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Editors

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Preface

As one of the series of academic activities which are launched by China Academy Printing Technology, "2016 China Academic Conference on Printing, Packaging Engineering & Media Technology" is co-hosted by China Academy of Printing Technology, Xi'an University of Technology and Stuttgart Media University, and co-organized by Beijing Key Laboratory of Printing and Packaging New Technology of China Academy of Printing Technology, Faculty of Printing, Packaging Engineering and Digital Media Technology of Xi'an University of Technology and Printing Technology Professional Committee of Chinese Society for Imaging Science and Technology. It will be held on November 25–27, 2016 in Xi'an, China.

By far, "China Academic Conference on Printing and Packaging" and its series of events have been held for seven sessions since the first session in 2010. Due to the influence of the sponsors, academic foresight in the keynotes and the active participation among scholars, the conference has become the most influential academic exchange activity in printing and packing field in China, aiming at promoting the exchange and innovation of academic research in the field of international printing and packaging, and improving, merging as well as elevating the printing technology, which is the traditional technology of recording the development of human culture, into the information age.

As China economic development has entered a new norm period, the printing and packaging industry of China has been keeping a stable growth. In 2015, the total output value of China printing industry has topped to RMB 1124.62 billion, increasing by 3.6% and the main business revenue of packaging industry has reached RMB 1136.55 billion, increasing by 4.08%. Research innovation is becoming more and more important in the enterprise development of printing and packaging industry, and technology is becoming the key factor for enterprises to win in the fierce market competition. In the meantime, with the deep application of IT technology and the Internet in printing and packaging technology innovation and product development, product form of printing and packaging industry has been extended from traditional media to digital media.

In accordance with the purpose of the conference, "2016 China Academic Conference on Printing, Packaging Engineering & Media Technology" focused on digital technology, environmental technology and advanced materials technology in printing and packaging fields. We invited Prof. Jon Yngve Hardeberg from Norwegian University of Science and Technology, Prof. Mathias Hinkelmann from Stuttgart Media University, Prof. Patrick Gane from Aalto University, and other internal famous scholars to make keynote speeches on key techniques of multi-spectral color imaging, new digital media technology and new business models in the printing industry, and surface pore network structure and fluid interaction. At the same time, all the participants shared the latest research trends and achievements on color science, image processing, digital media, printing engineering, packaging engineering, mechanical engineering and intelligence, information materials and detection technology on nine panel discussion meetings.

The conference received 245 papers this year, including 3 keynote speeches and 242 oral presentations, among which 143 were selected to be published on *Lecture Notes in Electrical Engineering* (LNEE) (ISSN: 1876-1100) by Springer.

Here we greatly acknowledge all the organizations that offered great support for the conference and they are: China Printing Technology Association, Chinese Society for Imaging Science and Technology, Beijing Institute of Graphic Communication, School of Printing and Packaging of Wuhan University, College of Communication and Art Design of University of Shanghai for Science and Technology, School of Media and Design of Hangzhou Dianzi University, College of Light Industry and Engineering of South China University of Technology, Zhengzhou Institute of Surveying and Mapping, Light Industry College of Harbin University of Commerce, College of Packaging and Printing Engineering of Tianjin University of Science and Technology, School of Mechanical Engineering of Jiangnan University, School of Light Industry & Chemical Engineering of Dalian Polytechnic University, School of Packaging & Material Engineering of Hunan University of Technology, School of Biological and Chemical Engineering/School of Light Industry of Zhejiang University of Science and Technology, College of Engineering of Qufu Normal University, College of Light Industry Science and Engineering of Nanjing Forestry University, College of Light Industry and Energy of Shaanxi University of Science & Technology, College of Printing and Packaging Engineering of Qilu University of Technology, College of Materials Science and Engineering of Beijing University of Chemical Technology, College of Material Science & Engineering of Zhengzhou University, School of Food and Chemical Engineering of Beijing Technology and Business University, School of Media and Communication of Shenzhen Polytechnic, Shanghai Publishing and Printing College, State Key Laboratory of Modern Optical Instrumentation, Zhejiang University, National Taiwan University of Arts, Norwegian University of Science and Technology, Stuttgart Media University, Aalto University, and Beijing Keyin Media & Culture Co., Ltd.

We would like to express our gratitude to the 55 experts from China, Germany, Britain, American and Japan for reviewing and recommending papers for the conference with strict standards.

We also thank Springer for offering us an international platform for publishing.

We look forward to our reunion at the next China Academic Conference on Printing and Packaging.

November 2016

Edited by
China Academy of Printing Technology

2016 China Academic Conference on Printing, Packaging Engineering & Media Technology

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Location Jianguo Hotel, Xi'an, China

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Part I
Color Science and Technology

Test Criteria and Investigation of Uniform Color Spaces to Meet the Requirements of Future Imagery

Muhammad Safdar and Ming Ronnier Luo

Abstract The television and cinema industry has grown very rapidly during last few years and future displays will likely be able to cover high dynamic range (HDR) and wide color gamut (WCG). A uniform color space is desired that is suitable not only for efficient quantization but also for color volume mapping in HDR and WCG environment. A design goal for the next generation display is Rec.2020 which is the minimum requirement for future video encoding. There are a number of aspects which must be considered while developing a color space in order to meet the requirements of future imagery. Current study lists eight different criterions to test the ability of a color space to meet these requirements. After defining the testing criteria, this study investigated four different color spaces including CIELAB, CAM16-UCS, ICaCb, and recently proposed zICaCb. Results showed that zICaCb outperformed other spaces tested for most of the measures and gave similar performance for others.

Keywords Color spaces · CIELAB · CAM16-UCS · ICaCb · zICaCb

1 Introduction

Many researchers have proposed different perceptually uniform color spaces for color image encoding. Such approaches target image encoding using a minimum number of code values without introducing visible quantization artifacts or loss of

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image details. To encode high quality images, a color space is needed which can cover high dynamic range (HDR) and wide color gamut (WCG), and should at least meet requirements of Rec.2020 [1, 2]. The selected color space should be suitable for color image processing such as blending, fading, chroma sub-sampling, and resizing quickly, and with minimal error. It is desirable to transmit video signals in an encoding color space that is not only suitable for efficient image encoding but also for tone and gamut mapping often referred to as color volume mapping. As the volume of color essence increases, color transformations become more costly. This paper defines comprehensive testing criteria for a color space to meet the requirements of future imagery and offers minimal computational cost.

Current study considered four perceptually uniform color spaces including CIELAB, CAM16-UCS (a revision of CAM02-UCS) [3, 4], ICaCb [5], and zICaCb [6]. All these color spaces are based on device independent CIE XYZ tristimulus space. The CIELAB is a CIE recommended uniform color space and CAM16-UCS is uniform color space based on CAM16 color appearance model (a revision of CIECAM02 with similar performance) [3, 4]. The CIELAB and CAM02-UCS (previous version of CAM16-UCS) have been tested for typical dynamic range [7, 8]. They need to be further investigated to investigate how good they meet the requirements for high dynamic range and wide color gamut imagery. Froehlich et al. [5] proposed a color space with simple structure named ICaCb for HDR and WCG color difference signals. Safdar and Luo [6] refined ICaCb and proposed new zICaCb (optimized using more reliable datasets). Current study compared the performance of the mentioned four color spaces after defining comprehensive test criteria.

The next section of this paper will explain the criteria for testing a color space in different aspects. Then the test results for selected four color spaces will be presented. Conclusions will be drawn in the end.

2 Defining Test Criteria

In this section we define the criteria for testing a color space if it meets the requirements of HDR and WCG color difference applications and is suitable for image processing work flows. Following criterions should be met by the selected model for future imagery.

I. **Local Uniformity**: The major goal of image encoding is to assign least number of digital code words required to prevent visible quantization artifacts or distortions in an image. The best encoding performance is typically achieved when quantization error is distributed perceptually evenly over the color space. Ideally, the color discrimination ellipses should turn out to be circles for a locally uniform color space.
II. **Global Uniformity**: For a globally uniform color space, all the color discrimination ellipses should appear to be of equal size.