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EVALUATION AND SELECTION OF COLOUR SPACES FOR DIGITAL SYSTEMS

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ABSTRACT

The research examined the changing of colour difference by the control colours depending on the choice of colour space when working with matrix photo detector. The spectral characteristics of photo detectors from different manufacturers noticeably differ from each other and from the addition functions of the working RGB system. This can explain the difference in colour quality between different digital devices. A software method for studying the colour rendition of the image obtained by digital devices based on the selection of an individual colour space for each matrix photo detector is proposed. To analyze and evaluate the capabilities of the spectral characteristics of matrix photo detectors, the control colour method based on the Mansell Atlas was used. The analysis of the obtained parameters of 14 colours was carried out according to various criteria for seven colour spaces: sRGB, AdobeRGB, DCI-P3 RGB, M1N1P1, PAL / SECAM, Wide Gamut RGB, ProPhoto RGB. Also studied the influence of the choice of colour space on the change in the coordinates of the source 6,500 K. Based on the colour differences of the control colours, it is possible to choose the optimal colour space for working with a specific matrix photo detector. The latter will reduce colour distortion at the initial stage of image registration. The ways for improving the colorimetric method of control colours are proposed as applied to digital devices at the software level.

Keywords: colour, colour space, colour difference, digital device, matrix photo detector, RGB

1. INTRODUCTION

The matrix, or the multi-element matrix photo detector (MPD), is one of the main electronic units of digital registering devices. The quality of obtained images depends on to a large extent of their characteristics. The process of colour separation in most image-capturing devices is conducted by MPD itself. Colour separation systems have been constantly developing, which requires large financial and temporal expenses [1]. Digital devices for registration and reproduction of colour images use different colour spaces. The variety of these spaces is related to capabilities of contemporary engineering. For instance, *ProPhoto RGB* is developed with digital capturing of photo film, *sRGB* is based on capabilities of reproducing systems, and *AdobeRGB* is based on capabilities of colour printing. Equipment manufacturers try to follow the established standards adjusting characteristics for correspondence with them. For instance, digital cameras with different spectral characteristics of MPD mostly utilise *sRGB* or *AdobeRGB* [2, 3] and colour distortions are compensated by different correction software. In the course of visualisation and printing of an input image, additional colour distortions occur, therefore, colour rendering in a ready picture becomes inadequate. That is why it is important to obtain the primary digital image which is "clean" to the maximum extent.

Advanced users use a special format to have an opportunity to select a colour space, *RAW*, which contains parameters of each primary colour: *R* (red), *G* (green) and *B* (blue) captured directly from the MPD and either not interpolated, or not digitally filtered. Then a user may set any colorimetric system using different software. Usually, such colour profiles as *Wide Gamut RGB* and *ProPhoto RGB* are selected because of their large colour gamut. However, sometimes application of a colour space with lesser gamut may allow us to obtain better results, which is mostly related to input colour data captured from MPD with different spectral characteristics of major colours.

Every year, newer methods of processing, transformation and improvement of images obtained by digital devices which are just the final stage of processing have been proposed [4–7]. All efforts of manufacturers aim at improvement of optics and software. At the same time, the effect of colour space interaction with MPD characteristics is omitted. Spectral characteristics of filters of camera colour separation systems significantly differ both from each other and from colour mixture curves of the applied standard colorimetric system.

In short, researchers try to solve the problem of colour distortions on a shallow level, without actually taking MPD characteristics into account.

The goal of this work was to study interaction of colour spaces with different spectral characteristics of MPD, and the objectives were to select and analyse spectral characteristics of MPDs by well-known manufacturers; to select and to describe colour spaces; to develop the study methodology; to analyse the obtained results; to formulate recommendations on interaction between colour spaces and spectral characteristics of PD.

2. THE PRESENTED MATRIX PHOTO DETECTORS

MPDs by three manufacturers were selected as study objects: *Sony, Kodak* and *Agilent* (Fig. 1) [3]. Their ideal spectral characteristics have smooth dome shape with single maximums at operational wavelength, λ. For instance, it is ideal when the peak of the green channel spectral curve corresponds to λ = 555 nm.

The curves of the *Sony* MPD are rather smooth and without secondary peaks. However, the peak of the green channel is at λ = 540 nm and the green and blue channel curves cover slightly larger spectral areas. Transmission of blue and green shades of colour is especially important for human, since it is these shades that prevail in the environment (the sky, reflection at water surface, leaves, grass, etc.). The red channel curve corresponds to high transmittance level and its peak is split in two.

When the *Kodak* MPD spectral characteristics are analysed, secondary peaks of the red and blue channels covering each other can be seen. Probably such non-uniformities of the system are taken into account by the manufacturers at the software level and are somehow compensated. However, the original curves will be processed in the study.

The spectral characteristics of the *Agilent* MPD are similar to the previous ones. The curves of the red and blue channels have "tails" covering non-operating regions rather than secondary peaks. Moreover, the peaks of all curves are wide and not smooth, and it worsens the operating properties of MPD and

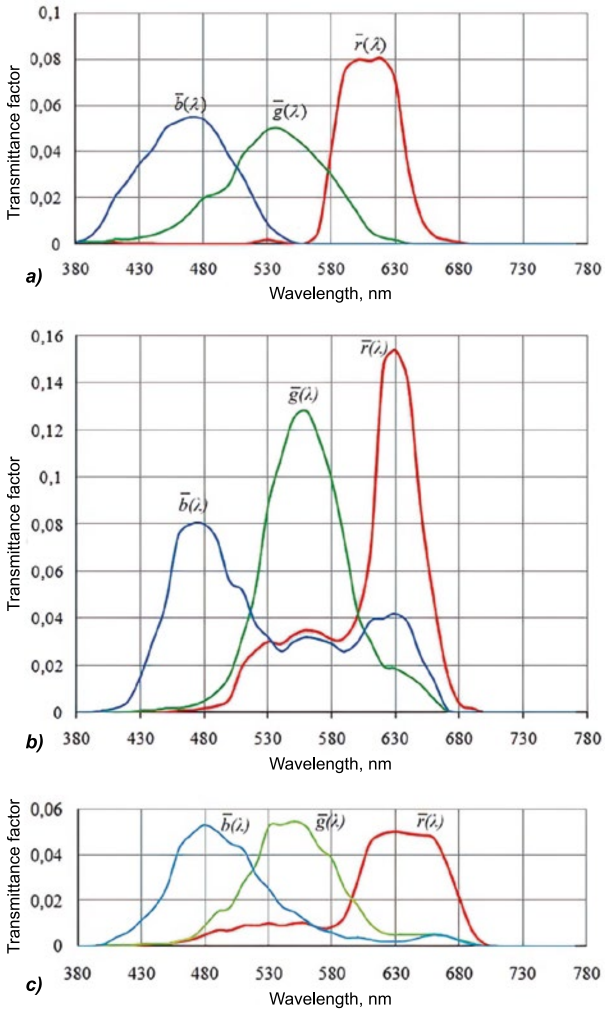

Fig. 1. Spectral characteristics of matrix photo detectors *Sony* (*a*), *Kodak* (*b*) and *Agilent* (*c*)

transmission of "clear" colours. These curves correspond to low transmission as compared to the other MPDs, and since chromaticity of control samples is taken into account hereinafter rather than their colour, transmittance shall not affect the results.

This implied that the *Sony* MPD should have the least colour distortions among the analysed ones. But we will return to this assumption in the end of the study, below.

3. THE STUDIED COLOUR SPACES

The contemporary colour spaces *sRGB*, *AdobeRGB*, *DCI-P3 RGB*, *M1N1P1*, *PAL/SECAM*, *Wide Gamut RGB*, *ProPhoto RGB* [1, 2] with different colour gamut [CG] were selected for the study. The systems with reference white *D65* were selected mostly. *Wide Gamut RGB* and *ProPhoto RGB* are exceptions: they have the *D50* colour and have no analogues in terms of CG.

The *sRGB* system is developed as a standard for web and multimedia applications. This and the following colour spaces are actually the main ones for all digital image capturing devices.

The *AdobeRGB* space has increased colour gamut as compared to *sRGB* and is used for typographical and digital printing.

DCI-P3 RGB is the new colour space which imitates the colour palette of motion picture film. This system was developed by the community of cinema and TV engineers as a standard for digital cinemas. The colour gamut of the new space is larger than that of *sRGB* and is smaller than that of *Adobe RGB* in the green-yellow region and is larger than it in the yellow-red region. Nowadays, the *DCI-P3 RGB* system has been being introduced in smartphones and tablets. But will it be able to compete well with the previous two colour spaces?

The *M1N1P1* system was developed by the author and studied both at the software level and experimentally [8, 9]. The system has showed good results according to all criteria but still has not been compared to the leading colour spaces. *M1N1P1* is described as the colour space with maximum colour gamut but minimal negative colour mixture curves for better interaction with digital devices. The *M1N1P1* system has real main colours. When analysing a standard light source (SLS) *E* (with equi-energy spectrum of radiation), correspondence of *M1N1P1* with the CIE1931 *XYZ* was proven. The shape of the obtained spectral characteristics (curves) is better than that of contemporary analogues and these characteristics will allow us to minimise losses in colour reproduction. Mathematical modelling and comparison of theoretical and practical curves have given satisfactory results.

The *PAL/SECAM* space is based on chromaticities of colour-forming stimuli recommended by the European video broadcasting standard. It is a standard of TV and video broadcasting systems.

The *Wide Gamut RGB* space has maximum possible colour gamut (78 %), clear main spectral colours (λ of 700 nm, 525 nm and 450 nm) and *D50* white point.

ProPhoto RGB almost completely covers the colour gamut of human eye; it is developed for storage of photos and images without losses of information if colour gamut of the used colour space is insufficient. Green and blue are nonphysical. The white point is *D50*.

The major colours of *RGB* systems are presented in Fig. 2.

4. THE METHOD OF COLOUR PARAMETERS CALCULATION

The tristimulus values of reference colours calculation method is based on integral calculation of colour values of an object illuminated by a light

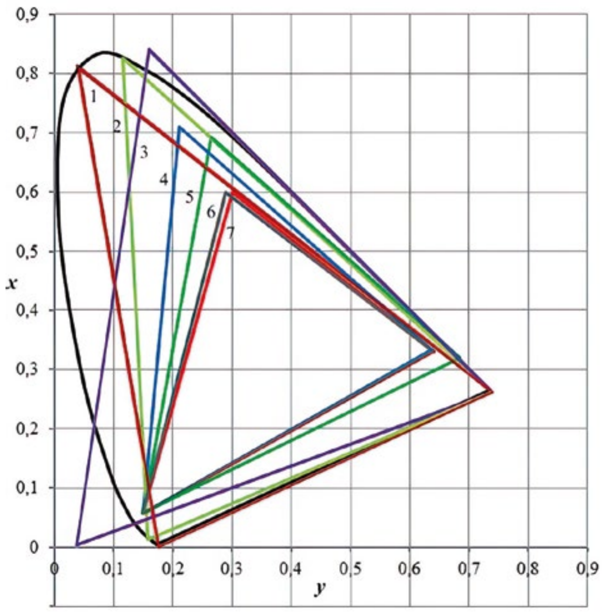

Fig. 2. The studied colour spaces on the *x, y* colour space: *1 – M1N1P1; 2 – Wide Gamut RGB; 3 – ProPhoto RGB; 4 – AdobeRGB; 5 – DCI-P3 RGB; 6 – PAL/SECAM; 7 – sRGB*

source with specific spectrum registered by a MPD with specific spectral characteristics and further transformation into one of the colour spaces using the formulas [10, 11].

$$R' = \int_{\lambda=400}^{770} \varphi(\lambda) S_{\mathrm{R}}(\lambda) \bar{r}(\lambda) r_{\mathrm{N},\lambda} d\lambda,$$

$$G' = \int_{\lambda=400}^{770} \varphi(\lambda) S_{\mathrm{G}}(\lambda) \bar{g}(\lambda) r_{\mathrm{N},\lambda} d\lambda,$$

$$B' = \int_{\lambda=400}^{770} \varphi(\lambda) S_{\mathrm{B}}(\lambda) \bar{b}(\lambda) r_{\mathrm{N},\lambda} d\lambda,$$

where $\varphi(\lambda)$ is the spectral radiant flux; $S_R(\lambda)$, $S_G(\lambda)$, $S_B(\lambda)$ are the spectral characteristics of MPD; $\bar{r}(\lambda)$, $\bar{g}(\lambda)$, $\bar{b}(\lambda)$ are the colour mixture curves; $r_{\mathrm{N},\lambda}(\lambda)$ is the spectral luminance factor of the reference samples.

In this case, the tristimulus values in the *R', G', B' linear space will be obtained.* To present the tristimulus values in the required space, it is necessary to transform them into a non-linear *RGB* space, i.e. to take the γ transformation, luminance transformation, etc. into account. If necessary, colorimetric correction is also conducted. But these steps are not made in this study since all values shall be presented in the *XYZ* system.

Then the tristimulus values are transformed into *XYZ* from *RGB* using the expression

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} X_{\mathrm{R}} & X_{\mathrm{G}} & X_{\mathrm{B}} \\ Y_{\mathrm{R}} & Y_{\mathrm{G}} & Y_{\mathrm{B}} \\ Z_{\mathrm{R}} & Z_{\mathrm{G}} & Z_{\mathrm{B}} \end{pmatrix} \begin{pmatrix} R' \\ G' \\ B' \end{pmatrix},$$

where X_{R}, X_{G}, X_{B}, Y_{R}, Y_{G}, Y_{B}, Z_{R}, Z_{G}, Z_{B} are the coefficients for recalculation for a specific *RGB* system.

The recalculation coefficients were calculated in accordance with the method [10, p. 236–247, 249–256]. For instance, for the *PAL/SECAM* space, the coefficients were equal to 0.514, 0.265, 0.024, 0.324, 0.670, 0.123, 0.162, 0.065, and 0.853 respectively.

After transformation, the chromaticity coordinates are found:

$$\begin{cases} \mathrm{x} = \dfrac{\mathrm{X}}{\mathrm{X}+\mathrm{Y}+\mathrm{Z}}; \\ \mathrm{y} = \dfrac{\mathrm{Y}}{\mathrm{X}+\mathrm{Y}+\mathrm{Z}}. \end{cases}$$

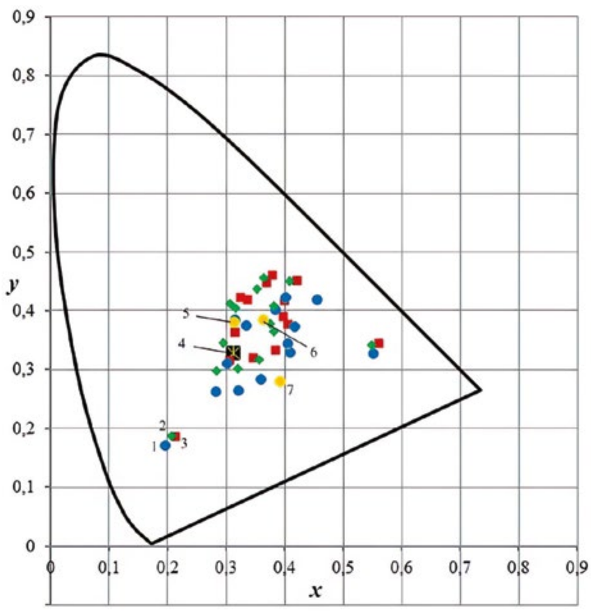

Fig. 3. Chromaticity coordinates of 14 colours from the Munsell Atlas in the *XYZ system: 1 – Sony; 2 – Agilent; 3 – Kodak; 4 –* SLS *D65; 5 –* light source *Agilent; 6 –* light source *Kodak; 7 –* light source *Sony*

The *XYZ* system is not a uniform chromaticity system, therefore, for adequate comparison of the obtained values with the theoretical data, the chromaticity coordinates shall be transformed into a uniform chromaticity colorimetric system in which colour difference threshold between two colours shall be the same over the entire colour space. According to the CIE recommendations, one of the large number of such systems may be selected: *CIEUVW*, *CIELUV*, *CIELAB,* and *CIECAM* [12, 13]. However, they all are oriented on determination of colour change, and if a colour space is selected based on MPD spectral characteristics, it is more necessary to aim at adequacy of chromaticity transmission. Many factors affect the tristimulus values in a real digital system: the dynamic range, the size of the sensitive surface, noises, etc. Colour depends on brightness, while chromaticity is constant. Therefore, in order to be capable to compare the results of the mathematical study with the experimental results, it was decided to analyse colour difference based on chromaticity by means of the 1976 *u'v'* uniform-chromaticity-scale diagram, where, as opposed to the 1960 *u, v* diagram, the yellow, orange and red chromaticities are more balanced.

The ratio of chromaticity coordinates on the *x, y* and *u', v'* colour diagrams is defined as

Table 1. Example of Colour Difference of the Samples for *Sony* MPD from *sRGB* Sample

Chromaticity coordinates	Numbers of the reference colours													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Groups	Medium saturation								Higher saturation				Special	
Colour	Light grey-red	Grey-yellow	Yellow-green	Light-green	Light-magenta	Light-blue	Light-violet	Purple	Red	Yellow	Green	Blue	Pinkish (skin colour)	Green (colour of foliage)
X	21.58	18.14	15.78	14.40	16.99	18.81	21.32	23.92	12.72	35.78	9.19	4.56	38.57	6.12
Y	17.30	16.20	16.51	16.07	17.25	17.32	17.47	18.74	7.49	32.64	11.20	3.94	32.49	6.37
Z	13.70	9.12	6.83	12.39	21.68	29.98	27.31	23.75	2.79	9.80	8.73	14.59	23.73	3.41
x	0.4104	0.4174	0.4035	0.3359	0.3038	0.2845	0.3226	0.3602	0.5531	0.4574	0.3155	0.1974	0.4069	0.3847
y	0.3290	0.3727	0.4220	0.3750	0.3085	0.2620	0.2642	0.2822	0.3258	0.4173	0.3845	0.1706	0.3428	0.4009
Δx	0.0129	0.0134	0.0172	0.0411	0.0375	0.0342	0.0236	0.0130	0.1159	0.0026	0.0558	0.0400	0.0145	0.0188
Δy	0.0197	0.0074	0.0365	0.0281	0.0016	0.0225	0.0379	0.0455	0.1341	0.0260	0.0328	0.0227	0.0076	0.0265
u'	0.2680	0.2515	0.2224	0.1968	0.1994	0.2041	0.2335	0.2543	0.3812	0.2580	0.1807	0.1698	0.2583	0.2185
v'	0.4832	0.5054	0.5234	0.4943	0.4556	0.4230	0.4304	0.4483	0.5052	0.5295	0.4956	0.3300	0.4897	0.5124
$\Delta u'$	0.0008	0.0123	0.0225	0.0340	0.0262	0.0178	0.0002	0.0155	0.2943	0.0093	0.0420	0.0285	0.0067	0.0207
$\Delta v'$	0.0128	0.0012	0.0105	0.0063	0.0065	0.0218	0.0324	0.0343	0.0699	0.0097	0.0060	0.0315	0.0061	0.0076
Δe	0.0128	0.0123	0.0248	0.0346	0.0270	0.0282	0.0324	0.0376	0.3025	0.0134	0.0424	0.0425	0.0090	0.0221
$\Delta\bar{e}_{u'v'}$	0.0262								0.1002				0.0156	

Table 2. Set of Correction Filters

Sony MPD	Δx	Δy
sRGB	0.080	–0.050
AdobeRGB	0.027	–0.019
DCI-P3 RGB	0.063	–0.034
PAL/SECAM	0.071	–0.048
M1N1P1	0.011	–0.053
Wide gamut RGB	0.030	–0.045
ProPhoto RGB	–0.004	–0.015

$$\begin{cases} u' = \dfrac{4x}{-2x+12y+3}; \\ v' = \dfrac{9y}{-2x+12y+3}. \end{cases}$$

The change in chromaticity was defined as an Euclidean distance in the uniform-chromaticity-scale area along the shortest way between colour points, i.e. the distance which is essentially the length of a particular curved way between the corresponding colour points in the CIE1931 space,

$$\Delta e_{u'v'} = \sqrt{\left(u'_{p} - u'_{T}\right)^2 + \left(v'_{p} - v'_{T}\right)^2},$$

where u'_p, v'_p are the chromaticity coordinates obtained in the course of interaction of spectral characteristics of MPD with the colour space; u'_T, v'_T are the chromaticity coordinates obtained in the *XYZ* space without the effect of MPD.

A *D65* SLS was selected as an emitter (CCT of 6,500 K) [14] with standardised radiation spectrum close to that of daylight at noon.

Fourteen colours of the Munsell Atlas applied for calculation of general colour rendering index R_a were selected as reference samples. Average values of colour difference Δe were analysed using the groups of samples with medium saturation (from 1 to 8), higher saturation (9 to 12) and special samples: No. 13 (face skin) and No. 14 (foliage).

The entire algorithm of the calculation method was implemented in *MATLAB*. Fig. 3 presents the chromaticity coordinates of 14 reference colours for the studied MPDs when using the *sRGB* space. An example of output tristimulus values for the *Sony* MPD and the *sRGB* space is summarised in Table 1 where Δx, Δy and $\Delta u'$, $\Delta v'$ are the differences between chromaticity coordinates of the reference samples calculated in the *XYZ* system without turning the MPD on and in the *sRGB* with turning the MPD on transformed into *XYZ* by means of the recalculation coefficients. In accordance with GOST [14], the values of chromaticity coordinates for SLS should not exceed 0.01. For the *Sony* MPD, none of the spaces meet this requirement to *D65* SLS (Tables 2 and 3).

When calculating coordinates of the light source in these spaces, it is necessary to conduct the γ correction, as a result of which the colour will probably correspond to the theory to maximum extent. For *sRGB*, the γ indicator is not uniform over the entire space, which complicates such manipulation. Probably, this is the reason why white balance in digital devices is based also on specific reference colours and not on the source itself. As seen from Table 2, the best result was obtained for *ProPhoto RGB*, and the worst one was obtained for *sRGB*. As a result of software calculation, the values of colour differences were obtained and their average values in particular groups of samples were found; they are presented in Tables 3–5.

Similar calculations and transformations were conducted for the *Kodak* and *Agilent* MPD's (Ta-

Table 3. Chromaticity Coordinates of *Sony* MPD

Colour spaces	Average value of Δ*e* of different colour groups					Δ*e* of LS
	Nos. 1–14	Nos. 1–12	Nos. 1–8	Nos. 9–12	Nos. 13 and 14	
sRGB	*0.0458*	*0.0509*	*0.0262*	*0.1002*	0.0156	*0.0862*
AdobeRGB	0.0361	0.0410	0.0173	0.0886	**0.0065**	0.0278
DCI-P3 RGB	0.0400	0.0443	0.0227	0.0877	0.0138	0.0626
M1N1P1	0.0325	0.0350	**0.0176**	0.0699	*0.0177*	0.0426
PAL/SECAM	*0.0445*	0.0496	0.0249	*0.0991*	0.0141	*0.0776*
Wide gamut RGB	**0.0279**	**0.0304**	**0.0134**	**0.0643**	0.0130	0.0466
ProPhoto RGB	**0.0321**	**0.0367**	0.0173	0.0757	**0.0045**	**0.0095**
Mean value	**0.04**	**0.04**	**0.02**	**0.08**	**0.012**	**0.05**

Table 4. Chromaticity Coordinates of *Kodak* MPD

Colour spaces	Average value of Δe of different colour groups					Δe of LS
	Nos. 1–14	Nos. 1–12	Nos. 1–8	Nos. 9–12	Nos. 13 and 14	
sRGB	**0.0588**	0.0650	0.0425	*0.1099*	**0.0218**	**0.0366**
AdobeRGB	0.0653	0.0691	*0.0506*	0.1059	0.0426	0.0570
DCI-P3 RGB	0.0622	0.0665	**0.0492**	0.1013	0.0361	0.0440
M1N1P1	0.0614	**0.0627**	**0.0492**	**0.0895**	0.0541	0.0427
PAL/SECAM	**0.0584**	0.0644	0.0420	*0.1091*	**0.0227**	**0.0346**
Wide gamut RGB	0.0611	**0.0627**	**0.0520**	**0.0840**	0.0520	0.0460
ProPhoto RGB	*0.0730*	*0.0752*	*0.0644*	0.0967	*0.0598*	*0.0743*
Mean value	**0.06**	**0.07**	**0.05**	**0.10**	**0.04**	**0.05**

Table 5. Chromaticity Coordinates of *Agilent* MPD

Colour spaces	Average value of Δe of various colour groups					Δe of LS
	Nos. 1–14	Nos. 1–12	Nos. 1–8	Nos. 9–12	Nos. 13 and 14	
sRGB	**0.0557**	**0.0612**	**0.0368**	*0.1099*	**0.0232**	**0.0302**
AdobeRGB	0.0653	0.0683	0.0489	0.1071	0.0473	0.0699
DCI-P3 RGB	0.0584	0.0621	0.0427	0.1010	0.0366	0.0493
M1N1P1	0.0650	0.0655	0.0507	0.0950	0.0624	0.0606
PAL/SECAM	**0.0558**	**0.0609**	**0.0367**	*0.1092*	**0.0254**	0.0344
Wide gamut RGB	0.0616	0.0624	0.0500	**0.0872**	0.0569	0.0586
ProPhoto RGB	*0.0780*	*0.0799*	*0.0678*	0.1041	*0.0664*	*0.0848*
Mean value	**0.06**	**0.07**	**0.05**	**0.10**	**0.05**	**0.06**

ble 3–5). The Tables present average values for the three main groups: Nos. 1–8, 9–12 and 13–14 as well as the average value for all colours and for Nos. 1–12, and the best and the worst results of calculations are marked.

5. ANALYSIS OF THE RESULTS

Analysis of the described MPDs and colour spaces was conducted within the framework of this study only.

For the *Sony* MPD, *Wide Gamut RGB* and *ProPhoto RGB* colour spaces turned out to be the best (Table 3) and *sRGB* and *PAL/SECAM* turned out to be the worst. Despite the fact that both the latter systems are rather close to each other in terms of major colour coordinates, *PAL/SECAM* is still better than *sRGB*. The other systems have shown the good but not excellent results.

DCI-P3 RGB, *M1N1P1* and *Wide Gamut RGB* (Table 4) proved themselves as the best ones for the *Kodak* MPD. These systems have good values in several groups. *ProPhoto RGB* is the worst space for application with this MPD despite its large colour gamut. As could be expected, the worst results were seen in the group with higher saturation. The MPD has secondary maximums in different regions of the spectre not allowing us to identify a "clear" colour in the saturated shades. As a result, in *Wide Gamut RGB* demonstrated the only good result in terms of average saturation. Combined with the *Kodak* MPD, the spaces *sRGB* and *PAL/SECAM* have both advantages and disadvantages although these spaces have the best light source values.

SRGB and *PAL/SECAM* may also be noted for the *Agilent* MPD. *AdobeRGB*, *DCI-P3 RGB*, *M1N1P1* and *Wide Gamut RGB* (Table 5) have demonstrated acceptable values and the *ProPhoto RGB* space turned out to be the worst, since this MPD, like the *Kodak* MPD, has spectral characteristics with secondary maximums.

Therefore, the more secondary maximums has MPD spectral characteristic curve, the less colour gamut should be (with large negative branches which probably compensate these secondary maximums).

Table 6. Average Chromaticity Values of MPDs

Colour space	MPD	Value $\Delta\bar{e}_{u'v'}$ of the sample groups			Changes of $\Delta\bar{e}_{u'v'}$ of the sample groups with respect to the indicators of *Wide Gamut RGB*:		
		medium saturation, Nos. 1–8	higher saturation, Nos. 9–12	Nos. 13 and 14	medium saturation, Nos 1–8	higher saturation, Nos. 9–12	Nos. 13 and 14
sRGB	*Sony*	0.0262	0.1002	0.0156	1.96	1.56	1.20
	Kodak	0.0425	0.1099	0.0218	3.17	1.71	1.68
	Agilent	0.0368	0.1099	0.0232	2.75	1.71	1.78
Adobe RGB	*Sony*	0.0173	0.0886	0.0065	1.29	1.38	0.50
	Kodak	0.0506	0.1059	0.0426	3.78	1.65	3.28
	Agilent	0.0489	0.1071	0.0473	3.65	1.67	3.64
DCI-P3 RGB	*Sony*	0.0227	0.0877	0.0138	1.69	1.36	1.06
	Kodak	0.0492	0.1013	0.0361	3.67	1.58	2.78
	Agilent	0.0427	0.1010	0.0366	3.19	1.57	2.82
M1N1P1	*Sony*	0.0176	0.0699	0.0177	1.31	1.09	1.36
	Kodak	0.0492	0.0895	0.0541	3.67	1.39	4.16
	Agilent	0.0507	0.0950	0.0624	3.78	1.48	4.80
PAL/ SECAM	*Sony*	0.0249	0.0991	0.0141	1.86	1.54	1.08
	Kodak	0.0420	0.1091	0.0227	3.13	1.70	1.75
	Agilent	0.0367	0.1092	0.0254	2.74	1.70	1.95
Wide gamut RGB	*Sony*	0.0134	0.0643	0.0130	1	1	1
	Kodak	0.0520	0.0840	0.0520	3.88	1.31	4.00
	Agilent	0.0678	0.1041	0.0664	5.06	1.62	5.11
Pro Photo RGB	*Sony*	0.0173	0.0757	0.0045	1.29	1.18	0.35
	Kodak	0.0644	0.0967	0.0598	4.81	1.50	4.60
	Agilent	0.0678	0.1041	0.0664	5.06	1.62	5.11

It follows from Table 6 that the colour spaces *DCI-P3 RGB* and *M1N1P1* may be identified as the best ones since they do not have any issues and even demonstrate some best results for all the MPD's. As opposed to that, the *Sony* MPD combined with the *Wide Gamut RGB* colour space turned out to be the best option since it has the least colour distortions in all groups of the reference samples. Table 6 demonstrates by many times the colour differences of other MPDs combined with different colour spaces exceed that of the *Sony* MPD combined with *Wide Gamut RGB*. As we can see, *Agilent MPD has demonstrated the worst results.* Generally, the *Sony* MPD proved itself as the best detector (the best results in all indicators as compared to the other two), and the colour spaces *DCI-P3 RGB* and *M1N1P1* proved themselves as the best colour spaces (without issues). This means that the new colour system *DCI-P3 RGB* may be highly competitive with *sRGB* and *AdobeRGB*. And yet it is necessary to keep developing new colour spaces, since the *M1N1P1* system also demonstrated good results and a number of advantages [9].

CONCLUSION

The colour spaces *sRGB*, *AdobeRGB*, *DCI-P3 RGB*, *M1N1P1*, *PAL/SECAM*, *Wide Gamut RGB*, and *ProPhoto RGB* were studied on the basis of spectral characteristics of the *Sony*, *Agilent*, *Kodak* MPDs for digital systems. The shapes of spectral characteristics of MPDs directly affect the results of colour resolution. Larger colour gamut does not always demonstrate the best results, and many factors depend on the MPD. However, as the study results have shown the disadvantages of the MPD spectral characteristic curves may be reduced by selecting a specific colour space. This may be foreseen by preliminary calculation of colour difference of reference colours. But there are still no methods of digital system evaluation at the software level. The reference colour method is applicable more to the transmitting colour systems. And colour scales and profiling test objects are designed for digital registering devices, which is not applicable at the software level.

The colorimetric method of separate colours may be taken as the basis of the method. However:

– It is necessary to widen the list of reference colours of (saturated) yellow, green and magenta, since it is these shades which human sight system reacts the most to accurate representation of as compared to red and blue colours;

– It is necessary to have at least 5 different colours for each major colour, since equal-chromaticity-scale systems in which colour differences are found are not ideal and each of them causes its own deviations of colour threshold for each shade, and it is important to create a method, which would take the disadvantages of the systems into account for result processing and in which the reference colours would be selected with a specific periodicity, e.g. with difference by 2 or 4 tones;

– It is also possible to start using such atlases as *Pantone* and *RAL* which are widely used in polygraphy and design respectively.

Such method will allow us to test MPDs as early as at the stage of spectral characteristics development and then to compare the calculation data with the experimental results obtained using real samples of reference colours.

It is planned to conduct the studies with a selection of 24 reference samples using MPDs with different spectral characteristics by the same manufacturer. In particular, this will allow us to conduct a more detailed analysis of nonlinearity of colour spaces. Moreover, colour difference will be conducted using *CIELAB* and “intensity” of MPD spectral characteristics will be taken into account.

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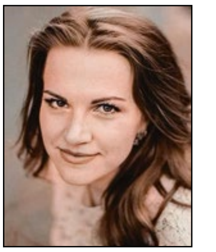

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