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# Gamut estimation with efficient sampling based on modified segment maxima ☆

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ABSTRACT

Gamut mapping is necessary to achieve color consistency between cross-media devices. In gamut mapping, accurate estimation of the gamut in each device is an important task because it directly influences on the quality of color consistency. However, depending on the samples or estimation method, a false gamut can be calculated, resulting in color distortion in the reproduced image. Accordingly, to address this problem, accurate gamut estimation with efficient sampling is proposed. The proposed method selectively determines the samples and plugs the local concavities formed from the segment maxima algorithm. We assumed that the surface of the RGB cube roughly corresponds to the surface of the real gamut. Thus, points on the surface of the RGB cube can be selected as samples. Furthermore, points around the primaries are more intensively selected than from other parts of the surface. The local concavities that generate a false gamut are plugged by using modified gamut boundary descriptors. A local concavity is detected using a CounterClockWise algorithm with three consecutive descriptors. The descriptor in a concavity region is then moved to a line connecting the preceding and subsequent descriptors. In experiments, the proposed method accurately estimates the gamut with a small number of samples when compared with previous methods, and largely reduces the color distortion in the reproduced images.



## 1. Introduction

An image can be processed through many types of device, such as a camera, display, and printer, where each device processes the image independently without considering color matching, resulting in different color perceptions for the same image. Thus, color consistency between different media devices is still not guaranteed. Therefore, to achieve color consistency, various types of color processing have been investigated, including device characterization, color space conversion, and gamut mapping [1–12].

A device gamut represents the capability of a device to reproduce color, which also means the volume in color space. A gamut mapping algorithm is required for matching colors to maintain color consistency between color imaging devices. Various approaches to gamut mapping have already been explored to achieve accurate color reproduction [7]. The essence of such methods is accurate gamut estimation.

The convex hull is the most common method, which determines the smallest convex set containing a set of samples for a device [13]. Although it is efficient, the use of the convex hull is limited to non-convex gamut estimation. Thus, a modified convex hull method was proposed by Balasubramanian and Dalal, where the radius of the data, which is centered on the middle point of the lightness axis, is expanded to make it convex [14]. The convex hull algorithm is then applied, and the original radius prior to the modification is finally retrieved. This method overcomes the weakness that fails to estimate concavities in the convex hull method. Meanwhile, the alpha shapes gamut estimation method, which corresponds to a Delaunay triangulation of the same set when the alpha is zero, was also proposed to overcome non-convex gamut estimation [15,16]. Notwithstanding, both the modified convex hull and alpha shape have difficulty in determining the optimal parameters such as the radius and alpha. Therefore, Morovic and Luo proposed the segment maxima method, which is based on color space segmentation [17]. It assumes that the most extreme color in each segment composes the gamut boundary. Thus, to calculate the gamut boundary, a gamut boundary descriptor (GBD) is selected per segment. This method is simple and efficient for

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describing the gamut. However, the accuracy of this gamut boundary depends on the number of segments, where a small number of segments induce a color contour, while a large number of segments create a gamut boundary with concavity. Shaw proposed a modified segmentation-based gamut estimation method [18]. This method is based on the assumption that an adjacent hue with a constant hue plane has a similar shape. Using this assumption, a gamut boundary can be constructed by sweeping through similar hue at specified intervals. At each hue interval, a spline is used to fit a curve to estimate the gamut boundary. However, this method generates large errors near the cusp and areas where the chroma change is high with respect to a hue change.

An image gamut represents a range of colors contained in the image. In contrast with the device gamut, an image gamut is neither convex nor continuous. It also contains many isolated pixels so the shape of an image gamut becomes a complex structure. To address an image gamut for image-dependent gamut mapping, the multiple focal point for segment maxima method was proposed. The multiple focal point is located at the lightness axis, where the gamut boundary slope is changed from high to low and low to high, respectively. Then, the gamut boundary is estimated using Overhauser spline functions [19]. Giesen et al. used a discrete flow complex for efficient image gamut estimation, where a polyhedral surface is assigned to samples on a grid, allowing an accurate estimation of the gamut boundary [20].

More recently, the gamut estimation for tri-primary displays was expanded to multi-primary devices. Unlike tri-primary displays, a multi-primary display has additional primaries for a wide gamut so the shape of the gamut in CIE *xy* space changes into convex polygon. One of the gamut estimation approach for a multi-primary display is to use all samples that the device can reproduce in consideration of additional primaries, and the gamut boundary

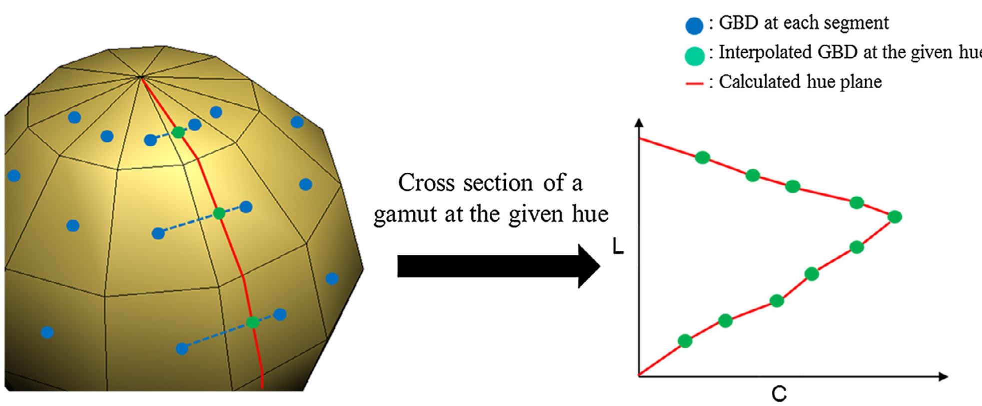


**Fig. 1.** Calculating a gamut boundary for the given hue using gamut boundary descriptors.

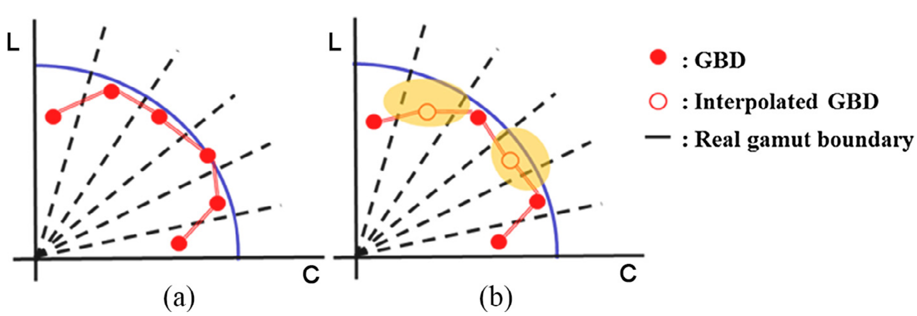


**Fig. 2.** Reduction of estimated gamut depending on number of samples: (a) gamut estimation with sufficient number of samples and (b) gamut estimation with insufficient number of samples.

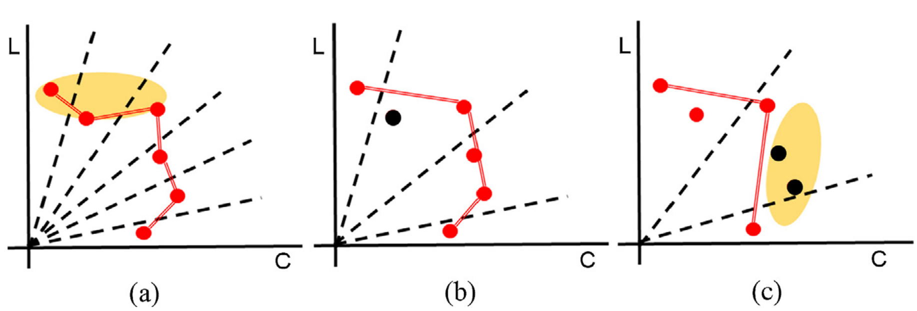


**Fig. 3.** Estimated gamut according to number of segments: (a) large number of segments, (b) moderate number of segments, and (c) small number of segments.