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ЗІСТАВЛЕННЯ КОЛЬОРОВИХ ПРОСТОРІВ, ЯКІ ШИРОКО ВИКОРИСТОВУЮТЬ У РІЗНИХ СФЕРАХ ВИРОБНИЦТВА ЗОБРАЖЕНЬ, З КОЛЬОРОВИМИ ПРОСТОРАМИ ТЕЛЕВІЗІЙНИХ СИСТЕМ

СОПОСТАВЛЕНИЕ ЦВЕТОВЫХ ПРОСТРАНСТВ, ШИРОКО ИСПОЛЬЗУЕМЫХ В РАЗНЫХ СФЕРАХ ПРОИЗВОДСТВА ИЗОБРАЖЕНИЯ, С ЦВЕТОВЫМИ ПРОСТРАНСТВАМИ ТЕЛЕВИЗИОННЫХ СИСТЕМ

MATCHING OF SOME COLOR SPACES FOR USE IN DIFFERENT INDUSTRIES AND COLOR SPACES OF TELEVISION SYSTEMS

Анотація. Наведено зіставлення колориметричних характеристик систем, що їх використовують У різних сферах виробництва зображень, таких як системи цифрового телебачення високої та надвисокої чіткості, системи цифрового фотодруку RIMM-ROMM та ROMM (Kodak) й Wide Gamut (Adobe). Представлено оцінку області передаваних кольорів у колірному просторі XYZ, а також в рівноконтрастному просторі CAM02-UCS для випадків варіації рівнів яскравості деталей зображення та яскравості адаптації.

Аннотация. Представлено сопоставление колориметрических характеристик пространств, используемых в разных сферах производства, таких как система цифрового телевидения высокой и сверхвысокой чёткости, системы цифровой печати RIMM-ROMM и ROMM (Kodak), а также Wide Gamut (Adobe). Представлены оценки области передаваемых цветов в цветовом пространстве XYZ, а также в равноконтрастной системе CAM02-UCS для случаев вариации изменения уровней яркости деталей изображения и яркости адаптации.

Summary. The comparison of the colorimetric characteristics of the systems used in different color image industries, such as digital television systems of high and ultrahigh-definition, digital photo printing systemы RIMM-ROMM and ROMM (Kodak), and Wide Gamut (Adobe) is presented. Transmitted color gamut evaluation in the XYZ color space as well as in uniform color space CAM02-UCS for cases of variation of the brightness levels of image detail and lightness adaptation.

Introduction

From the point of view of the colorimetric characteristics an important characteristic of the new image systems, including digital graphics systems, digital Photography, etc., is color gamut, evaluated as the area of the transmitted portion of chromaticity diagram. This area depends on the chromaticity coordinates of primary colors and coordinates of reference white, and border of area of colors, which can be transmitted, varies with the image brightness variation between black and white.

Graphical information from such image systems as Adobe [1] and Eastman Kodak [2–5] with an extended color gamut, in particular, can be used as sources of video in TV program production HDTV according to the Recommendation ITU-R BT.709 [6] and UHDTV in accordance with Recommendation ITU-R BT.2020 [7].

In Adobe system with extended color gamut and in Eastman Kodak system the use of the coordinates of primaries, different from those in the TV systems, is provided.

Considering that in future will take place, on the one hand, the use in television production of video materials, created with imaging systems, on the other hand, the use of television video materials in the image industry, it is important to compare the colorimetric characteristics of such video applications, in particular, color gamut.

Some color spaces used in different industries and color spaces of digital TV systems matching

Tristimulus values of the primaries and reference white of HDTV, UHDTV, RIMM-ROMM (Kodak), ROM (Kodak) and Wide Gamut (Adobe) systems are presented in Table 1.

Table 1 – Reproduction system primaries and reference white chromaticity coordinates

Systems	R		G		B	
	x	*y*	*x*	*y*	*x*	*y*
HDTV	0.6400	0.3300	0.3000	0.6000	0.1500	0.0600
UHDTV	0.7080	0.2920	0.1700	0.7970	0.1310	0.0460
RIMM-ROMM	0.7347	0.2653	0.1596	0.8404	0.0366	0.0001
ROM	0.8730	0.1440	0.1750	0.9270	0.0850	0.0001
Wide Gamut	0.7347	0.2653	0.1152	0.8264	0.1566	0.0177

Below the projections of the field of colors, which can be transmitted by systems under consideration, are presented on the CIE-31 tristimulus values plane of and on the plane the chromaticity coordinates a'_M, b'_M of CAM02-UCS color space J', a'_M, b'_M obtained with use of proposed by Luo et al. [8] transformation of color space J, a_M, b_M of CIECAM02 [9], which is the most perfect color appearance model at present time [10]. Here J – lightness; $a_M = M \cdot \cos h$, $b_M = M \cdot \sin h$ – chroma Cartesian coordinates, M – colorfulness, h – hue angle. The curves were constructed for relative luminance values, $Y \in \overline{0,1}$, for adaptation level $L_A = 0.2\, L_W$, where L_W – the maximum brightness of reference white in cd/m^2.

Color gamut transmitted by HDTV system

Figure 1 shows the projection of the color gamut area transmitted by HDTV system [11] on CIE-31 Chromaticity coordinates plane. Figures 2, 3 present projections of color gamut transmitted by HDTV system on the plane of chroma Cartesian coordinates a'_M, b'_M of J', a'_M, b'_M uniform color space. The projections are presented for relative luminance levels of 0.25 and 0.5 and luminance levels on white of 250 cd/m^2, which corresponds to observer visual system adapting luminance respectively equal to 50 cd/m^2.

The Table 2 and another tables are marked with: S_{CD} – the area on the chromaticity diagram

of the plane of coordinates a'_M, b'_M for a given relative luminance; S_{CG} – the area of transmitted color gamut for given relative luminance.

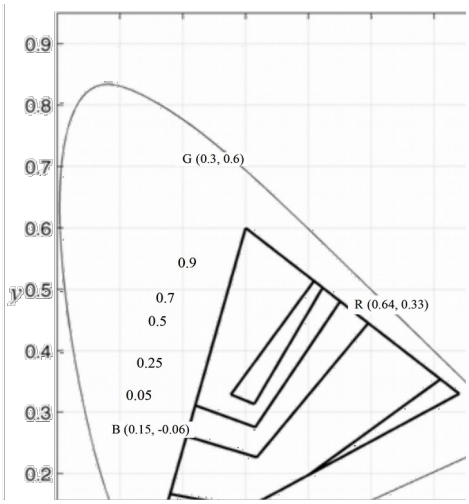

Figure 1 – Color gamut, which can be transmitted by HDTV system, on CIE-31 chromaticity diagram plane

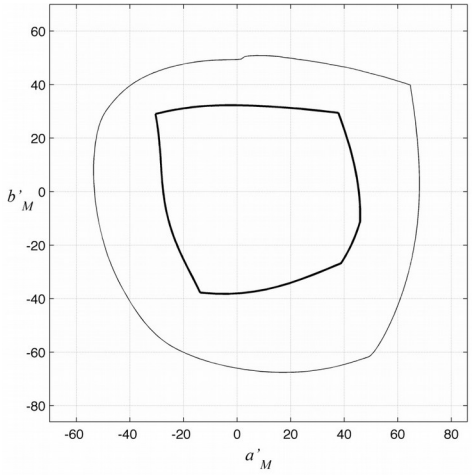

Figure 2 – Color gamut, which can be transmitted by HDTV system for $Y = 0.25$ and $L_A = 50\ \text{cd/m}^2$, presented on the plane of a'_M, b'_M

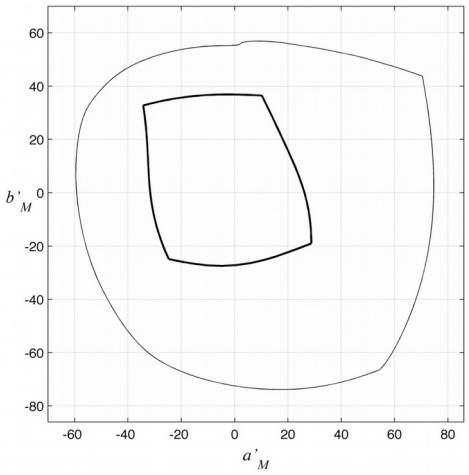

Figure 3 – Color gamut, which can be transmitted by HDTV system for $Y = 0.5$ and $L_A = 50\ \text{cd/m}^2$, presented on the plane of a'_M, b'_M

Area of chromaticities, transmitted by UHDTV system

Figure 4 shows color gamut transmitted by UHDTV system projections on CIE-31 tristimulus values plane.

Figures 5, 6 present projections of color gamut transmitted by UHDTV system on the plane of chroma Cartesian coordinates a'_M, b'_M of J', a'_M, b'_M uniform color space. The projections are presented for the relative luminance levels of 0.25 and 0.5 and luminance level on white of 250 cd / m^2, which corresponds to observer visual system adapting luminance respectively equal to 50 cd/m^2.

Area of chromaticities, transmitted by RIMM-ROMM system

Figure 7 shows the projections of color gamut transmitted in RIMM-ROMM system on CIE-31

chromaticity coordinates plane.

Figures 8–12 show projections of the color gamut transmitted in RIMM-ROMM system on the plane of chroma Cartesian coordinates a'_M, b'_M of J', a'_M, b'_M uniform color space. The projections are presented for the relative luminance levels of 0.05; 0.25; 0.5; 0.7; 0.9 and luminance level on white of 250 cd/m^2, which corresponds to observer visual system adapting luminance respectively equal to 50 cd/m^2.

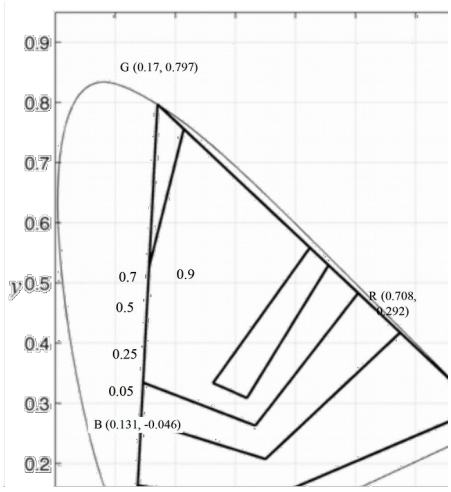

Figure 4 – Color gamut, which can be transmitted by UHDTV system, on CIE-31 chromaticity diagram plane

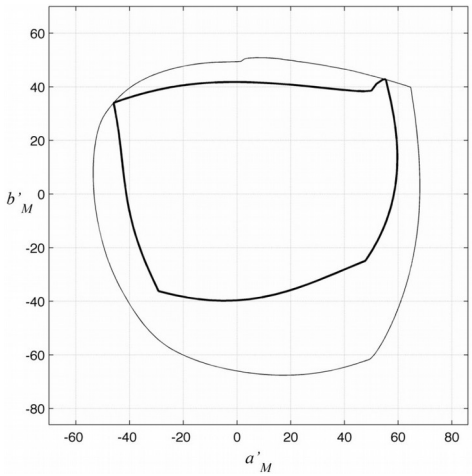

Figure 5 – Color gamut, which can be transmitted by UHDTV system for $Y = 0.25$, presented on the plane of a'_M, b'_M

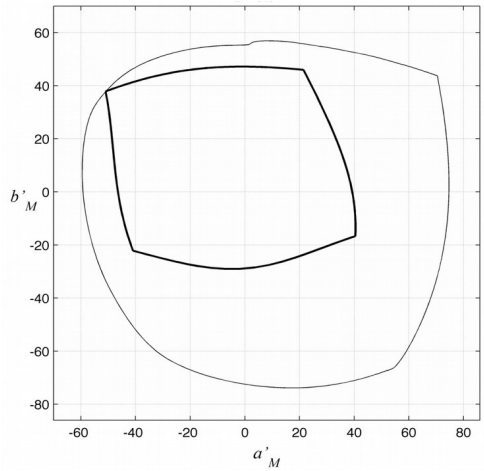

Figure 6 – Color gamut, which can be transmitted by UHDTV system for $Y = 0.5$, presented on the plane of a'_M, b'_M

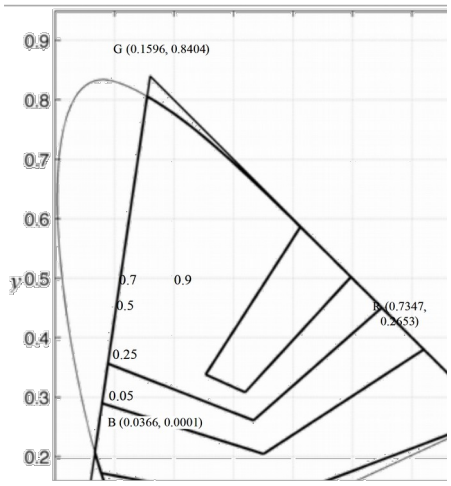

Figure 7 – Color gamut, which can be transmitted by RIMM-ROMM system, on the CIE-31 chromaticity diagram plane

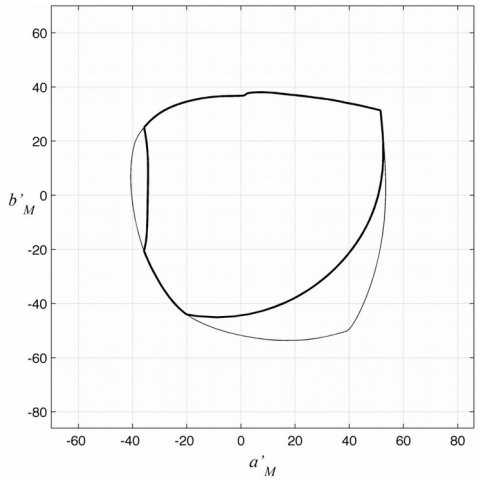

Figure 8 – Color gamut, which can be transmitted by the system RIMM-ROMM, for $Y = 0.05$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

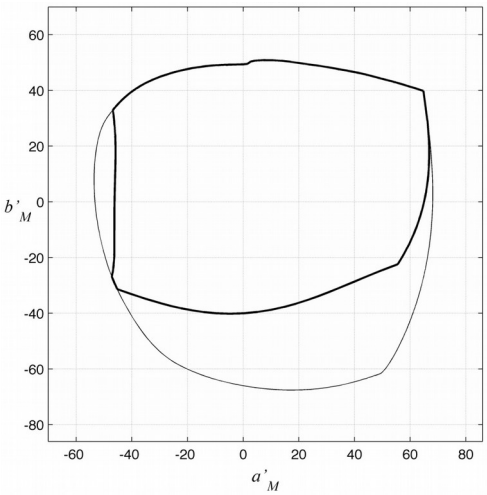

Figure 9 – Color gamut, which can be transmitted by RIMM-ROMM system for $Y = 0.25$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

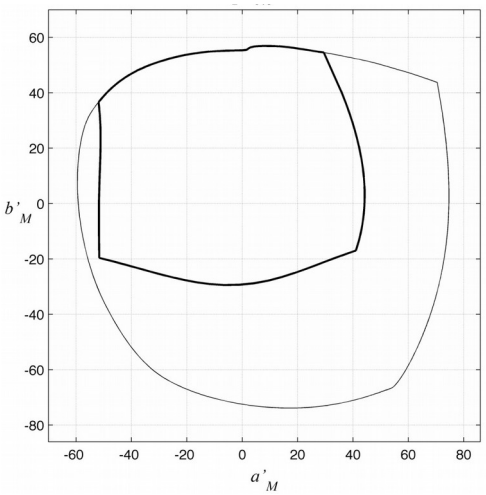

Figure 10 – Color gamut, which can be transmitted by RIMM-ROMM system for $Y = 0.5$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

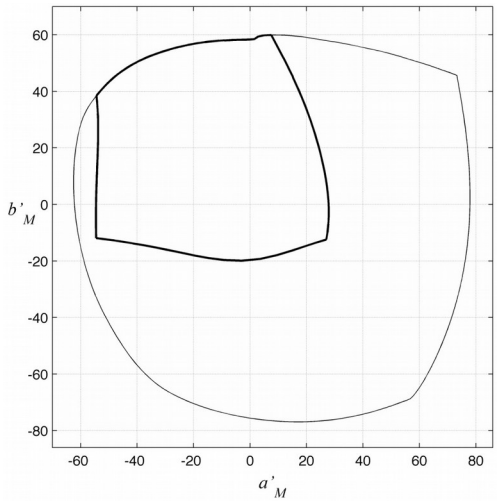

Figure 11 – Color gamut, which can be transmitted by RIMM-ROMM system, for $Y = 0.7$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

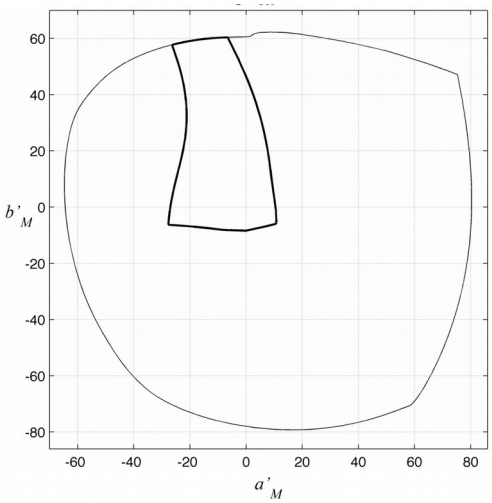

Figure 12 – Color gamut, which can be transmitted by RIMM-ROMM system, for $Y = 0.9$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

The projections are presented for the relative luminance levels of 0.05; 0.25; 0.5; 0.7; 0.9 and luminance levels on white of 250 cd/m^2, which corresponds to observer visual system adapting luminance respectively equal to 50 cd/m^2.

Color gamut, transmitted by ROM system

Figure 13 shows the projections of color gamut transmitted by ROM system on CIE-31 chromaticity plane. Figures 14–18 show projections of color gamut transmitted by ROM system on the plane of chroma Cartesian coordinates a'_M, b'_M of J', a'_M, b'_M uniform color space.

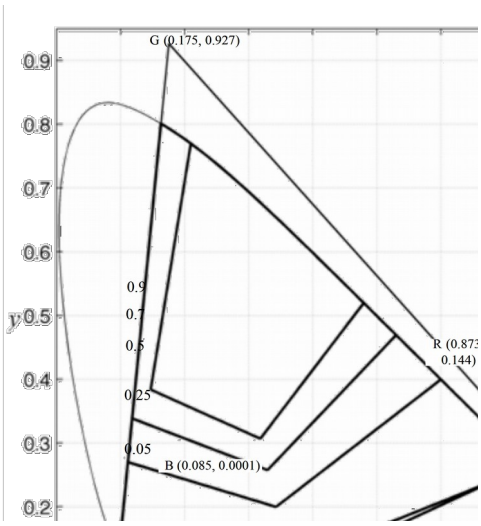

Figure 13 – Color gamut, which can be transmitted by ROM system, on the CIE-31 chromaticity diagram plane

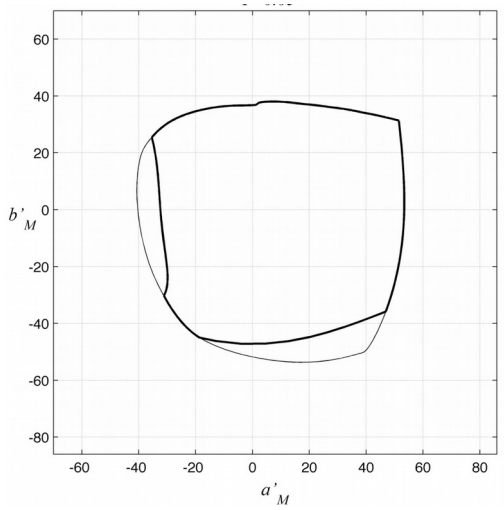

Figure 14 – Color gamut, which can be transmitted by ROM system, for $Y = 0.05$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

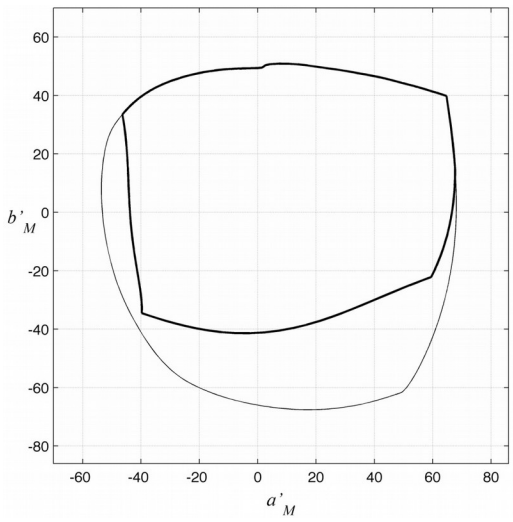

Figure 15 – Color gamut, which can be transmitted by the system ROM, for $Y = 0.25$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

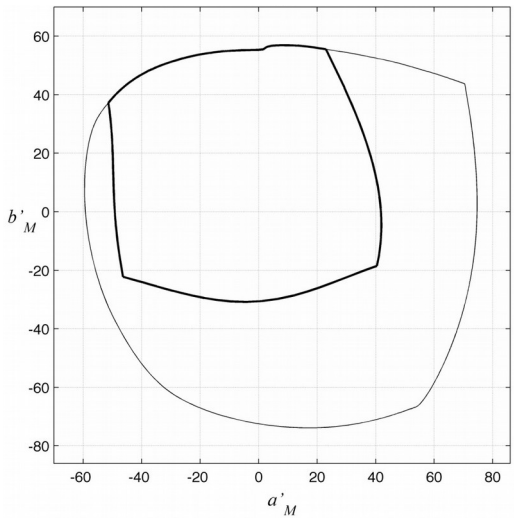

Figure 16 – Color gamut, which can be transmitted by the system ROM, for $Y = 0.5$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

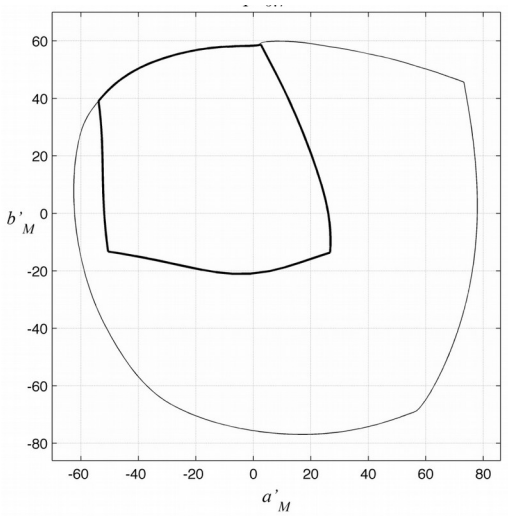

Figure 17 – Color gamut, which can be transmitted by the system ROM, for $Y = 0.7$ and $L_A = 50\ \text{cd/m}^2$, presented on the plane a'_M, b'_M

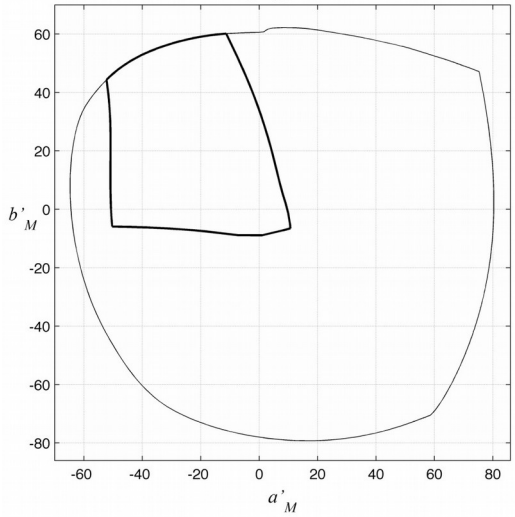

Figure 18 – Color gamut, which can be transmitted by the system ROM, for $Y = 0.9$ and $L_A = 50\ \text{cd/m}^2$, presented on the plane a'_M, b'_M

Color gamut transmitted by Wide Gamut system

Figure 19 shows the projections of color gamut transmitted by Wide Gamut system on CIE-31 tristimulus values plane. Figures 20–24 show projections of the color gamut transmitted by Wide Gamut system on the plane of chroma Cartesian coordinates a'_M, b'_M of J', a'_M, b'_M uniform color space.

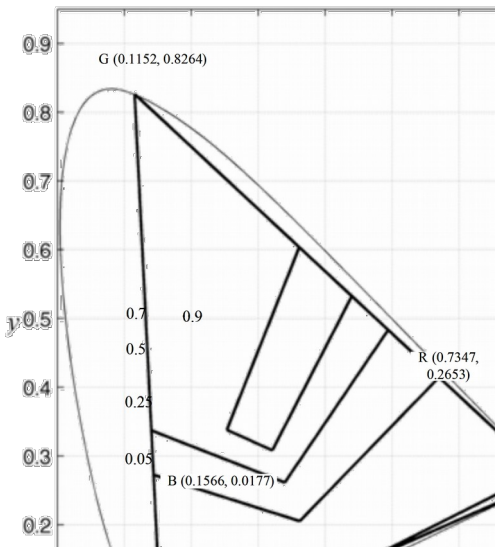

Рисунок 19 – Color gamut, which can be transmitted by Wide Gamut system, on the CIE-31 chromaticity diagram plane

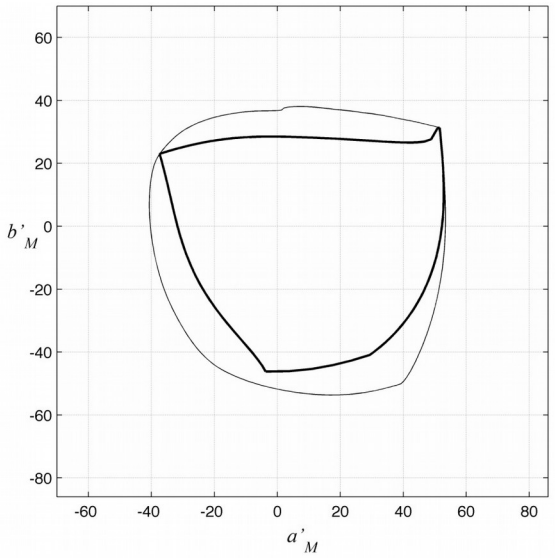

Figure 20 – Color gamut, which can be transmitted by Wide Gamut system, for $Y = 0.05$ and $L_A = 50\ \text{cd/m}^2$, presented on the plane a'_M, b'_M

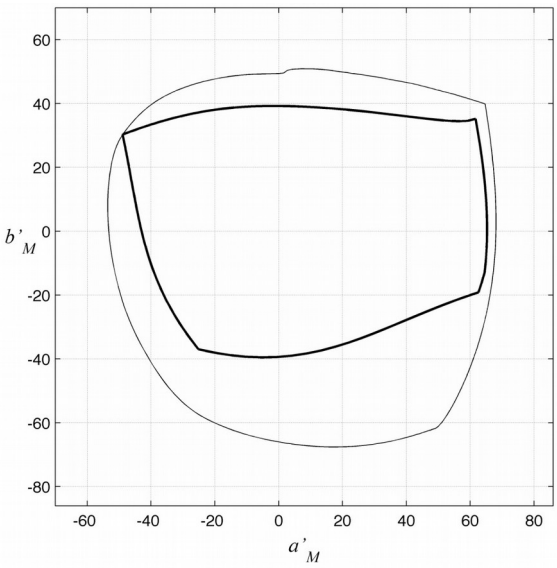

Figure 21 – Color gamut, which can be transmitted by Wide Gamut system, for $Y = 0.25$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

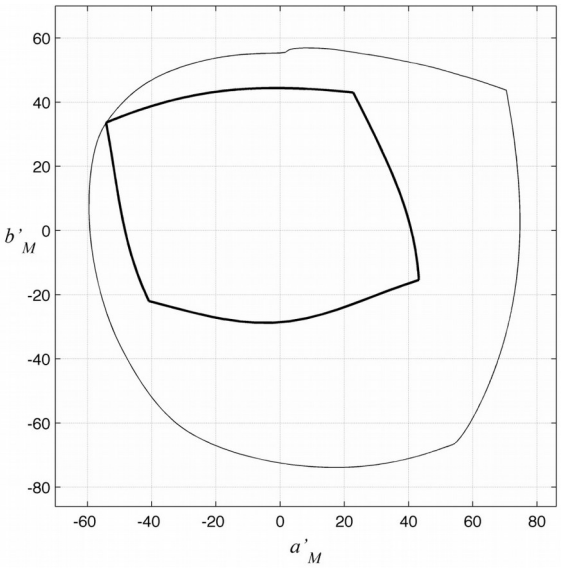

Figure 22 – Color gamut, which can be transmitted by Wide Gamut system, for $Y = 0.5$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

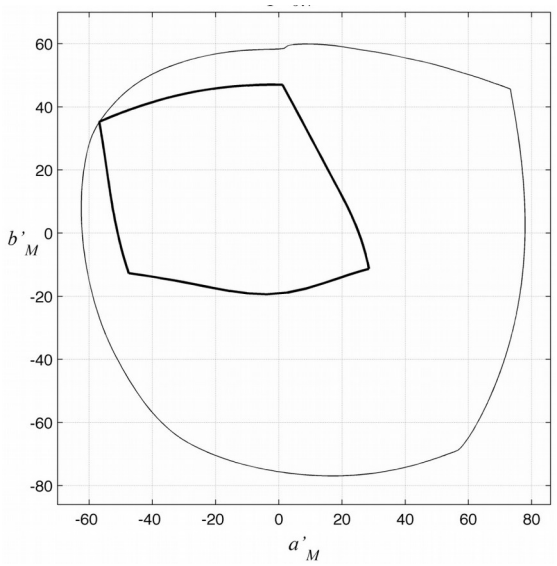

Figure 23 – Color gamut, which can be transmitted by Wide Gamut system, for $Y = 0.7$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

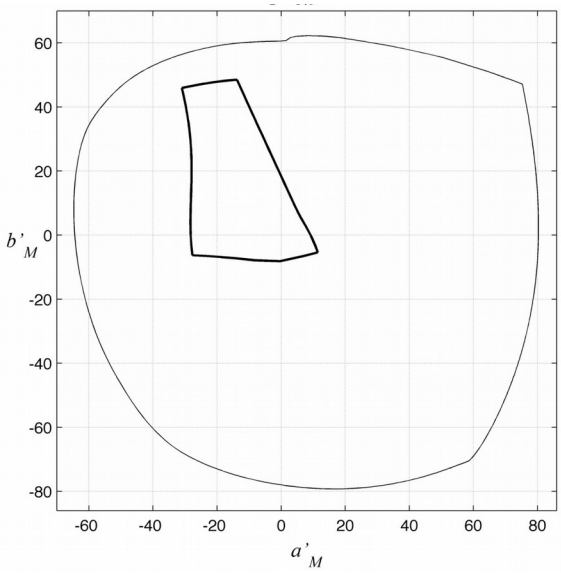

Figure 24 – Color gamut, which can be transmitted by Wide Gamut system, for $Y = 0.9$ and $L_A = 50$ cd/m^2, presented on the plane a'_M, b'_M

Comparison of color gamut transmitted by RIMM-ROMM, ROM, Wide Gamut systems with color gamut transmitted by HDTV and UHDTV systems

In the Table 2 are presented the comparative estimations of color gamut transmitted by RIMM-ROMM, ROM and Wide Gamut systems and of color gamut transmitted by HDTV system, realized in accordance with Recommendation ITU-R BT.709 and by UHDTV system, realized in accordance with Recommendation ITU-R BT.2020.

Table 2 – Comparative estimations of color gamut transmitted by RIMM-ROMM, ROM and Wide Gamut systems and of color gamut transmitted by HDTV system and by UHDTV system

Y	$S_{CD}/S_{CG}\cdot 100\%$				
	HDTV	UHDTV	RIMM-ROMM	ROM	Wide Gamut
0.05	39.1	64.0	82.4	89.5	71.6
0.25	37.0	59.6	72.8	73.0	60.7
0.50	22.3	38.9	48.3	46.4	38.6
0.70	14.8	26.2	33.6	31.8	26.3
0.90	3.70	6.50	11.2	19.4	8.80

Study undertaken allows to give a comparative estimates of the size of the color gamut area for multimedia applications and high and ultrahigh definition television systems. Since these estimates are given in uniform color space, they characterize the color gamut area in terms of standard human visual system.

The estimates obtained make it possible to come to the following conclusions::

- color gamut area size of UHDTV system compared to HDTV system greater than about 1.7 times for all levels of luminance;
- for RIMM-ROMM system (Kodak) compared with UHDTV color gamut area size is greater about 1.3 times for all levels of luminance; the same order of color gamut area increase is achieved for the case of ROM system (Kodak).
- for the Wide Gamut (Adobe) system for all luminance levels color gamut area size is approximately the same as for UHDTV system.

Presented data can be used to make decisions on further improvement of TV and other systems. It should be noted that the above estimates are obtained taking into account the dependence of color gamut area size on the image luminance in relation to the restriction of the field of transmitted colors with luminance increasing.

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