Preface

We welcome you to the proceedings of CCIW 2015, the Computational Color Imaging Workshop, held in Saint-Étienne, France, during March 24–26, 2015.

This fifth CCIW was organized by University Jean Monnet, Saint-Etienne, with the endorsement of the International Association for Pattern Recognition (IAPR), the *Association Française pour la Reconnaissance et l'Interprétation des Formes* (AFRIF) affiliated with IAPR, and the *Groupe Français de l'Imagerie Numérique Couleur* (GFNIC).

The aim of the workshop was to bring together engineers and scientists of various imaging companies and research laboratories from all over the world, to discuss diverse aspects of their latest work, ranging from theoretical developments to practical applications in the field of color imaging, as well as color image processing and analysis.

Since the first Computational Color Imaging Workshop organized in 2007 in Modena, Italy, CCIW has been an inspiration for researches and practitioners in the fields of digital imaging, multimedia, visual communications, computer vision, and consumer electronics, who are interested in the fundamentals of color image processing and its emerging applications.

For CCIW 2015 there were many excellent submissions of high scientific level. Each paper was peer reviewed by at least two reviewers. Only the best 17 papers were selected for presentation at the workshop. The final decision for the papers selection was based on the criticisms and recommendations of the reviewers, and the content relevance of papers to the goals of the workshop. In addition to the submitted papers, six distinguished researchers were invited to this fifth CCIW to present keynote speeches.

In this 5th Computational Color Imaging Workshop, challenging issues and open problems not sufficiently addressed in the state of the art were addressed. In the following, we summarize issues and problems that were covered by the papers accepted in CCIW 2015 or invited speeches, and put in perspective these papers relative to the other papers published recent in the state of the art.

The 5th Computational Color Imaging Workshop (CCIW 2015) was started on March 24, 2015 with a keynote presentation by Mathieu Hébert on *Color and Spectral Mixings in Printed Surfaces*. Meanwhile, many studies addressed issues related to color mixing, but very few studies were carried out on spectral mixing within the visible range. In his presentation, Mathieu Hébert presented different computational mixing models (additive, non linear additive, multiplicative, non linear multiplicative, etc.,) of spectra data for modeling of heterogeneous surfaces (e.g., textured materials, goniochromatic surfaces, printed samples, etc.,). Recently, spectral variability within an image has raised more attention in the field of hyperspectral images and some techniques have been proposed to address this issue, e.g., spectral bundles [33], but most of these techniques have been developed for spectral data outside the visible range.

In the Color reproduction session, Dmitry Kuzovkin et al. proposed an automatic method for example-based image colorization and a robust color artifact regularization method [15]. This paper proposed new improvements for color mapping which were not covered by the recent survey on color mapping written by H.S Faridul et al. [9]. In the next presentation, G.M. Atiqur Rahaman et al. proposed to extend the Murray–Davies reflectance model used for modeling spectral halftone images and to improve the efficiency prediction of this model to changes in reflectance by a power function [27]. Lastly, Ryosuke Nakahata et al. proposed a dynamic relighting method for moving planar objects with unknown reflectance [25]. By acquiring the surface spectral reflectance of moving objects, this method is able to reproduce accurate colors on a display device. This research topic is still largely unexplored. Most of the solutions using a projector-camera system were published recently in the state-of-the-art address issues related to photometric compensation but not to color compensation. Moreover, most of these papers deal with static surfaces and not with moving surfaces. However, wide range of applications such as augmented reality, education, cultural heritage, and interactive art installations could benefit from progress in this field.

Another challenging issue in computational color imaging is related to the color rendering of color reproduction. Some authors tried to improve this issue by improving first the color acquisition. In his invited speech, titled *The good, the bad and the ugly: the color we would like, the color we have, its appearance and dynamic range*, Alessandro Rizzi discussed some "hidden" issues, often not taken into account, related to color acquisition that can introduce severe errors in the color information [22]. Among these issues, he focused on the limits of accurate camera acquisition, the usable range of light of our vision system, and the role of accurate versus non-accurate luminance recording for the final appearance of a scene.

In the Color sensation and perception session, G.M. Atiqur Rahaman et al. investigated issues related to the acquisition and analysis of memory colors of objects found in natural scenes [28]. In the next presentation, João M.M. Linhares et al. investigated the effect on a display gamut of varying the optical density and the position of the maximum sensitivity of the cones spectra of anomalous trichromatic observers [16]. Lastly, Jorge L.A. Santos et al. investigated reaction times for normal color and dichromatic observers in a visual search experiment. [29]. These three papers addressed a wide range of problems related to vision science (i.e., to sensation and perception). As discussed by J.J. McCann in [23], the problems investigated in color image processing community are not only related to digital imaging disciplines but define an area of research on the frontier between vision science and image/display technology and must be addressed from several different perspectives/disciplines (physics, psychophysics, artificial intelligence, and fine arts). Thus, for example, according to J.J. McCann, the color appearance of a scene is not only correlated to the surfaces reflectance (which depend on the spectral distribution and the dynamic range of the illumination) and to the scene spatial content (e.g., a flat representation or a 3D scene), but also to the sensitivities of the human L, M, S cones.

The 5th Computational Color Imaging Workshop (CCIW 15) continued till March 25, 2015 with a presentation, by invited speaker, Joost Van de Weijer on *Color features in the era of big data*. The process of unsupervised feature learning (e.g., deep learning) has recently received a lot of attention in the field of computer vision. Meanwhile many studies were carried out only on color data, since recently few studies have been carried out on multimodal data (e.g., RGB and depth data [12] or RGD and temporal data [26]). However, several papers have demonstrated that machine learning plays an important role in bridging the gap between feature representations and decision making (e.g., for object/scene recognition, human pose estimation, and gesture/activity recognition) by learning useful information from a large set of RGB-D data [2]. In [2], Kai Berger discussed challenging issues related to the use of the publicly available datasets and suggested that in the following years there will still be challenges for multiple RGB-D sensors relying on the emission of light to be addressed by the community. One challenging issue of unsupervised feature learning is to benchmark dataset with ground truth (e.g., for video labelling). Unfortunately, very interesting datasets, such as the KITTI dataset, do not provide a semantic segmentation benchmark yet. In [32], Joost Van de Weijer et al. provided an overview of color name applications in computer vision, including image classification, object recognition, texture classification, visual tracking, and action recognition and demonstrated that in general color names outperform photometric invariants.

In the Color image processing session, Pablo Martinez-Canada et al. proposed a configurable simulation platform that reproduces the analog neural behavior of different models of the human visual system at the early stages [21]. Next, Yann Gavet et al. proposed to use the Color Logarithmic Image Processing (CoLIP) for white balance correction and color transfer [11]. Yann Gavet demonstrated that the CoLIP framework is correlated to the human visual perception system, as first, it follows the Weber/Fechner law with its logarithmic model and second, it is based on the opponent-process theory from Hering. Next, Gianluigi Ciocca et al. investigated the influence of color on the perception of image complexity. To this end they performed two different types of psychophysical experiments that they reported [6]. These three papers addressed a wide range of color image processing solutions related to vision science. Lastly, Andreas Kleefeld et al. proposed a new framework for color-valued median filters [14].

Another challenging issue in computational color imaging is related to the processing of spectral imaging data. In his invited speech, titled *Optics and Computational Methods for Hybrid Resolution Spectral Imaging*, Masahiro Yamaguchi introduced the concept of “Hybrid Resolution Spectral Imaging” (HRSI) and presented algorithms for reconstructing a spectral images [35]. The goal is to combine a high-resolution RGB image and a low-resolution spectral image in order to capture high resolution spectral video with a compact and handy camera system. Thanks to hybrid spectral imaging systems, it becomes possible to think of new applications and new developments in spectral imaging.

In the Spectral imaging session, Simone Bianco investigated if the performance of hyperspectral face recognition algorithms can be improved by considering 1D projections of the whole spectral data along the spectral dimension [3]. Feature band selection, dimensionality reduction, and feature extraction are challenging issues for face recognition task and also for other computer vision tasks. Even if, in the last ten years, many studies tried to solve these issues in the field of face recognition, several of them remain to be overcome. Similar issues remain to be overcome in other application fields. For example, Naveed Akhtar et al. proposed a sparse representation-based approach for hyperspectral image super-resolution [1]. They tested their approach using the hyper spectral images of objects, real-world indoor and outdoor scenes, and remotely sensed hyper-spectral images. In the next presentation, Hilda Deborah et al. proposed a spectral noise model using spectral database of uniform color/pigment patches, which answers the challenge of identifying spectral noise model [8]. Lastly, Xingbo Wang et al. investigated the colorimetric performance of CFA/MSFA-based image acquisition system [34]. Despite the number of studies dealing with spectral imaging, little attention has been given to the evaluation of the quality of spectral images and of spectral imaging systems. However, we can note that there is a general tendency to address this issue from several different perspectives (physics and psychophysics).

Next, in cooperation with the European COST action TD 1201, on March 26, 2015, a special session on Color in digital cultural heritage was organized.

The process of color digitization of 3D objects in cultural heritage has recently received much attention due to still improving quality and resolution of digital objects [19, 4, 5]. One tendency to improve color accuracy is to use a multispectral system. Thus, Jay Arre Toque et al. proposed to use a high-resolution multispectral scanning for mesoscopic investigation of discoloration of traditional Japanese pigments [30]. On the other hand, Ailin Chen et al. proposed to use a hyperspectral camera to visualize invisible information (i.e., outside the visible range) in paintings for restoration purpose [7].

Another tendency is to improve the performance of color-difference formulas [24] or to evaluate with these formulas if a color digitization system is accurate enough. Thus, Tatiana Vitorino et al. proposed to use the ColorChecker chart to assess the usefulness and comparability of data acquired with two hyper spectral systems [31]. On the other hand, Juan Martinez-Garcia et al. proposed to use a specular color chart to calibrate the color digitization of highly specular materials with a microscopic imaging system [20].

The process of 3D objects visualization in cultural heritage has also received much attention due to the development of color rendering and color correction algorithms. Some authors studied these issues from the observer's perspective (i.e., visual observation). Thus, Sergio Nascimento et al. investigated which color compositions observers prefer when they look at some paintings [17]. Other authors proposed to address these issues using photometry/spectrophotometry models. For example, Lindsay MacDonald in his invited speech, titled *Representation of Cultural Objects by Image Sets with Directional Illumination* addressed problems related to the modeling of the diffuse and specular reflectance of 3D objects and to the 3D surface reconstruction from photometric stereo [18]. Another approach consists of addressing these issues using computer vision models. For example, Zoltan Kato in his invited speech, titled *Relative Pose Estimation and Fusion of 2D Spectral and 3D Lidar Images* discussed problems related to the pose estimation without the use of any special calibration pattern or explicit point correspondence [13]. This paper addressed one of the most challenging issues in digital cultural heritage, which is the fusion of 2D RGB/spectral imagery with other 3D range sensing modalities (e.g., Lidar). On the other hand, Citlalli Gamez Serna et al.

proposed a semi automatic 2D-3D registration framework to produce accurate realistic results from a set of 2D uncalibrated images and a sparse 3D point cloud representation of an object digitized with laser scanning [10].

March 2015

Alain Trémea
Raimondo Schettini
Shoji Tominaga

Acknowledgments

Many organizations and people helped us in the planning of this meeting. Among them, we are pleased to acknowledge the generous support of the University Jean Monnet at Saint-Etienne, the Laboratoire Hubert Curien (UMR 5516) and Télécom Saint-Etienne, France, the University of Milano-Bicocca, Italy, and the Graduate School of Advanced Integration Science, Chiba University, Japan.

Special thanks to the COSCH action (COST action TD 1201) for the co-organization and co-funding of the special session on color in digital cultural heritage. The research laboratory hosting this workshop was supported by Saint-Etienne Métropole, the Région Rhone-Alpes (ARC 6, programme MONEITHS), and the PRES of Lyon (programme PALSE IRF).

Special thanks also go to all our colleagues on the Conference Committee for their dedication and hard work, without which this workshop would not have been possible.

References

1. Naveed Akhtar, Faisal Shafait, Ajmal Mian, Sparse Spatio-spectral Representation for Hyperspectral Image Super-resolution, Lecture Notes in Computer Science, Proceedings of ECCV Volume 8695, pp 63-78, 2014.
2. Kai Berger, A State of the Art Report on Multiple RGB-D Sensor Research and on Publicly Available RGB-D Datasets, Chapter 2, pp 27-44, Book titled Computer Vision and Machine Learning with RGB-D Sensors, Springer, 2014
3. Simone Bianco, Can linear data projection improve hyperspectral face recognition?, Proceedings of the 5^{th} International Workshop CCIW'2015.
4. F. Boochs, A. Bentkowska, C. Degrigny, M. Karaszewski, A. Karmacharya, Z. Kato, M. Picollo, R. Sitnik and A. Trémeau, Colour and space in cultural heritage. Key questions in 3D optical documentation of material culture for conservation, study and preservation, Proceedings of the 5th International Conference EuroMed 2014, Best paper award, pp 11-14, Limassol, Cyprus, november 3-8, 2014.
5. F. Boochs, A. Trémeau, O. Murphy, M. Gerke, J.L. Lerma, A. Karmacharya, and M. Karaszewski. Towards a knowledge model bridging technologies and applications in cultural heritage documentation, Proceedings of the ISPRS Technical Commission V Symposium, pp 81-88, 23-25 June, Riva del Garda, Italy, 2014.
6. Gianluigi Ciocca, Silvia Corchs, Francesca Gasparini, Emanuela Bricolo, and Riccardo Tebano, Does color inuence image complexity perception? Proceedings of the 5^{th} International Workshop CCIW'2015.

7. Ailin Chen, Colour Visualisation of Hyperspectral Images in Art Restoration. CIMET Master Thesis, Gjøvik University College, Norway.
8. Hilda Deborah, Noël Richard and Jon Yngve Hardeberg. Spectral Impulse Noise Model for Spectral Image Processing, Proceedings of the 5^{th} International Workshop CCIW'2015.
9. H. S. Faridul, T. Pouli, C. Chamaret, J. Stauder, A. Tremeau, and E. Reinhard, A Survey of Color Mapping and its Applications, Eurographics 2014 - State of the Art Reports, pp. 43-67, 2014.
10. Citlalli Gamez Serna, Ruven Pillay, and Alain Trémeau, Data fusion of objects using techniques such as Laser Scanning, Structured Light and Photogrammetry for Cultural Heritage Applications, Proceedings of the 5^{th} International Workshop CCIW'2015.
11. Yann Gavet, Johan Debayle, and Jean-Charles Pinoli, The Color Logarithmic Image Processing (CoLIP) antagonist space and chromaticity diagram, Proceedings of the 5^{th} International Workshop CCIW'2015.
12. Md. Abul Hasnat, Olivier Alata and Alain Trémeau, Unsupervised RGB-D image segmentation using joint clustering and region merging, Oral presentation (7.7%) in the British Machine Vision Conference (BMVC), Nottingham, UK, Nottingham, Sept 2014.
13. Zoltan Kato, and Levente Tamas, Relative Pose Estimation and Fusion of 2D Spectral and 3D Lidar Images, Proceedings of the 5^{th} International Workshop CCIW'2015.
14. Andreas Kleefeld, Michael Breub, Martin Welk, and Bernhard Burgeth, Adaptive Filters for Color Images: Median Filtering and its Extensions, Proceedings of the 5^{th} International Workshop CCIW'2015.
15. Dmitry Kuzovkin, Christel Chamaret, and Tania Pouli, Descriptor-based Image Colorization and Regularization, Proceedings of the 5^{th} International Workshop CCIW'2015.
16. João M.M. Linhares, Jorge L. A.Santos, Vasco M. N. de Almeida, Catarina A.R. João, and Sérgio M.C. Nascimento, The display gamut available to simulate colors perceived by anomalous trichromats, Proceedings of the 5^{th} International Workshop CCIW'2015.
17. Sérgio M.C. Nascimento, João M.M. Linhares, Catarina A. R. João, Kinjiro Amano, Cristina Montagner, Maria J. Melo, Marcia Vilarigues, Estimating the colors of paintings, Proceedings of the 5^{th} International Workshop CCIW'2015.
18. Lindsay MacDonald, Representation of Cultural Objects by Image Sets with Directional Illumination, Proceedings of the 5^{th} International Workshop CCIW'2015.
19. Maciej Karaszewski1, Krzysztof Lech, Eryk Bunsch, Robert Sitnik, In the pursuit of perfect 3D digitization of surfaces of paintings : geometry and color optimization, Proceedings of the 5th International Conference EuroMed'2014, pp 25-34, Limassol, Cyprus, November 3-8, 2014.
20. Juan Martínez-García, Mathieu Hébert, and Alain Trémeau, Color calibration of an RGB digital camera for the microscopic observation of highly specular materials. Proceedings of the SPIE conference on Measuring, Modeling, and Reproducing Material Appearance, 9 - 10 February 2015.

21. Pablo Martinez-Canada, Christian Morillas, Juan Luis Nieves, Begona Pino,and Francisco Pelayo, First Stage of a Human Visual System Simulator: the Retina, Proceedings of the 5^{th} International Workshop CCIW'2015.
22. John J. McCann and Alessandro Rizzi, The Art and Science of HDR Imaging, Wiley-IS&T Series in Imaging Science and Technology, ISBN: 978-0-470-66622-7, 416 pages, November 2011.
23. John J. McCann, Spatial imaging in color and HDR: Prometheus unchained, Proceedings of SPIE, Human Vision and Electronic Imaging XVIII, Vol. 8651, pp 865107, 2013.
24. Manuel Melgosa, Alain Trémeau, and Guihua Cui, Colour Difference Evaluation, Chapter 3, pp 59-79, Book title Advanced Color Image Processing and Analysis, C. Fernandez-Maloigne eds., 2013.
25. Ryosuke Nakahata, Keta Hirai, Takahiko Horiuchi, and Shoji Tominaga, Development of a Dynamic Relighting System for Moving Planar Objects with Unknown Reflectance, Proceedings of the 5^{th} International Workshop CCIW'2015.
26. M. M. Nawaf, A. Trémeau, M.D. Abul Hasnat, D. D. Sidibé, Color and Flow Based Superpixels for 3D Geometry Respecting Meshing, Proceedings of the IEEE Winter Conference on Applications of Computer Vision (WACV 2014), Steamboat Springs, pp 147-154, march 24-26, 2014.
27. G M Atiqur Rahaman, Ole Norberg, and Per Edström, Experimental analysis for modeling color of halftone images, Proceedings of the 5^{th} International Workshop CCIW'2015.
28. G M Atiqur Rahaman, and Md. Abul Hasnat, Collection, Analysis and Representation of Memory Color Information, Proceedings of the 5^{th} International Worshop CCIW'2015.
29. Jorge L. A. Santos, Vasco M. N. de Almeida, Catarina A. R. Joa, Joao M. M. Linhares, and Sérgio M. C. Nascimento, Visual search for normal color and dichromatic observers using a unique distracter color, Proceedings of the 5^{th} International Workshop CCIW'2015.
30. Jay Arre Toque, Pengchang Zhan, Peng Wang, and Ari Ide-Ektessabi, High-resolution multispectral scanning for mesoscopic investigation of discoloration of traditional Japanese pigments, Proceedings of the 5^{th} International Workshop CCIW'2015.
31. Tatiana Vitorino, Andrea Casini, Costanza Cucci, Ana Gebejes, Jouni Hiltunen, Markku Hauta-Kasari, Marcello Picollo, and Lorenzo Stefani, Accuracy in colour reproduction: using a ColorChecker chart to assess the usefulness and comparability of data acquired with two hyper-spectral systems, Proceedings of the 5^{th} International Workshop CCIW'2015.
32. Joost Van de Weijer and Hahad Khan, Color features in the era of big data, Proceedings of the 5^{th} International Workshop CCIW'2015.
33. Miguel Angel Veganzones, Lucas Drumetz, Guillaume Tochon, Mauro Dalla Mura, Antonio Plaza, José M. Bioucas-Dias, and Jocelyn Chanussot, A New Extended Linear Mixing Model to Address Spectral Variability, Proceedings of the IEEE Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS 2014), Jun 2014, Lausanne, Switzerland.
34. Xingbo Wang, Phlip Green, Jean-Baptiste Thomas, Jon Hardeberg and Pierre Gouton. Evaluation of the colorimetric performance of single-sensor image acquisition

systems employing colour and multispectral filter array, Proceedings of the 5^{th} International Workshop CCIW'2015.
35. Masahiro Yamaguchi, Optics and computational methods for hybrid resolution spectral imaging, Proceedings of the 5^{th} International Workshop CCIW'2015.

Springer
http://www.springer.com/978-3-319-15978-2

Computational Color Imaging
5th International Workshop, CCIW 2015, Saint Etienne, France, March 24-26, 2015, Proceedings
Trémeau, A.; Schettini, R.; Tominaga, S. (Eds.)
2015, XVII, 244 p. 133 illus., Softcover
ISBN: 978-3-319-15978-2