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A method for optimising settings of colour primaries for wide colour gamut displays

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ABSTRACT

Recently, wide colour gamut displays which adopt highly saturated primaries of red, green, blue have been rapidly applied. These displays can evoke more vivid and more pleasing effects for images. However, images shown on these newly developing wide gamut devices cannot achieve preferred quality under the control of conventional signal standards that are developed based on smaller colour gamut. To achieve the preferred display effects on wide gamut devices in digital image reproduction, a whole procedure to optimise gamut settings of colour primaries were proposed, in which particular algorithms were designed to render images from signal standard such as sRGB via simulating various gamut settings on the given display. Thus, the optimum specifications of colour primaries can be determined by calculations of the proposed preference index. Furthermore, a psychophysical experiment along with a detailed discussion were carried out as a verification, in which the consistence between the preference index calculation and the visual data could certify the effectiveness of the proposed procedure and algorithms. This study may help display researchers and manufactories by supporting some recommendations to determine the primaries of wide gamut devices in applications.

1. Introduction

Wide colour gamut is an advantage to evoke more vivid and more pleasing images for different displays including desktop monitors, TVs (televisions), tablet computers, and smart phones [1]. Recently, various display technologies [2,3] have been raised to produce highly saturated primaries of red, green, blue. However, the conventional broadcasting standards such as PAL (phase alteration line) and NTSC (National Television Standards Committee) are based on smaller colour gamut, as well as the sRGB (it means standard red green blue colour space) system [4] widely used in the display industry. Consequently, when images are displayed on wide gamut devices according to these standard signals without additional processing, the mismatch of their gamut would cause unavoidable colour distortions by introducing oversaturated, unpleasant effects [5]. The reason is that, both naturalness and colourfulness are key factors to influence the perceptual quality in image colour reproduction, but they show contradictions in some situations [6,7]. The perceptual image quality will firstly be improved gradually with the increase of colourfulness and then be suffered from the over-colourful situation, which is due to poor effect of naturalness in that case [8,9]. Though wider gamut is acceptable or even preferable for representing outdoor scene images to show more colourful sky, flowers, grass, but it may fail for reproducing some familiar colours such as skin [10,11].

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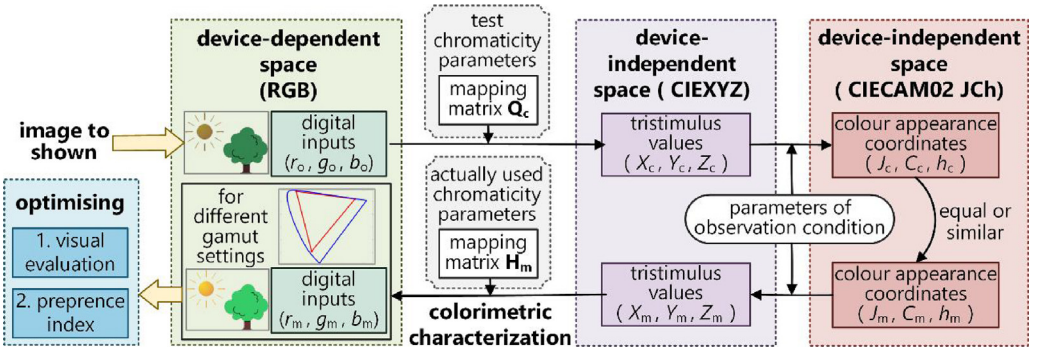

Fig. 1. Procedure of optimising settings of colour primaries for a wide colour gamut display. (For interpretation of the references to colour in the text, the reader is referred to the web version of this article.)

In pace with the spread uses of wide gamut devices, a series of researches were concentrated on discussing the correlations between gamut features and image effects [12,13], and revealing how to calculate gamut parameters such as size and boundaries [14–16], which built a good foundation in this field. Therefrom, some approaches should be put forward to deal with the mismatch between wide gamut displays and current standards. At present, new signal standards based on wider colour gamut appears accordingly, such as the ITU-R (International Telecommunications Union-Radiocommunications Sector) BT. 2020 and the SMPTE (Society of Motion Picture and Television Engineers) for highly developed TVs [17,18]. New signal standards can solve the problem in some degree. However, there are various display technologies, which make different displays from such a many manufactories show large diversities on their colour gamut features, so that employing one universal standard to suit those different displays will still cause image distortions.

To resolve the problem in terms of principles, quite a few scholars endeavored in introducing some treatments on images or displays, which were aimed to achieve preferred image quality under the control of existed signal standards. For pretreatment process of images, some researchers made efforts on improving image reproduction effects for specific colour contents, e.g. a procedure to protect skin colours via a content-based analysis on wide gamut displays [19]. Considering content-based algorithms might be complicated and unstable in applications, more studies were focused on designing colour conversion schemes with pertinence for different wide gamut devices rather than for image contents, e.g. based on multi-channel technology which supported a way of enlarging colour gamut. For multi-channel displays with several pixel combinations such as RGBY (red, green, blue, yellow), RGBCY (red, green, blue, cyan, yellow), RGBCW (red, green, blue, cyan, white), RGBW (red, green, blue, white), the algorithms for converting traditional RGB (red, green, blue) signals were proposed accordingly [20–22], whereas similar works were carried out on TVs with RGB primaries [23]. Also, methods of determining gamut boundary or optimising between brightness and gamut were deeply discussed [24,25].

In the field of pretreatment procedure on displays, this study concentrated on optimising settings of colour primary specifications on wide gamut devices, in which an image rendering procedure was designed and a psychophysical experiment was then conducted. Finally the optimum colour primaries was determined to produce preferred colour reproduction for sRGB images. This work may support some recommendations to determine the primaries of wide gamut devices for display researchers and manufactories as an example of application.

2. Procedure and algorithms

2.1. Strategy for optimising settings of colour primaries

For a given wide gamut display, a procedure for optimising settings of its colour primaries is designed, which can supply a strategy of seeking appropriate gamut settings for different displays. The proposed work flow is described step by step as shown in Fig. 1. For this wide gamut display, different gamut settings can be obtained within the sRGB gamut and the display maximum gamut by adjusting the positions of its three primaries (red, green, blue) in the CIE1976UCS diagram [26]. To test these new gamut settings, a series of algorithms is put forward to simulate their image display effects on the same display, so that the performances of these gamut settings can be judged by two approaches, i.e. the visual evaluation from psychophysical experiment, and a proposed preference index with particular calculations. Therefore, the optimum gamut settings can be determined based on considering results of the visual evaluation and the preference index. The process and algorithms for simulating the image display effects for individual gamut settings on this given display are depicted in detail in the following.

2.2. Image simulation of different gamut settings

An image processing procedure is established to search for the optimum chromaticity coordinates of the three primaries by adjusting their positions in the CIE1976UCS diagram. For each determined gamut setting, we assume that it can be regarded