunen

Photos: Jouni Hiltunen



General Chair Jussi Parkkinen, Program Chair Alain Trémeau, Coordinating Chair Markku Hauta-Kasari, and Program Chair Theo Gevers at the conference banquet.

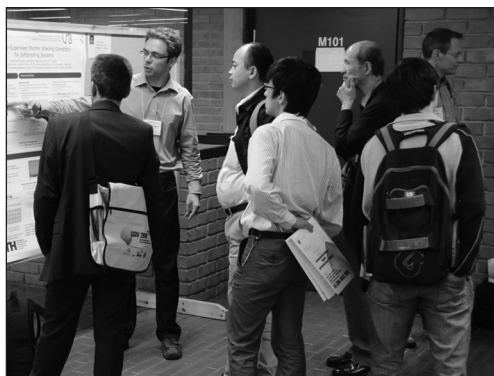
geometries; bispectral fluorescence measurements and simulations; and line scanning and LCTF spectral image capturing.

### Keynote Talks

CGIV2010 opened with a keynote presentation by Karl Gegenfurtner (Justus-Liebig-Universität, Germany) on "Cortical mechanisms of Color Vision." Wednesday Alexander Logvinenko (Glasgow Caledonian University, UK) gave the keynote "An Object-Colour Space." Jon Y. Hardeberg (Gjøvik University College, Norway) presented the MCS'10 keynote "Color by Numbers—Quantifying the Quality of Color Reproduction" on Thursday morning.

### Engaging Social Program

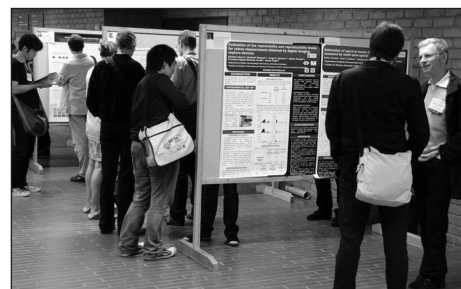
In addition to the exciting and substantive



technical program, a number of social functions provided opportunities to network and enjoy Joensuu including the opportunity to experience a famous Finnish sauna! The Welcome Reception was hosted by the City of Joensuu in a welcoming environment where a delectable banquet with memorable dishes was served. The Conference Banquet featured traditional

A highlight of the conference were the two Interactive Paper Sessions. Casper F. Andersen, Mediehighskolen, and Graham D. Finlayson, University of East Anglia, won the Best Interactive Paper Session I award for "Estimation of an Individual's Human Cone Fundamentals from Their Color Matching Functions" and David Geisler-Moroder and Arne Dür, University of Innsbruck Best Interactive Paper Session II award for "Estimating Melatonin Suppression and Photosynthesis Activity in Real-World Scenes from Computer Generated Images."

Below left: Casper Andersen receives his award and a Finnish gift from Markku Hauta-Kasari.



and contemporary songs and dance performances, as well as allowed attendees to try their hand at Finnish folk dance. CGIV2010 proved to be a week full of intellectually and personally satisfying events.

### CGIV 2012

The next CGIV will be held in May 2012 in Amsterdam, the Netherlands. ▲

*continued from page 2*

the object. Then, the creation of the ICC profile has been carried out referring to the new target. The main results obtained through a comparison between the developed custom profiling procedure and the standard profiling procedure confirmed a higher precision of the new procedure.

## Effect of Colorimetric Attributes on Perceived Blackness of Materials

Reid Clonts, Renzo Shamey, and David Hinks,  
North Carolina State University (USA)

**Abstract:** While black is one of the most prevalent industrial colors in the world, the colorimetric attributes of what is considered black vary significantly and the range of subtle hue undertones can be numerous. However, no systematic study can be found in the literature pertaining to the potential role of colorimetric attributes in the per-

ceptual assessment of blackness. We have experimentally determined that the perception of blackness is influenced by hue and chroma using psychophysical assessments of a range of black materials.

In the initial part of this study a series of  $2 \times 2$ " precision cut glossy Munsell color samples comprising a hue circle with a lightness ( $L^*$ ) of approximately 20.5 and chroma ( $C^*$ ) between 4 and 6 were assessed using thirty color normal observers and a filtered tungsten daylight simulator (D65). Observers were asked to arrange samples in order from most like black to least like black with no time limits in three separate sittings. In the second part of the study 27 over-dyed woolen samples were arranged in  $2" \times 3"$  dimensions. Samples in this set had a lightness range of 14-16 and  $C^*$  of 0.5-3.5, and were assessed by 25 observers in two sittings in the same manner. The third set of samples comprised 24 precision cut  $2" \times 2"$  dyed acrylic samples with a  $L^*$  range of 10.5-12 arranged around the hue circle. Samples were selected such that they comprised three concentric hue circles of eight evenly spaced samples each. The samples were divided into five sets according to chroma: A ( $C^* = 0.12-0.20$ ), B ( $C^* = 0.42-0.57$ ),

*continued on page 8*



## STANDARDS UPDATE:

David Q. McDowell, Editor

This issue of *Standards Update* will highlight the meetings of the TC 130 Working Groups and the TC 130 Plenary held in São Paulo, Brazil October 11-16, 2010. With more than 70 delegates and observers from 14 countries this was probably the largest meeting of TC 130 since its formation in 1989.

In addition to a strong attendance at the meeting, the Secretariat reported that in the last year three countries changed from O-member (observer) to P-member (participating) status. These are Australia, Ireland, and the Republic of Korea. In addition Israel joined as a new P-member, bringing participation in TC 130 to 23 P-members and 17 O-members.

The Secretariat's report also noted that TC 130 published seven standards in the last year, which brings active TC 130 standards to a total of 68. There are currently 33 documents in process in TC 130, including 12 work items introduced at this Plenary. While the bulk of the existing standards have been produced by the five Working Groups (WGs) that formed the original core of TC 130, there are now 13 working groups and the diversity of the TC 130 standards will expand.

The current WGs, including the three created at this Plenary, are:

- WG 1 Terminology
- WG 2 Prepress data exchange
- WG 3 Process control and related metrology
- WG 4 Media and materials
- WG 5 Ergonomics/Safety
- WG 6 Certified reference materials (standby)
- WG 7 Colour management (Joint WG with ICC)
- JWG 8 Revision of ISO 13655 (Joint WG with ISO/TC 42) (standby)
- WG 9 Development of ISO 12640-5 (Joint WG with ISO/TC 42)
- WG 10 Management of security printing processes
- WG 11 Carbon footprinting

- WG 12 Postpress
- WG 13 Printing certification requirements

Other items of note from the Plenary meeting itself are:

- ISO 16684-1, *Graphics technology — Extensible metadata platform (XMP) specification — Part 1: Data model, serialization and core properties*, is presently in the ISO fast track process; responsibility for this document is assigned to WG2/TF4.
- TC 130 resolved to use CIEDE2000, where appropriate, for all new ISO/TC 130 standards and revisions of existing standards.
- TC 130 added a preliminary work item (PWI) for the development of an international standard titled: *Graphic technology — Requirements for measuring the carbon footprint of printed products*
- TC 130 added a preliminary work item (PWI) for the development of an international standard entitled: *Graphic technology — Criteria and Requirements for Printing Quality Management Systems*.
- The spring 2011 meetings of TC 130 WGs will be held in Berlin, Germany the week of April 11 and the Fall 2011 WG meetings and Plenary will be held in Tokyo, Japan in conjunction with the IGAS graphic arts show in September.

A PWI is also referred to as a Stage 0 project. It is the mechanism used to allow an ISO TC to formally start work on a project when the subject matter is clearly identified, but the details of the probable standard(s) is still being developed. One key issue is that once a project moves beyond Stage 0, the ISO clock starts ticking with regard to required progress through the various stages of approval. Stage 0 allows work to be started, a formal reference number to be assigned, but without the clock running.

Brief summaries of the work of each active TC 130 Working Group follow.

### WG1 Terminology

WG1's new Convenor is David Penfold of Great Britain. It is working on two standards: ISO 5776, *Graphic technology — Symbols for text correction*, and a revision of the multi-part standard ISO 12637, *Graphic technology — Vocabulary*.

### WG2 Prepress Data Exchange

Key current, ongoing activities in WG2 are: ISO 12640-5, *Graphic technology — Prepress digital data exchange — Part 5: Scene-referred standard colour image data (RIMM/SCID)*; ISO 17972, *Graphic technology — Prepress data exchange — Colour data exchange format (CxFx)*; and ongoing work to develop solutions for a variety of issues related to PDF/X.

The PDF/X issues include: Ink Attributes, Page level output intents, Black point compensation, Overprint simulation requirements, Non-printable content, PDF/X packages and Alternate presentations, and Multi-media co-existence in PDF/X.

WG2 is responsible for ISO 16684-1, *Graphic technology — XMP specification — Part 1: Data model, serialization, and core properties*, which is currently in the Fast-Track voting procedure. TF4 has been created in WG2 to follow XMP work.

Work has also been started on a new standard that will define the preparation and visualization of RGB images used in RGB-based graphic arts workflows. This work comes out of several years effort by the Japanese TC 130 National Body and is expected to progress quickly to a completed International Standard.

### WG3 Process Control and Related Metrology

WG3 probably has the largest workload of all of the TC 130 WGs. Current ongoing projects include: Revision of ISO 12646, *Graphic technology — Displays for*

colour proofing — characteristics and viewing conditions; ISO 14861, *Graphic technology — Colour Proofing using electronic displays*; ISO 12647-6, *Graphic technology — Process control for the manufacture of half-tone colour separation, proofs and production prints — Part 6: Flexographic printing*; ISO 12647-8, *Graphic technology — Process control for the manufacture of half-tone colour separation, proofs and production prints — Part 8: Validation print processes working directly from digital data*; and ISO 15339-1, *Graphic technology — Printing of digital data — Part 1: Basic principles*.

In addition WG3 has several new standards being started. These include: a revision of Parts 1, 2 and 3 of ISO 12647, *Graphic technology — Process control for the manufacture of half-tone colour separation, proofs and production prints*, which deal with general parameters, offset lithography, and coldest offset on newsprint; and a multi-part standard ISO 15311, *Graphic technology — Requirements for printed matter utilizing digital printing technologies for commercial and industrial production*.

#### WG4 Media and Materials

The WG4 standards currently under active work include: ISO 12705, *Graphic technology — Laboratory test method for chemical ghosting in lithography*, ISO 15341, *Graphic technology — Method for radius determination of printing cylinders*, and the revision of the ISO 2846-3, *Graphic technology — Colour and transparency of printing ink sets for four-colour printing — Part 3: Publication gravure printing* and ISO 2846-5: *Flexographic printing*.

A new document ISO 15397 *Graphic technology — Communication of optical and surface properties of printing substrates — Graphic papers for proofing, rotogravure, heat-set web offset and offset sheets* has been prepared and is currently in ballot.

#### WG5 Ergonomics/Safety

WG5 is focused on a five-part document

called ISO 12643, *Graphic technology— Safety requirements for graphic technology equipment and systems*, and a technical report, TR 15847, *Graphic technology — Graphical symbols for printing press systems and finishing systems, including related auxiliary equipment*.

The five parts of ISO 12643 are:

Part 1: General requirements

Part 2: Press equipment and systems

Part 3: Bindery equipment and systems

Part 4: Converting equipment and systems

Part 5: Stand-alone platen presses

These have all been completed and are in various stages of balloting and publication. A New Work Item (NWI) to update Part 1 is currently being prepared.

#### WG 7 Colour management

WG7 works jointly with the International Color Commission (ICC) and is responsible for ISO 15076-1 *Image technology colour management — Architecture, profile format and data structure — Part 1: Based on ICC.1:2010*. The first revision of this document has just completed final ballot and it will be published shortly.

#### JWG 9 Development of ISO 12640-5

The fifth document in the ISO 12640 SCID series (standard colour image data) deals with scene referred data. Like the other SCID standards it will contain image data that is part of the normative part of the standard. ISO 12640-5, *Graphic technology — Prepress digital data exchange — Part 5: Scene-referred standard colour image data (RIMM/SCID)* is the first to contain data that is un-rendered. That is, it is still in scene space and represents to the best of our ability what the camera saw, not what it captured.

Work is almost complete on the first ballot draft (CD) of RIMM/SCID and it is anticipated that it will be in ballot by early 2011.

#### WG 10 Management of security printing processes

WG10 will have its first meeting Nov. 17, 2010 in the Netherlands. TC 247, Fraud countermeasures and controls, has

requested that this work be done in a JWG between TC 130 and TC 247. This request will be considered at the November meeting.

#### WG 11 Carbon Footprinting

Up until this meeting WG11 was TC 130 Task Force 1. The first standard undertaken by WG11 will be *Graphic technology — Requirements for measuring the carbon footprint of printed products*, which was approved by the Plenary meeting as a Stage 0 project.

#### WG 12 Postpress

WG12 started as Task Force 2 and was also converted into a WG by this Plenary. It received Plenary approval to start work on two standards at Stage 0. These are: *Graphic technology — Requirements for postpress — General* and *Graphic technology — Requirements for postpress — Bound products*.

#### WG 13 Printing certification requirements

This is the newest of the TC 130 WGs. It grew out of activities of a informal group in WG3 that studied the way various national bodies were looking at compliance of printers to various TC 130 standards. One title suggested for its first document is *Graphic technology — Criteria and Requirements for Printing Quality Management Systems*.

Much of the work of WG13 will draw upon the ISO 9000 family of standards to describe the relationship between the existing TC 130 standards and certification and compliance recommendations of the ISO 9000 series.

As we move more and more into the globalization of printing, it is important that the certification of printers, and printing, is consistent among and between national body groups that provide certification.

*For questions about the activities of TC 130, for suggestions for (or input to) future updates, or standards questions in general, please contact the editor at mcdowell@npes.org.*

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C ( $C^* = 0.89-0.97$ ), D ( $C^* = 1.58-1.86$ ), and E ( $C^* = 3.34-3.46$ ). For the assessment of samples in the third set 100 color normal observers were employed that repeated the assessments in three separate sittings with at least 24 hours gap between each sitting. Analysis of the data indicates that, irrespective of chroma, on average samples with hue angles between approximately  $200^\circ$  and  $270^\circ$  were perceived to be the most black, *i.e.*, cyan to bluish-blacks. Blacks with hue angles above  $315^\circ$  or below  $45^\circ$  (reddish-blacks) were considered to be the least black. Chroma and lightness also influenced the perceived blackness but for the majority of samples the effect was less pronounced.

## Comparison of Colour Difference Methods for Natural Images

Henri Kivinen, Mikko Nuutinen, and Pirkko Oittinen,  
Aalto University School of Science and Technology (Finland)

**Abstract:** Perceptual colour difference in simple colour patches has been extensively studied in the history of colour science. However, these methods are not assumed to be applicable for predicting the perceived colour difference in complex colour patches such as digital images of complex scene. In this work existing metrics that predict the perceived colour difference in digital images of complex scene are studied and compared. Performance evaluation was based on the correlations between values of the metrics and results of subjective tests that were done as a pair comparison, in which fifteen test participants evaluated the subjective colour differences in digital images.

The test image set consisted of eight images each having four versions of distortion generated by applying different ICC profiles. According to results, none of the metrics were able to predict the perceived colour difference in every test image. The re-

sults of iCAM metric had the highest average correlation for all images. However, the scatter of the judgements was very high for two of the images, and if these were excluded from the comparison the Hue-angle was the best performing metric. It was also noteworthy that the performance of the CIELAB colour difference metric was relatively high.

## Angular Variations of Color in Turbid Media – The Influence of Bulk Scattering on Goniochromism in Paper

Magnus Neuman,<sup>1</sup> Per Edström,<sup>1</sup> Mattias Andersson,<sup>1</sup> Ludovic Coppel<sup>1,2</sup> and Ole Norberg<sup>1</sup>; <sup>1</sup>Mid Sweden University and <sup>2</sup>Innventia AB (Sweden)

**Abstract:** The angular variations of color of a set of paper samples are experimentally assessed using goniophotometric measurements. The corresponding simulations are done using a radiative transfer based simulation tool, thus considering only the contribution of bulk scattering to the reflectance. It is seen that measurements and simulations agree and display the same characteristics, with the lightness increasing and the chroma decreasing as the observation polar angle increases. The decrease in chroma is larger the more dye the paper contains. Based on previous results about anisotropic reflectance from turbid media these findings are explained. The relative reflectance in large polar angles of wavelengths with strong absorption is higher than that of wavelengths with low absorption. This leads to a loss of chroma and color information in these angles. The increase in lightness is a result of the anisotropy affecting all wavelengths equally, which is the case for transmitting media and obliquely incident illumination. The only case with no color variations of this kind is when a nonabsorbing, non-transmitting medium is illuminated diffusely. The measured and simulated color differences are clearly large, and it is an open issue how angle resolved color should be handled in standard color calculations. ▲

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## UPCOMING IS&T EVENTS

January 23-27, 2011; San Francisco Airport Hyatt Regency  
**Electronic Imaging 2011**  
Symposium Chairs: Sabine Süssstrunk and Majid Rabanni

May 16-19, 2011; Salt Lake City, Utah  
**Archiving 2011**  
General Co-chairs: Wayne Metcalfe and Kate Zwaard

October 2-6, 2010; Minneapolis, Minnesota  
**NIP27: 27th International Conference on Digital Printing Technologies/Digital Fabrication Processes 2011**  
General Chairs: Xavier Bruch (NIP27) and Shinri Sakai (DF2011)

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