Multiprimary Decomposition Method Based on a Three-Dimensional Look-Up Table in Linearized LAB Space for Reproduction of Smooth Tonal Change

Dong-Woo Kang and Yang-Ho Cho
School of Electrical Engineering and Computer Science, Kyungpook National University, 1370, Sankyuk-dong, Puk-gu, Taegu 702–701, Korea

Yun-Tae Kim and Won-Hee Choe
Samsung Advanced Institute of Technology, San 14-1, Nongseo-ri, Giheung-eup, Yongin-si, Gyeonggi-do 449-712, Korea

Yeong-Ho Ha
School of Electrical Engineering and Computer Science, Kyungpook National University, 1370, Sankyuk-dong, Puk-gu, Taegu 702–701, Korea
E-mail: yha@ee.knu.ac.kr

Abstract. With the recent development of multiprimary display devices, the three primary colors (red, green, and blue) of a conventional display need to be decomposed into control values for a multiprimary display (MPD) under the constraints of tristimulus matching. To achieve tristimulus matching between such different display systems, the MPD color signals need to be estimated based on a device-independent color space, such as CIEXYZ or CIELAB. Yet, since the focus of a MPD is to display motion picture data, the color space conversion and multiprimary control value decomposition must be simplified. Accordingly, this paper presents a color signal decomposition method for a MPD using a three-dimensional look-up-table (3D LUT) in linearized LAB space. Linearized LAB space satisfies the linearity and additivity required for the color space conversion, and can easily construct a 3D LUT that considers the lightness, chroma, and hue. In addition, to reproduce moving picture data in a MPD, the proposed decomposition method uses a 3D LUT structure to reduce the hardware complexity and processing time. First, a 3D LUT that contains the gamut boundary points of the MPD is created to decompose the multiprimary control values. The chroma and multiprimary color signals for the gamut boundary are then stored in the 3D LUT along with the quantized hue and lightness values. Next, a quadrangular pyramid composed of four gamut boundary points and one lightness point on an achromatic axis is generated according to the input linearized LAB values. Consequently, MPD color signals can be obtained for the input values by interpolating between the multiprimary color signals for the gamut boundary points and the lightness point on an achromatic axis. Furthermore, additional gamut boundary points within 10° of the hue are used to interpolate the input values in regions that involve an abrupt change in the multiprimary control values to achieve a smooth change of hue. As a result, the proposed method guarantees computational efficiency and color signal continuity. Plus, less memory space is required when compared with conventional color decomposition methods. © 2006 Society for Imaging Science and Technology.

INTRODUCTION
Wide gamut displays, including red, green, and blue (RGB)-laser displays and multiprimary displays (MPDs), have recently been introduced to reproduce highly saturated colors outside the color gamut of conventional HDTV systems. RGB-laser displays use pure color light sources with a narrow spectral radiance, thereby producing colors that are far more saturated than those produced by conventional display systems. Nonetheless, although RGB-laser displays increase the number of perceptible colors, controlling the driving signals is difficult and such systems are complex and expensive to implement. In contrast, a MPD can produce a wide gamut at a much lower cost than with a RGB-laser display, plus it can minimize the color mismatch caused by observer metamerism. Therefore, to reproduce plentiful colors on display devices, this study focuses on a MPD to generate multiprimary color signals, corresponding to the three primary input signals, under the constraints of tristimulus matching.

MPDs that use more than three primary colors are currently realized based on five-primary DLP projection, six-primary LCD projection, and a four-primary or six-primary LCD. Research related to reproducing images on a MPD is classified into two main areas. The first area of research is image reproduction based on colorimetric information, including the spectral reflectance of an object and the illumination estimated by a multispectral camera or measured spectrum data. Although this method can generate accurate colors in MPDs, it cannot be directly applied to current HDTV systems. Meanwhile, the second area of research is image reproduction based on colorimetric information, including standard RGB (sRGB), CIEXYZ, and so on, for the purpose of application to current color management systems. However, there are various choices of multiprimary control val-
ues for a set of tristimulus values due to the 3-to-
N-dimensional transformation. Thus, a color signal decom-
position algorithm is needed to remove the degree of free-
dom in the multiprimary color signal selection. A variety of
color signal decomposition methods based on colorimetric
information have already been developed for image repro-
duction on MPDs. However, in the case of color repro-
duction from just tristimulus values, a smooth change in the
device control signals cannot be guaranteed, even with a
smooth change in the tristimulus values, due to the freedom
of the signal selection. For example, this problem occurs in a
CMYK printer system when deriving the control values for
CMYK inks from CMY inks.9 However, in the case of the
more recently developed MPD, a smooth tonal change is also
needed. Thus, color decomposition methods based on coloro-
metric information have to ensure a smooth color signal
tonal change in MPD, according to a smooth change in the
tristimulus values.10 In addition, to reproduce motion picture
images on a MPD in real time, the process of color
space conversion and color signal decomposition should
be computationally efficient with minimal memory
requirement.

Accordingly, this paper proposes a color signal decom-
position method for MPDs that provides both computa-
tional efficiency and color signal continuity. Thus, a color
signal decomposition method based on a three-dimensional
look-up table (3D LUT) is proposed in linearized LAB
space. First, a 3D LUT determined by the gamut boundary
and gray axis information is created in linearized LAB color
space10 to reduce the hardware complexity. Then, to main-
tain the color signal continuity, neighboring boundary
points are also used to generate a smooth hue change. In
experiments, the proposed 3D LUT decomposition method
is applied to a six-primary LCD and compared with conven-
tional decomposition methods based on the color difference
in CIELAB color space to evaluate the colorimetric matching
performance. In addition, the smoothness of the color tonal
change is tested to prove the signal continuity, along with the
lightness, chroma, hue, which all change. Therefore, the pro-
posed color signal decomposition method not only decreases
the complexity of the color space conversion and selection of
multiprimary control values, but also enhances the color sig-
nal continuity compared to conventional decomposition
methods.

COLOR REPRODUCTION MODEL FOR MPD

The target six-primary LCD is composed of red, green, blue,
cyan, magenta, and yellow, (RGBCMY) as the primary col-
ors. The gamut of the 6-primary LCD is shown in Fig. 1,
and the spectral characteristics of its primary colors are
shown in Fig. 2. Thus, the gamut of the MPD is extended,
when compared with the gamut of sRGB, and the additional
primary colors (cyan, magenta, yellow) can be independently
selected.

If the colorimetric characteristics of a display device in-
clude linearity and additivity, the forward transform10 that
converts the color signals of the MPD into CIEXYZ can be
expressed as follows:

$$
\begin{pmatrix}
X \\
Y \\
X
\end{pmatrix} = T_{N\text{-signal to } XYZ} \begin{pmatrix}
S_1 \\
S_2 \\
S_N
\end{pmatrix} + \begin{pmatrix}
X_{bias} \\
Y_{bias} \\
Z_{bias}
\end{pmatrix},
$$

(1)

where $N$ is the number of primary colors, $(X_{bias}, Y_{bias}, Z_{bias})'$ is the tristimulus value of bias, and $S_i (i=1, 2, \ldots, N)$ are the
ith primary colors. Thus, the forward transforming matrix, $T_{N\text{-}signal \rightarrow XYZ}$ is

$$
T_{N\text{-}signal \rightarrow XYZ} = 
\begin{pmatrix}
X_{\max,i} & X_{\max,s_2} & \cdots & X_{\max,s_N} \\
Y_{\max,i} & Y_{\max,s_2} & \cdots & Y_{\max,s_N} \\
Z_{\max,i} & Z_{\max,s_2} & \cdots & Z_{\max,s_N}
\end{pmatrix},
$$

(2)

where $(X_{\max,i}, Y_{\max,s_2}, Z_{\max,s_N})$ are the maximum tristimulus values for the ith primary colors. Although the color signals of the MPD can be calculated using the inverse matrix of $T_{N\text{-}signal \rightarrow XYZ}$, in the case of $N > 3$, there is no inverse matrix because $T_{N\text{-}signal \rightarrow XYZ}$ is not a square matrix. Thus, a color signal decomposition method is needed to obtain the multiprimary control values for the MPD.

CONVENTIONAL COLOR DECOMPOSITION METHODS

Several color signal decomposition methods have already been developed for a MPD to obtain colorimetric matching between the input and output systems. As the gamut of a MPD forms a polyhedron structure, most color decomposition methods use a geometrical interpolation, such as a pyramid interpolation,\(^7,8\) triangle interpolation on an equiluminance plane,\(^7,8\) or tetrahedral interpolation based on the center of gravity for tetrahedrons.\(^10\)

The matrix switching method\(^2\) proposed by Ajito et al. splits the color gamut into pyramid structures with a gamut boundary face. A two-dimensional (2D) LUT is used to specify which matrix is selected for a given tristimulus value. Then, the color signals are computed using the 2D LUT and corresponding 3 x 3 inverse matrices. Although this method has a good computational efficiency, color signal discontinuities arise at the boundaries between pyramids. Meanwhile, the triangle interpolation method proposed by Tomura uses two intersection points and a gray point on an equiluminance plane to calculate the multiprimary control signals. The input values inside the MPD gamut are then linearly interpolated with these selected points. As a result, the continuity of the color signal is ensured according to the lightness and chroma changes. Yet, for hue changes, discontinuities still occur at the boundaries of the triangle, and complex calculations are involved in identifying valid intersection points and computing the inverse matrix for each input value. Recently, the metamer black method was introduced,\(^10\) which calculates the center of gravity of the volume in (N – 3) dimensional space. Although this method generates more continuous color signals than conventional methods, it is complex to apply directly to HDTV systems.

Therefore, this paper proposes a color signal decomposition method to reduce the complexity for MPD implementation, while also enhancing the signal continuity.

PROPOSED COLOR DECOMPOSITION METHOD BASED ON 3D LUT STRUCTURE

The computational efficiency and color signal smoothness are both important for implementing a MPD. Thus, the proposed method uses a chroma ratio to decompose the multiprimary control values. The gamut boundary points and a point on the gray axis stored in a 3D LUT are selected according to the input signal. A block diagram of the proposed method is shown in Fig. 3. First, the input HDTV images are converted to linearized LAB space. The nearest gamut boundary points and lightness point on the gray axis are then identified in a 3D LUT, defined by the chroma and multiprimary control values of the MPD. 3D LUT data are constructed for each hue and lightness plane in linearized LAB space. In this paper, the six-primary control values are stored in a 3D LUT. These selected points are then used to interpolate the input values. For the selected lightness plane, the chroma ratio is calculated according to each hue plane from 1° to 10° to guarantee signal smoothness. As a result, the multiprimary driving signals of the MPD are obtained. Finally, the proposed 3D LUT for color decomposition in a MPD is implemented as a three input signal (RGB) to six output values for a six-primary LCD (RGBCMY), including the process described in Fig. 3.

FORWARD TRANSFORM IN LINEARIZED LAB COLOR SPACE

Linearized LAB space\(^11\) eliminates the power factor from CIELAB space, ensuring the linearity and additivity of the primary colors and defining the lightness, chroma, and hue. In Figs. 4 and 5, the CIEYxy, CIELAB, and linearized LAB color spaces are compared with one another using 2729 Munsell data.\(^12\) Figure 4 shows the Munsell data distributed in the chromaticity plane, while Fig. 5 shows the Munsell data distributed in the projected lightness plane. The six-primary colors (R, G, B, C, M, Y) are marked in Figs. 4 and 5 to compare the linearity of the hue and chroma values and lightness, respectively. Since the hue, chroma, and lightness values cannot be defined in CIEYxy color space, this space is not suitable to generate a 3D LUT. Also, since the Munsell data are uniformly distributed in CIELAB color space, in contrast to CIEYxy and linearized LAB color space, it is...
difficult to determine the gamut boundary, plus the nonlinear transformation in CIELAB color space increases the hardware complexity. Therefore, the proposed method uses linearized LAB space to consider the human visual characteristics and complexity. Although the lightness values cannot reflect the human visual system in linearized LAB color space, the linearity of the hue and chroma values is similar to a uniform color space, such as CIELAB color space. In addition, CIEXYZ space can be easily converted to linearized LAB space using a $3 \times 3$ transform matrix as follows:

Figure 4. Munsell data distributed in chromaticity plane; (a) CIExy plane, (b) CIEa′b′ plane, and (c) linearized ab plane.

Figure 5. Munsell data distributed in projected lightness plane; (a) CIExy plane, (b) CIEL*a′b′ plane, and (c) linearized LAB plane.
where \((X_n Y_n Z_n)^t\) are the tristimulus values for white, as a reference, and \(T_{\text{Lab}}\) is the \(3\times3\) transform matrix from CIEXYZ to linearized LAB. The transform from the \(N\)-color signals of the MPD to linearized LAB is similar to Eqs. (1) and (2). The \(3\times N\) transform matrix for a multiprimary display is

\[
\begin{pmatrix}
L \\
a \\
b
\end{pmatrix} = T_{\text{Lab}} \begin{pmatrix}
X \\
Y \\
Z
\end{pmatrix} = \begin{pmatrix}
0 & 100/Y_n & 0 \\
500/X_n & -500/Y_n & 0 \\
0 & 200/Y_n & -200/Z_n
\end{pmatrix} \begin{pmatrix}
X \\
Y \\
Z
\end{pmatrix},
\]

(3)

where \((L_{\text{max}}, a_{\text{max}}, b_{\text{max}})^t\) are the maximum linearized LAB values for the \(i\)th primary colors. Accordingly, a 3D LUT with gamut boundary information can be composed according to the quantized level of lightness from 0 to 100 and hue from 0° to 360° in linearized LAB space.

**PROCESS OF 3D LUT IMPLEMENTATION**

The 3D LUT is implemented based on the gamut boundary data. For a simple explanation, assuming that the bias value is \((L_{\text{bias}}, a_{\text{bias}}, b_{\text{bias}})=0\) and the number of primary colors is \(N=4\), the primary vector \(\vec{P}_i\) can be defined by linearized LAB values and four-dimensional color values as follows:

\[
\begin{pmatrix}
L \\
a \\
b
\end{pmatrix} = \begin{pmatrix}
L_{\text{max},i} & L_{\text{max},2} & \cdots & L_{\text{max},N} \\
a_{\text{max},i} & a_{\text{max},2} & \cdots & a_{\text{max},N} \\
b_{\text{max},i} & b_{\text{max},2} & \cdots & b_{\text{max},N}
\end{pmatrix} \begin{pmatrix}
S_1 \\
S_2 \\
S_3 \\
S_4
\end{pmatrix} + \begin{pmatrix}
L_{\text{bias}} \\
a_{\text{bias}} \\
b_{\text{bias}}
\end{pmatrix},
\]

(4)

where \((L_{\text{max},i}, a_{\text{max},i}, b_{\text{max},i})^t\) are the maximum linearized LAB values for the \(i\)th primary colors. The multiprimary control values are

\[
s_i = \begin{cases} 
1, & i = k, \quad k = 1, 2, 3, 4 \\
0, & \text{otherwise}, \end{cases}
\]

where \(s_i\) is the \(i\)th primary color signal \((i=1, 2, 3, 4)\). The linearity and additivity of the colors are satisfied in linearized LAB space, as the linearized LAB values are only the linear transformed values of CIEXYZ space, which satisfies those characteristics. Thus, arbitrary color signals are derived from a scalar mixture of the multiprimary vectors, as shown in Fig. 6. The color vector \(M_i\) is then represented by four primary MPD vectors in linearized LAB space.

![Figure 6](image6.png)

*Figure 6. Arbitrary color signals derived from scalar mixture of multiprimary vectors, for example, four-primary MPD.*

![Figure 7](image7.png)

*Figure 7. Chroma and multiprimary color signals for gamut boundary stored in 3D LUT along with quantized lightness and hue.*

![Figure 8](image8.png)

*Figure 8. Symmetrical characteristic of MPD gamut boundary on constant hue plane in linearized LAB space.*
\[ \tilde{M}_i = \alpha \cdot \tilde{P}_1 + \beta \cdot \tilde{P}_2 + \gamma \cdot \tilde{P}_3 + \delta \cdot \tilde{P}_4 \]
\[ = [L_M a_M b_M]_{\text{Linearized LAB}} \]
\[ = [L_M H_M c_M]_{\text{Linearized LAB}} \]
\[ = [\alpha \ \beta \ \gamma \ \delta]_4 \text{dimensional color values} \quad (7) \]

where \( \alpha, \beta, \gamma, \) and \( \delta \) are the scalar values \((0 \leq \alpha, \beta, \gamma, \) and \( \delta \leq 1) \) that determine the input values.

To construct the 3D LUT, the chroma and multiprimary color signals of the gamut boundary are stored in the 3D LUT along with the quantized lightness and hue, as shown in Fig. 7, where the 3D LUT was constructed with gamut boundary information in the case of \( N = 6 \). As the quantization level of the lightness and hue is 100 levels and 360 levels, respectively, the size of the 3D LUT is \( 100 \times 360 \times (N+1) \). Yet, since the gamut of a MPD is symmetric to the lightness axis, the 3D LUT size can be reduced to \( 100 \times 180 \times (N+1) \). The symmetrical characteristic of the MPD gamut boundary on a constant hue plane in linearized LAB space is shown in Fig. 8. The quantized lightness and hue are \( l \) and \( h \), respectively, and the stored 3D LUT is

\[
\text{3D LUT}[l][h] = \begin{cases} 
[\gamma \ s_1 \ s_2 \ \cdots \ s_N], & -90^\circ < h \leq 90^\circ \\
[\gamma \ 1-s_1 \ 1-s_2 \ \cdots \ 1-s_N], & \text{otherwise}, 
\end{cases} \quad (8)
\]

where \( \gamma \) is the chroma and \( s_i(i=1-N) \) are the multiprimary color signals.

---

**PROPOSED MULTIPRIMARY DECOMPOSITION METHOD**

Under the constraints of colorimetric matching, the proposed decomposition method based on a 3D LUT uses the linearity of linearized LAB color space. Figure 9 shows the representation of the gamut boundary points within \( 1^\circ \) of hue and unit difference of lightness, along with the lightness value on a gray axis according to the input value, where \( D_i \) is the input value and the gamut boundary points, \( G_{LL}, G_{LH}, G_{HL}, \) and \( G_{HH} \), are quantized points \((1^\circ \) of hue and unit
difference of lightness) of the gamut boundary that include the chroma and multiprimary color signals.

First, the chroma and multiprimary color signals at the boundary points \( G_1 \) and \( G_2 \) are calculated using the quantized level of the gamut boundary point. The chroma of \( G_1 \) is interpolated using the quantized gamut boundary point

\[
C_{G_1} = \frac{L_{Di} - L_{G_{1L}}}{L_{G_{HL}} - L_{G_{1L}}} \cdot (C_{G_{HL}} - C_{G_{1L}}) + C_{G_{1L}},
\]

where \( C_M \) is the chroma value for point \( M \). In addition, the multiprimary color signals are calculated as follows:

\[
S^i_{G_1} = \frac{L_{Di} - L_{G_{1L}}}{L_{G_{HL}} - L_{G_{1L}}} \cdot (S^i_{G_{HL}} - S^i_{G_{1L}}) + S^i_{G_{1L}},
\]

where \( S^i_M \) is the \( i \)th color signal of point \( M \). The same method is used to calculate the chroma and multiprimary color signals of \( G_2 \), then the multiprimary color signals for the gray axis point with the same lightness of input are interpolated as follows:

\[
S^i_{Di} = \frac{L_{Di}}{100}.
\]

Next, the boundary point for the input value \( G_{bound} \) is approximated using

\[
C_{G_{bound}} = \frac{C_{G_1} + C_{G_2}}{2}
\]

and the multiprimary color signals are approximated using

\[
S^i_{G_{bound}} = \frac{\text{dist}(G_{bound}, G_1)}{\text{dist}(G_2, G_1)} (S^i_{G_2} - S^i_{G_1}) + S^i_{G_1},
\]

where \( \text{dist}(A, B) \) is the Euclidian distance between \( A \) and \( B \). Finally, the multiprimary color signals for the input values are computed using the chroma ratio \( C_{Di}/C_{G_{bound}} \)

\[
S^i_{Di} = \frac{C_{Di}}{C_{G_{bound}}} (S^i_{G_{bound}} - S^i_{Di}) + S^i_{Di},
\]

where \( i = 1, 2, \ldots, N \).

However, color signal discontinuity can still exist because the interpolation is processed within \( 1^\circ \) of hue. In Fig. 10, the regions of color signal discontinuity caused by a signal transition are marked by a circle (A, B, and C). Figure
10(a) presents the multiprimary color signal transition in linearized LAB space, with the transition regions illustrated in a linearized \(ab\) plane in Fig. 10(b). Therefore, the proposed method employs additional gamut boundary points, \(G_1^p\) and \(G_2^p\), within \(\pm 6^\circ\) to guarantee a smooth color signal with a hue change, as shown in Fig. 11. Similarly, these points can be computed using Eqs. (9)–(11), then the boundary point \(C_{\text{bound}}^p\) with the same lightness and hue as the input point is calculated using Eqs. (12)–(14). Finally, all the multiprimary color signals are averaged corresponding to \(C_{\text{bound}}^p\). Meanwhile, in a color signal transition region, when \(C_D > C_{G_{\text{bound}}}^p\), the color signals are extrapolated using Eq. (14) with a chroma ratio based on \(C_{C_{\text{bound}}}^p\) and \(C_D\). As a result, the color signals of the MPD can maintain continuity with a change in hue.

**EXPERIMENTAL RESULTS**

In experiments, the input color signal was assumed to be sRGB or CIEXYZ values. First, the colorimetric matching between the input and output values was evaluated using the CIELAB color difference, and the proposed method was compared with the matrix switching method\textsuperscript{2} and linear interpolation method.\textsuperscript{8} Second, the smoothness of the multiprimary color signals was assessed using a graph when changing the lightness, chroma, and hue individually and all at the same time. The final smoothness evaluation was based on the images reproduced on a MPD. All the simulations used a six-primary LCD composed of red, green, blue, cyan, magenta, and yellow as the primary colors.
The performance of the multiprimary decomposition methods was evaluated using 124 randomly selected uniform patches. The color difference $E_{ab}^*$ between the input and output colors in CIELAB color space is shown in Table I. For the colorimetric matching, the conventional methods and proposed method produced a similar performance that was adequate to reproduce images on the MPD. When evaluating the smoothness of the color signals, the tested gradation pattern (1–4) is presented in Table II. Figures 12–15 show the resulting multiprimary color signals for each color pattern in Table II, where Fig. 12 is the result when changing the lightness, Fig. 13 when changing the chroma, Fig. 14 when changing the hue change, and Fig. 15 when changing them all at the same time. The conventional methods and proposed method all exhibited continuity for lightness, as shown in Figs. 12(a)–12(c). However, the matrix switching method was unable to produce a continuous tone when the chroma and hue were changed, as shown in Figs. 13(a) and 14(a). Although the linear interpolation method and proposed method produced a similar pattern for a chroma change, as shown in Figs. 13(b) and 13(c), the proposed method was more continuous than the linear interpolation method when changing the hue, as shown in Figs. 14(b) and 14(c), which was due to the consideration of the neighboring gamut boundary color signals. To apply the proposed method to real images, pattern 4 was applied, which changed the lightness, chroma, and hue all at the same time. As shown in Fig. 15(c), the proposed method was smoother than the other methods in the color signal transition regions. In addition, the graphical image was tested to demonstrate the signal continuity results. Figure 16 is the original three-channel (RGB) image, which was then decomposed into multiprimary color signals using the conventional and proposed methods. The result images for MPD cannot directly be presented in this paper without MPD. Thus, to compare the smoothness of the MPD signals, the resulting images were expressed using the extracted RGB and CMY control values, respectively. Figures 17(a)–17(c) show the results for the RGB control values, while Figs. 18(a)–18(c) show the results for the CMY control values when using each decomposition method. The CMY control value results are represented by pseudo colors. Nonetheless, since the accuracy of the color reproduction is already evalu-

<table>
<thead>
<tr>
<th>Table I. Simulated color difference in CIELAB.</th>
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<tr>
<td>$\Delta l'$</td>
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<tr>
<td>Matrix switching method</td>
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<tr>
<th>Table II. Gradation pattern with change in lightness, chroma, and hue individually and combined.</th>
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<td>Gradation pattern</td>
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<tr>
<td>Pattern 1 (lightness change)</td>
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<tr>
<td>Pattern 2 (chroma change)</td>
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<tr>
<td>Pattern 3 (hue change)</td>
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<tr>
<td>Pattern 4 (lightness, chroma, hue change)</td>
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Figure 15. Result of lightness, chroma, and hue change (pattern No. 4 in Table II): (a) matrix switching method, (b) linear interpolation method, and (c) proposed decomposition method.
ated in Table I, Figs. 17 and 18 are not meaningful as regards their colors, as the final images are reproduced as a combination of six-primary colors (RGBCMY). Instead, only the signal smoothness can be evaluated from these figures. If each decomposed control value is changed smoothly, the images resulting from the control values will also reflect a smooth change. In Figs. 17(a), 17(b), 18(a), and 18(b), a signal discontinuity is exhibited in the images reproduced using the matrix switching method and linear interpolation method. The results of the matrix switching method also included abrupt color changes at the circle circumferences. Although the results for the linear interpolation method were smoother than those for the matrix switching method, contour artifacts were still observed at the edges of the color changes. In contrast, the image reproduced using the proposed method was smoother than those produced by the other methods, as shown in Figs. 17(c) and 18(c).

Figure 16. Original three-channel (RGB) image.

Figure 17. Graphical images to test smoothness of multiprimary decomposition methods. Images are reproduced by the extracted RGB control values from six-primary MPD: result of (a) matrix switching method, (b) linear interpolation method, and (c) the proposed decomposition method.

Figure 18. Graphical images to test smoothness of multiprimary decomposition methods. Images are reproduced by the extracted CMY control values from six-primary MPD: result of (a) matrix switching method, (b) linear interpolation method, and (c) the proposed decomposition method.
CONCLUSION
This paper proposed a 3D LUT color decomposition method in linearized LAB space that can produce N-color signals on a MPD. The linearized LAB space and 3D LUT structure is used to reduce the hardware complexity and processing time when reproducing motion picture data. Under the constraints of tristimulus matching between the input and output colors, the MPD color signals for the input values are obtained by interpolating between the gamut boundary points and a point on the gray axis. Plus, additional neighboring gamut boundary points are used to interpolate the input values in regions where there is an abrupt change in the multiprimary control values to achieve a smooth change of hue, thereby improving the smoothness of the color signal. In experiments, the images reproduced using the proposed method were smoother than those produced using conventional methods, as demonstrated based on testing the color signal transition. As a result, the proposed method guarantees computational efficiency and color signal continuity. Plus, less memory space is required compared with conventional color decomposition methods. Nonetheless, since the proposed method still involves quantizing the gamut boundary, future research will attempt to minimize the quantization error when the gamut boundary information is described in linearized LAB space, while enabling the gamut mapping to use the full range of the MPD gamut.

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