Analysis of the Effectiveness of Means to Achieve Optimal Color Balancing in Obtaining a Digital Photographic Image

Bohdan Kovalskyi[a], Myroslava Dubnevych[a] , Tetyana Holubnyk[a], Inna Skarga-Bandurova[b] Ludmyla Maik[a], Zoryana Selmenska[a]

[a] *Ukrainian Academy of Printing, Lviv, Ukraine*
[b] *Oxford Brookes University, United Kindom*

Abstract

The publication considers one of the most important indicators of the quality of a digital halftone image - colour reproduction, in particular colour balancing. The authors systematized the factors influencing this indicator, compiled an informational multilevel model of the importance of factors of influence and determined the priority of each of them. Based on the model of priority influence of factors, it is determined that in order to achieve optimal colour reproduction of digital images, the highest priority is the spectral composition of lighting, and the next most important is the format of data digitization. Based on the results of mathematical modelling, an experimental study of the influence of data digitization format on the degree of colour balance and determined that the optimal result provides data digitization in raw format with subsequent processing of the data file in specialized software. The authors also investigated that the use of automatic balancing in white on the degree of colour balancing has a significant impact on the method of exposure metering mode, which is recommended for consideration in the practical implementation of the photographic process. Recommendations for optimal adjustment of the workflow of formation and subsequent processing of qualitative characteristics of digital photo images are given.

Keywords

digital halftone image, colour balance, raw format, matrix of photosensitive elements, spectral characteristics, factors influencing the color balance, methods of exposure metering, auto white balance mode, RAW converter, gradation characteristics.

Introduction

Digital photography today has confidently taken the position of the only means of obtaining the halftone photographic image in the modern workflow of optical information recording. But the predominantly obtained photographic images require significant improvement in their quality characteristics in graphic editors and other software products. Further complicating the process of post-photographic processing is the absence of a standard procedure for an objective assessment of the quality of a digital photographic image, and the list and maximum permissible values of quality indicators are not regulated by any regulatory document. The international ISO standards standardize only a certain list of technical indicators of the quality of recording tools, but do not describe the methodology for evaluating and quality indicators of digital photographic images. In particular, the ISO 12232 standard defines how digital camera manufacturers set the exposure index, ISO value, output level, how exposure is recorded in metadata. A number of other ISO standards relate to the construction, operation and testing of digital cameras: resolution (ISO 12233), noise (ISO 15739),

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EMAIL: bkovalskyi@ukr.net (B. Kovalskyi), dubnevychmyroslava@gmail.com (M. Dubnevych); tanagolubnik@gmail.com (T. Holubnyk), iskarga-bandurova@brookes.ac.uk (I. Skarga-Bandurova), ludmyla.maik@gmail.com (L. Maik), zorselm@gmail.com (Z. Selmenska)
ORCID: 0000-0002-5519-0759 (B. Kovalskyi), 0000-0002-5519-0759 (M. Dubnevych); 0000-0002-8325-9813 (T. Holubnyk), 0000-0003-3458-8730 (I. Skarga-Bandurova), 0000-0001-8552-0942 (L. Maik), 0000-0002-9514-7923 (Z. Selmenska)

tone reproduction (ISO 14524), shading (ISO 17957), geometric distortion (ISO 17850), chromium ISO 19084) , image flare (ISO 18844), shooting delay (ISO 15781), low light (ISO 19093) and image stabilization (ISO 20954-1), test procedures for color characteristics (ISO 17321-1) and cameras in general /TR 19247) [1, 6].

Analyzing information about the perception of visual information by a person, we can summarize the following list of quality indicators of a digital photographic image: geometric parameters, structural characteristics, gradation and color characteristics. The human brain reacts especially critically to shortcomings in the structural indicators of the image [9, 10] (the presence of digital noise, reduced sharpness and non-reproduction of small details of objects). But gradation loss and color reproduction disturbances are no less important for adequate perception of information by the consumer (reader).

The color image when shooting with any photographic equipment, including digital, depends on many factors such as the distribution of the brightness of the subject (the ability to reflect or absorb certain zones of the radiation spectrum of the light source), lighting features (power and spectral composition of the light flux), optics characteristics (lens aperture) , the correct choice of exposure (combination of shutter speed and aperture), the type and characteristics of separating media (a device for registering single-color components of complex radiation), the characteristics of photosensitive sensors.

Sensors of the photosensitive matrix register colors almost objectively, that is, if there is a dominant radiation in the spectrum of the light source, this shade will prevail in the image. This negative moment can be minimized by using the white balance function. The software of all models of cameras (of different technical classes and purposes, including cameras for smartphones) has this option. At the same time, depending on the development of the software of a particular camera, this function can be implemented according to different algorithms: automatic balance, by source type, by color temperature, and manual white balance. The latter algorithm also requires the use of special test objects for adjusting the white point parameters to implement the color balancing process.

Complicating the process of obtaining a digital tone image with satisfactory color characteristics is also the problem of integrating color management systems into the workflow of photography due to changing lighting conditions.

Thus, the search for the optimal implementation of the balance of color reproduction of a digital photographic image is an urgent problem that requires an integrated approach, taking into account the significance of the factors influencing the specified quality indicator.

Related Works

Let us consider what physical phenomena underlie the process of forming the color characteristics of photographic images. To obtain a full-color image in additive space, it is necessary to fix its three single-color components as accurately as possible: red, green and blue partial image. The accuracy of fixing these arrays of information is one of the determining factors influencing the color characteristics of a digital photographic image (color reproduction). The chain of transformation of color information from a real object (subject) to its digital image (digital color halftone photo image) is as follows (Fig. 1). An object with certain spectral characteristics (the ability to reflect the visible zones of the spectrum described by the function $\rho_0(\lambda)$, receives radiation from a light source with a spectral distribution of energy $E_0(\lambda)$. Each natural or artificial light source is characterized by a certain spectral composition of radiation, in which, depending on the color temperature, one or another zone of the visible spectrum predominates. The luminous flux reflected by the object of shooting $E_1(\lambda)$, modulated according to the spectral composition , enters the light energy receiver - a matrix of photosensitive elements, composed of charge-coupled devices (CCD) or complementary metal oxide semiconductors (CMOS) through the optical system of the lens throughput $\tau_0(\lambda)$.

Both types of semiconductors (CCD and CMOS) are not characterized by selective photosensitivity to individual zones of the visible spectrum. On fig. Figure 2 shows the dependence of the relative sensitivity of transceivers of both types of matrices on the radiation wavelength. As can be seen from these dependences, the magnitude of the photoelectric effect is practically the same in the entire range of the visible spectrum (from 400 to 700 nm).

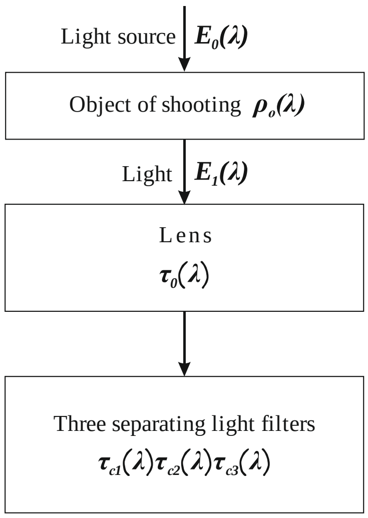


Figure: 1. Scheme of the process of transforming color information from the subject into a photographic image

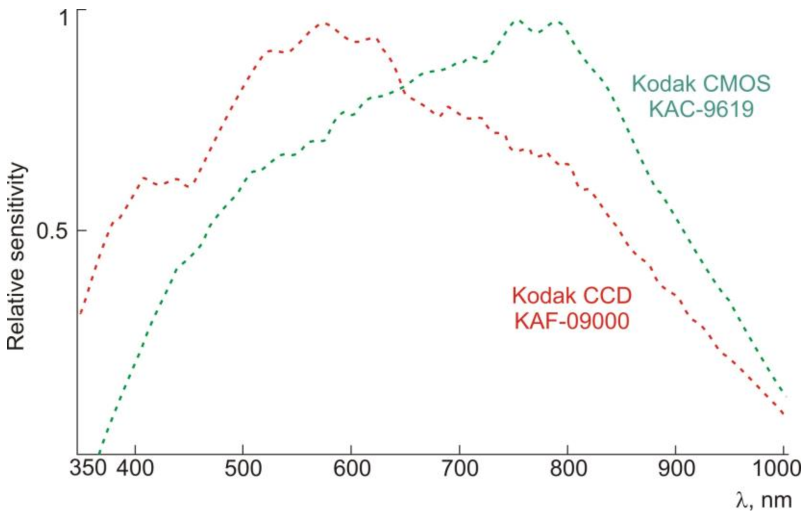


Figure: 2. Spectral photosensitivity of typical CCD and CMOS arrays

The spectral characteristics of CCD and CMOS elements necessitate the use of separating devices in photosensitive matrices [1] for separating a polychromatic light flux into three monochromatic components. The vast majority of models of modern digital photographic equipment (except for a few models equipped with a multilayer Foveon matrix, which, however, is of limited use) use arrays of light filters (Bayer array) with subsequent mathematical interpolation of color data in each image pixel (debayering algorithms). The transmittance of three separating light filters ($\tau_{c_1}(\lambda)$, $\tau_{c_2}(\lambda)$, $\tau_{c_3}(\lambda)$,) installed in front of light-sensitive transceivers determines the quantity and quality of the light flux entering the receiver.

Thus, the integral response of the light energy receiver, which describes the characteristics of a section of a color photographic image, is defined as (1):

$$r = f(a) = f\left(\int_0^\infty \rho_0(\lambda)\cdot E_1(\lambda)\cdot \tau_0(\lambda)\cdot \tau_c(\lambda)\,d\lambda\right). \tag{1}$$

The color characteristics of a photographic image in digital form depend on a whole list of factors, among which one of the most significant is the spectral characteristics of separating media, according to the sources [2, 3] [8], are far from ideal.

The status of the spectral sensitivity of light energy receivers of digital photographic equipment from three different manufacturers according to a standard set of light filters is shown in fig. 3 as a dependence of the relative response of the receiver on the light filter on the wavelength [5]. The blue dash-dotted line describes the sensitivity of the receiver to the blue filter, the green line to the green filter, and the red line to the red filter, respectively. It can be seen from the depicted graphic dependences that all sets of light filters are wide-zoned (transmission zones of light filters within the set overlap), which will inevitably lead to the registration of light fluxes of some individual wavelengths of radiation by two or even three light filters. This is the reason for the inaccuracy of fixing the color information and the subsequent inaccuracy of the color image of the photographic object in the digital image.

It is possible to prevent the occurrence of color reproduction deficiencies caused by the imperfection of the separating media by using color management systems. The purpose of color management systems is to coordinate the color gamut of various colorimetric systems of input and output devices (visualization) of information, as well as the conversion of color coordinates from one color system to another [8, 11]. It is especially difficult to achieve satisfactory color reproduction in digital photographic images due to the technical limitations of using color management systems in the digital photographic process.

All color transformation operations are carried out using ICC profiles, which describe, on the basis of standardized colorimetric systems, the possibilities of reproducing the color gamut of a particular device (in particular, a digital camera). For image input devices, a number of factors affect the final color rendering result: the optical system, the characteristics of the separating media and devices (filters, light sources), and software.

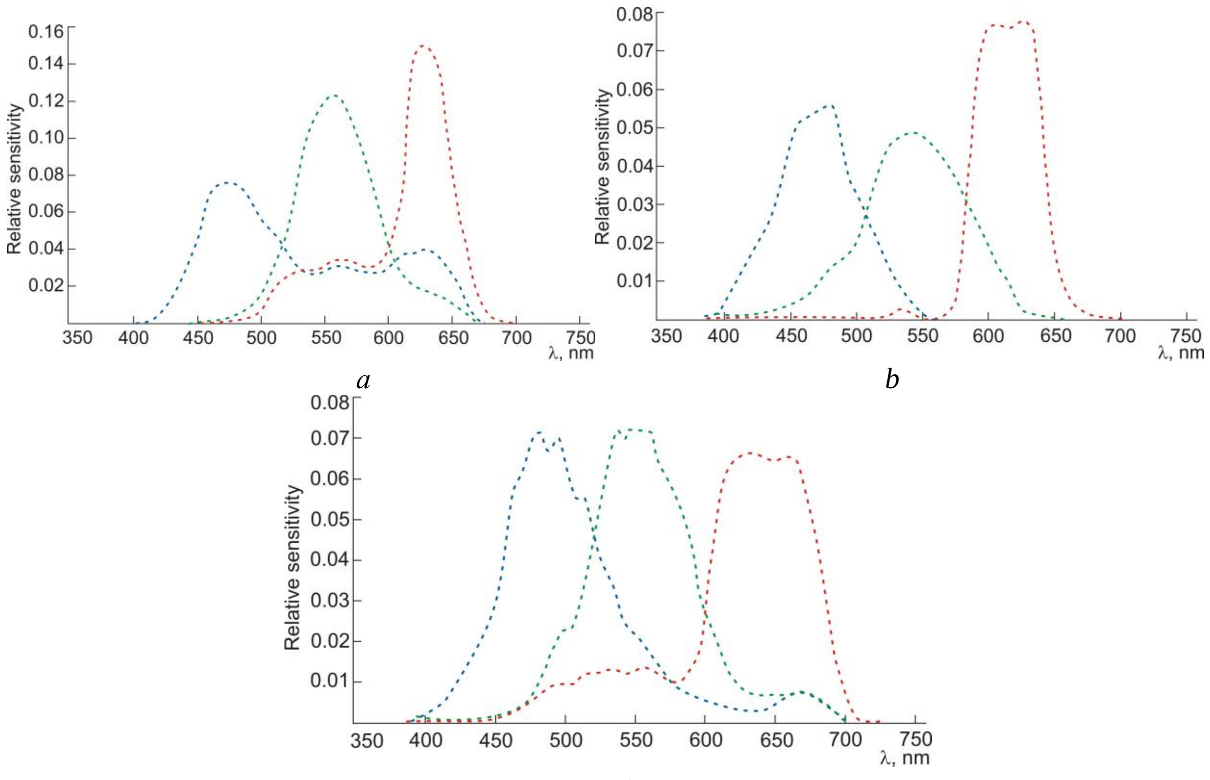


Figure: 3. Status of the spectral sensitivity of receivers of CCD and CMOS matrices of various configurations (as a dependence of the relative response of the receivers on the wavelength of light radiation) (a – full-frame Kodac CCD; b – Sony column-buffered CMOS array; c – Agilent CMOS array) [1, 5]

The reasons for the limited use of the color management system in the workflow of the digital photographic process, as shown in [4, 8], are significant technological and technical limitations:

1. When photographing with digital photographic equipment, the exposure is carried out each time under changing lighting conditions: both in terms of the intensity of the light flux and with its different spectral composition, which is especially critical for color reproduction. The profile obtained in this way will be a strictly narrow application for frames taken only under these specific lighting conditions. In each particular case, the profiling procedure should be repeated.

2. Profiling the process of photographing with digital photographic equipment is very laborious and has a number of features:

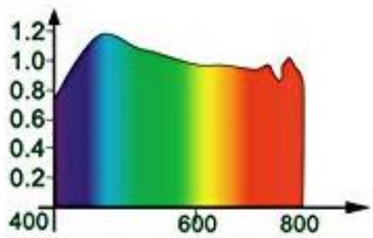
– ensuring the uniformity of the lighting conditions of the photographed object (the use of the same light sources with a strictly controlled color temperature, the absence of extraneous illumination of a different spectral composition in the frame, the uniformity of the illumination of the object);

– the test object must be located in the frame in way to avoid reflections from light sources and nearby foreign objects, which will violate the correspondence of the colorimetric coordinates of the fields of the test object itself;

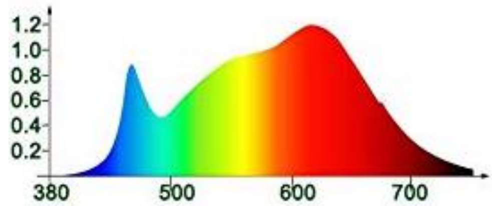
- illumination of the test object must be strictly uniform in terms of the intensity of the light flux, and the exposure itself must be accurately calculated to avoid under- and overexposure;

– when photographing, it is necessary to deactivate the algorithms for improving the qualitative and quantitative characteristics of a photographic image, which are used by default by the software for photographic equipment at the stage of processing data from a photosensitive matrix.

3. When constructing a profile of input devices, test objects with a large number of control fields (from several hundred to several thousand) are used, the absolute number of which has a direct impact on the accuracy of the result. Each type of photographic material, on which a test object for calibration is produced, is characterized by its own unique features in color reproduction.



a)



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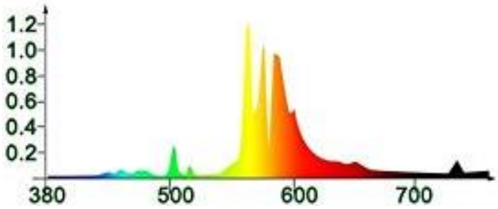


c)

Figure: 4. Distribution of luminescence energy over the spectrum of light sources: a) - daylight; b) - LED lamp of a warm glow spectrum; c) - fluorescent mercury lamp [10]

Thus, color management systems can be used only in a limited list of photography genres: fashion photography, food photography, portrait photography and other types of staged scenes, static in time, before photographing which it is possible to carry out profiling. Other things like reportage, sports photography, street photography, due to the dynamics of the scenes and the rapid change of events in the plane of the frame, do not allow for preliminary photography of the test object to build an ISS profile. If you do not profile the camera, then the photo image cannot avoid the appearance of color reproduction flaws, which, in turn, must be eliminated during post-photographic processing in graphic editors.

Another significant factor influencing the color characteristics of a digital photographic image is the spectral composition of the light at which the frame is exposed. Different light sources have different spectral composition of the luminous flux, which is described by the color temperature (Fig. 4).

In conventionally white radiation from different light sources, a certain part of the visible spectrum always predominates. Sensors of the photosensitive matrix of the photorecording system react to the light flux reflected from the photographed object, and the spectral composition depends both on the spectral characteristics of the object itself and on the spectral composition of the illumination.

Since light-sensitive receivers fix light radiation objectively, in order to achieve the correspondence of colors in the photographic image to the color gamut of the subject and eliminate the excessive tint due to the peculiarities of the spectral composition of the radiation of the light source in the software of cameras of various technical classes and purposes, in particular, and cameras of smartphones, the available function white balance. Depending on the development of the software of a particular camera, this function can be implemented using different algorithms: automatic balance, source type, color temperature, and manual white balance. The latter algorithm also requires the use of special test objects for adjusting the white point parameters to implement the color balancing process.

The color balance of a photographic digital image can be improved at the stage of post-photo processing in RAW converters. This is a class of software products that work with a special data digitization format, which is called the RAW format. The working environment of all RAW converters without exception allows you to adjust the color balance using the appropriate tools, since the RAW file format provides for recording information without processing by the camera software.

To sum up, there are several algorithms for achieving color balance in a digital photographic image. Information sources do not contain data on an objective analysis and comparison of the results of applying each of the white balance implementation options, except for a purely description of the sequence of applying specific options from the camera software menu or graphic editors [13]. It is appropriate to compare the results that provide the listed means. In addition, it is known that in order to achieve optimal color balance, already at the exposure stage (obtaining a digital photographic image), it is necessary to provide an optimal level of illumination according to the exposure meter. Built-in and external exposure meters, depending on the selected method of estimating (measuring) illumination in the plane of the frame, take into account the brightness of a larger or smaller number of objects and the background. From the ratio of dark and light objects in the plane of the frame, the exposure metering system of photographic equipment sets the value of the exposure pair. It can be assumed that not only tone reproduction, but also the color balance will be different for each metering method.

Information model of the significance of factors influencing the accuracy of balancing the colors of a digital photograph

To solve the problems formulated above, we will first of all build an information model for determining the significance of factors influencing the accuracy of color balancing of a digital photographic image at the stage of its acquisition. For this purpose, a technique was chosen that provides for the selection of many factors that directly affect the quality of the impact on the balance of colors of a digital photograph, the formation of the initial graph of relationships between them, the implementation of iterative procedures over the reach matrix, and the synthesis of the factor model by the method of structuring relations [7].

Based on the analysis carried out, we highlight the main factors influencing the balance of colors. They are as follows: status of the spectral sensitivity of receivers (SS), white balancing algorithm (WBA), application of color management systems (ICC), spectral composition of illumination (SL), spectral characteristics of the subject (OS), type of photosensitive matrix (TM), and format data digitization (FF).

We will consider the process of influencing the color balance of a digital photographic image as a certain function, the arguments of which will be the listed factors.

$$PR = F\left(s_1, s_2, s_3, s_4, s_5, s_6, s_7\right), \quad (2)$$

where s_1 – status of spectral sensitivity of receivers (SS); s_2 – photosensitive matrix type (TM) s_3 – spectral warehouse lighting (SL); s_4 – spectral characteristics of the subject (OS); s_5 – white balance algorithm (WBA); s_6 – data digitization format (FF); s_7 – application of color management systems (ICC).

Certain factors in terms of terminology and essence are referred to linguistic variables, which in the tasks of the prepress process can be indicators of the quality of a digital photographic image: geometric parameters, structural characteristics, gradation and color characteristics. To do this, we will build an initial graphical model (directed graph), taking into account expert judgments on pairwise effects (relations) between factors (Fig. 5).

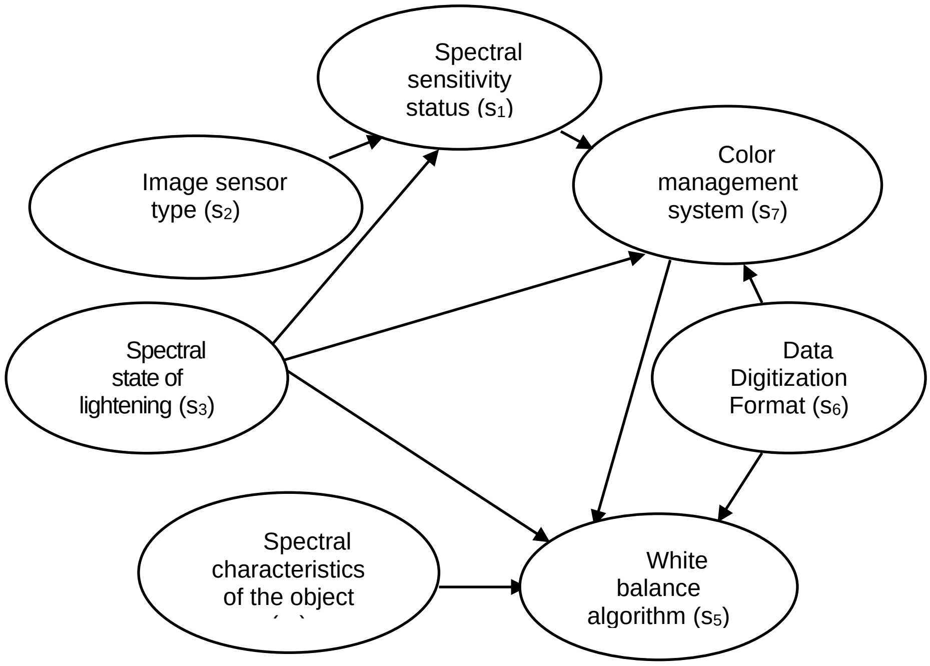


Figure: 5. The initial graph of relations between the factors for balancing the colors of a digital photo

Source graph Fig. 5 is used to order the factors according to the importance of the impact on the process under study, which will result in a multilevel model of the factors influencing the color balance of the digital photographic image. To synthesize a linguistic model, we use the tools of matrix theory and system analysis.

Using the existing graphical model - an analogue of the semantic network, we build a binary reach matrix (Table 1), which simulates possible options for getting from each vertex of the graph to other vertices.

The matrix is constructed by filling in the table, the binary elements of which are determined by the following logical rule:

$$b_{ij} = \begin{cases} 1, \text{ if } b_i \text{ you can get into } b_j \\ 0, \text{ if } b_i \text{ you can not get into } b_j \end{cases} \quad (3)$$

Almost top s_j (j=1, 2, …, 7) the original graph in Fig. 5 is considered reachable from the top s_i (i=1, 2, …, 7), if from the latter it is possible to get to an arbitrary path, taking into account transitions through other vertices. The result of the analysis of all vertices leads to a subset of reachable vertices $D(s_i)$.

At the same time the top s_i we will consider the predecessor of the vertex s_j, if it is reached from it, and their totality forms a subset $P(s_i)$. Finally, the section of subsets of reachable vertices and predecessors forms a separate subset:

$$Z(s_i) = D(s_i) \cap P(s_i), \quad (4)$$

which determines a certain level of priority for the action of factors related to these vertices. An additional condition for this is to ensure equality

$$P(s_i) = Z(s_i), \quad (5)$$

the implementation of dependencies (4) and (5) using iterative tables leads to the formation of the corresponding levels, the initial of which is the highest in terms of the priority of the impact on the process under study. To determine the specified level, we use the reach matrix and mathematical dependencies (4) and (5), on the basis of which we build Table. 2.

Table 1
Reach Matrix

	SS	TM	SL	OS	WBA	FF	ICC
SS	1	0	0	0	1	0	1
TM	1	1	0	0	1	0	0
SL	1	0	1	0	1	0	1
OS	0	0	0	1	1	0	0
WBA	0	0	0	0	1	0	0
FF	0	0	0	0	1	1	1
ICC	0	0	0	0	1	0	1

Table 2
Results

$D(s_i)$	$P(s_i)$	$D(s_i) \cap P(s_i)$
1,5,7	1,2,3	1
1,2,5	2	2
1,3,5,7	3	3
4,5	4	4
5	3,4,5,6	5
5,6,7	6	6
5,7	1,3,6,7	7

Subset - the numbers of reachable vertices or the numbers of single elements of the corresponding rows of the reach matrix are entered in the second column of the table; the third column defines a subset of the vertices of the predecessors - the numbers of unit elements of the columns of this matrix. In this case, dependency (5) means the fulfillment of the condition of equality of the numbers of factors specified in the second and third columns of the table, as a result of which a certain level of the hierarchy of factors is formed in the resulting graphical model.

As can be seen from Table. 2, the coincidence of numbers is fixed for factor 3 - spectral illumination. This factor will be considered the highest in terms of the priority level of influence on the process of influencing the color balance of a digital photographic image.

According to the methods of system analysis and mathematical modeling of hierarchies [7], we remove from the table. 2 is the third line, and in the second and third columns of this table we cross out the number 3, respectively. We get a table that is the basis for calculating the next iteration - the basis of the next most important level of the hierarchy of factors.

Analysis of the table. 3 is produced according to the above algorithm. It is easy to see that the coincidence of numbers is fixed for factor 6 - the format of data digitization, which forms the next level of the hierarchy from the top.

Actions similar to those described above are given in table 4, in which the row with the number 6 is extracted, and this number is missing in the second and third columns of the table.

Table 3

$D(s_i)$	$P(s_i)$	$D(s_i) \cap P(s_i)$
1,7	1,2,3	1
1,2	2	2
4,5	4	4
5	3,4,5,6	5
5,6,7	6	6
7	1,3,6,7	7

Table 4

$D(s_i)$	$P(s_i)$	$D(s_i) \cap P(s_i)$
1,7	1,2,3	1
1,2	2	2
4,5	4	4
5	3,4,5,6	5
7	1,3,6,7	7

From Table. 4 we obtain factors 2 and 4 - the spectral composition of the illumination and the spectral characteristics of the subject. As a result of repeating the procedures, we get:

Table 5

$D(s_i)$	$P(s_i)$	$D(s_i) \cap P(s_i)$
1,7	1,2,3	1
5	3,4,5,6	5
7	1,3,6,7	7

Actions similar to those described above are given in table. 5, in which the row with number 1 is extracted, and this number is missing in the second and third columns of the table.

Table 6

$D(s_i)$	$P(s_i)$	$D(s_i) \cap P(s_i)$
5	3,4,5,6	5
7	1,3,6,7	7

Tab. 6 leads to the exclusion of two factors at once 5 - the white balancing algorithm, 7 - the use of color management systems.

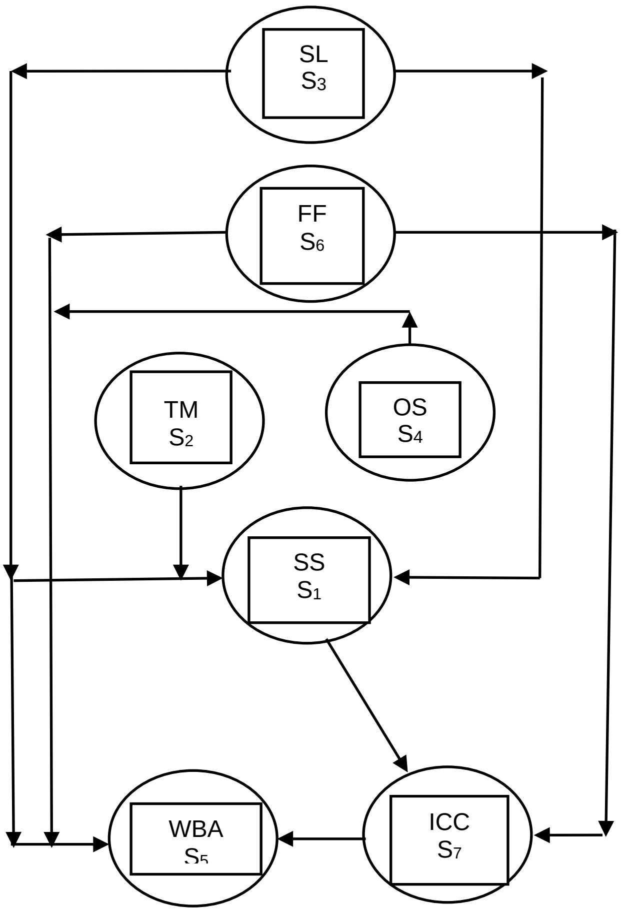


Figure: 6. Multilevel model of factors influencing the color balance of a digital photographic image

Using the iterative analysis data and taking into account [7], we synthesize a multilevel structured graphical model (Fig. 6), which clearly displays the place of each factor and reproduces the relationships between them specified in the original model in Fig. 5.

On the basis of a multilevel synthesized model of the effect on the color balance of a digital photographic image, we construct a priority model in which (Fig. 7) the priority of the factor is determined by the level of its placement. The highest priority among the selected factors has the spectral composition of illumination, which is associated with the next factor - the data digitization format.

Taking into account the factors reflected in the qualitatively weighted original graph of Fig. 6 and using the tools of the system analysis matrix theory, a linguistic model is synthesized, resulting in a multilevel model of factors influencing the color balance of digital photographic image. To ensure the quality of the impact on the color balance of a digital photographic image, a model of priority impact was built by the method of structuring relationships.

Determining the degree of influence of the exposure metering method on the accuracy of the balance from a white digital photo

The constructed model of the priority influence of factors influencing the color balance of a digital photographic image found that the format of data digitization is one of the most priority factors. Therefore, based on the information received, we will conduct a practical study of the effect on the quality characteristics of digital photographic images, the color balance tools of the camera software when digitizing information immediately after exposure, and the corresponding color balance tools of the RAW converter. In addition, we will determine how the method of exposure metering with automatic white balance affects the color characteristics of a photographic image. Such a factor of influence on the accuracy of color balancing is not noted by any researchers of the described technological processes, however, the authors' preliminary studies of the influence of this factor on the gradation (quantitative) characteristics of a color digital photographic image indicate its significance, which suggests an effect on the mentioned factor and on qualitative (color) photographic image characteristics.

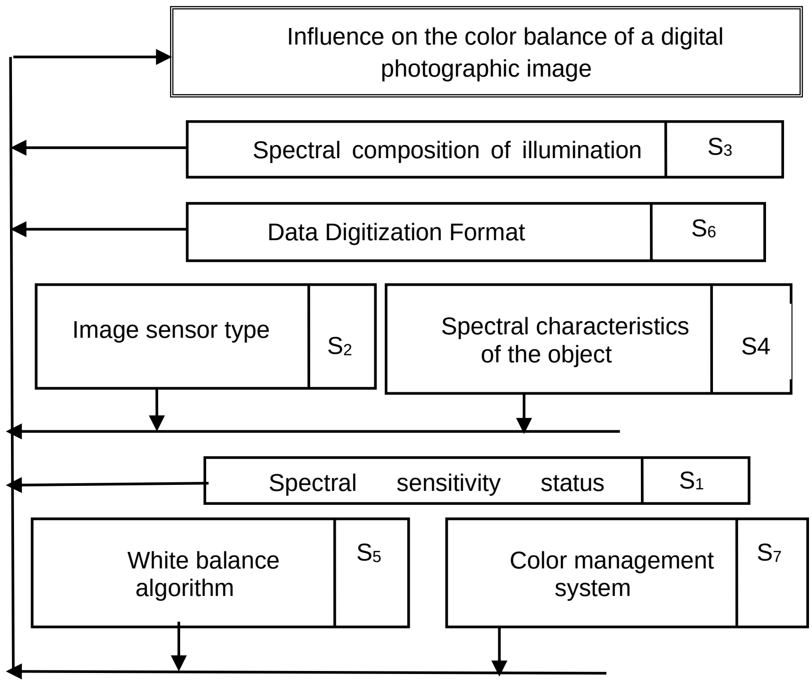


Figure: 7. Model of the priority influence of factors of influence on the color balance of a digital photographic image

There are several ways to adjust the color balance in a photographic image immediately after exposure: automatically, by source type, and manual balance by sample. The latter requires a white or neutral gray reference and is only available on high-end camera models. White balance according to the type of light source, as studies have shown, does not always guarantee the best result, since there is often a discrepancy between the description of the spectral characteristics of common light sources and their spectral characteristics (for example, fluorescent and gas discharge lamps) [9].

Thus, automatic white balance is often used. When using this option, according to the manufacturers of digital photographic equipment, the camera software analyzes the image and determines the brightest part of it, which the application tries to bring to white. The hue that the software fixes on the brightest object is considered parasitic and is removed during processing from the entire image.

The process of image analysis itself is of interest, in particular, what part of the frame plane of a photographic image is taken into account. It can be assumed that metering methods that differ in the light measurement area affect the result of collecting data for color balancing. As you know, four methods of exposure metering are used, which differ in the area of light measurements in the frame: matrix or segment (taking into account the frame area), center-weighted (80% of measurements are made in the central part of the frame, 20% - along the periphery), partial (measurement in the center of the frame within the area that occupies up to 10% of the frame area) and spot (measuring in the very center of the frame plane in a very narrow area - 2-5% of the total area).

To test the formulated hypothesis, an experiment was carried out with the following technical shooting parameters: manual setting of exposure conditions according to the data of the built-in exposure meter, ISO 200 sensitivity, automatic white balance mode, file recording format: JPEG. Under these exposure conditions, a photographic image of the test object (an achromatic stepped scale) was obtained on differently colored backgrounds using various exposure metering methods. The color characteristics of the obtained photographic images are shown in Figs. 8 and fig. 9.

The presented graphic dependences demonstrate the content of the primary colors of additive synthesis in the fields of the achromatic scale on photographic images from similar indicators of the test object.

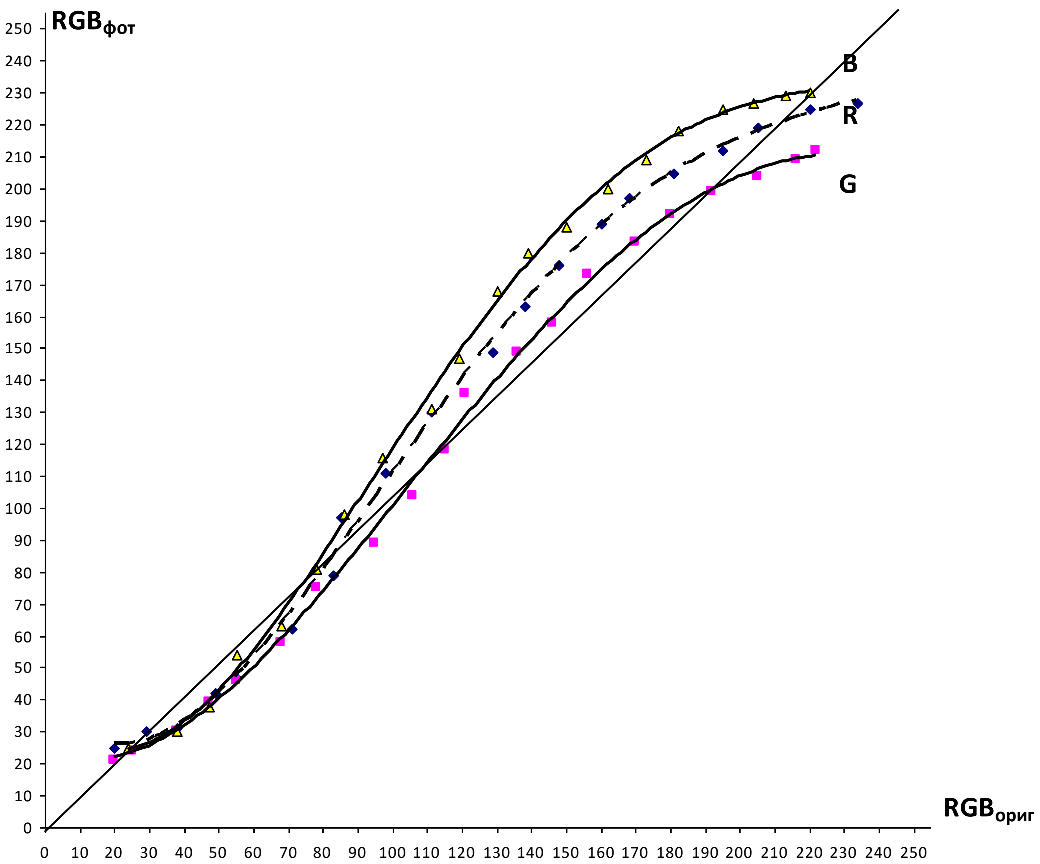
The presented characteristics show that the selected metering method is essential for automatic white balance.

Regardless of the background color, with the segment metering method, which is characterized by the largest area for collecting information about the light reflected by the subject, there is a significant imbalance of colors, namely, the content of the color component is minimized, which corresponds to the color of the background.

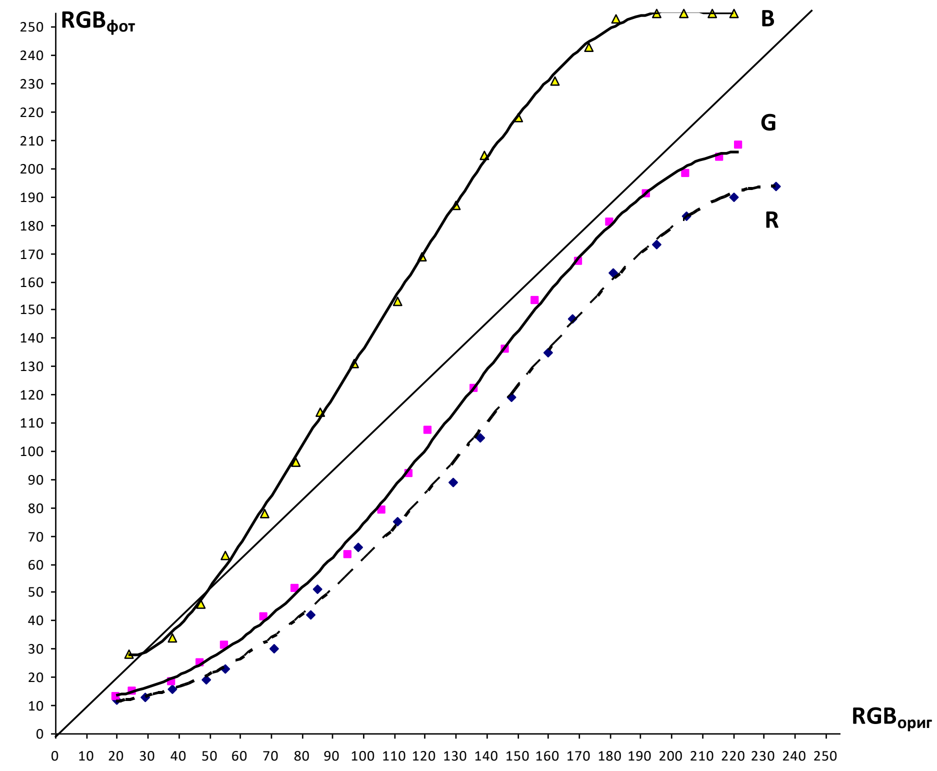
The degree of color imbalance is directly proportional to the background brightness, which for a green background is - 67, 54 - fig. 8 (a), and yellow - 96.63 - fig. 8 (b), respectively.

When applying the point method of exposure metering and adjusting the plane for collecting information on the quantity and quality of the light radiation according to the neutral gray field of the achromatic scale, we obtained a much better, close to ideal, degree of color balance (Fig. 9). Subsequent studies have shown that the achromatic background of a frame of different brightness does not affect the color characteristics of a photographic image with all exposure metering methods.

Thus, the conducted studies allow us to give the following practical recommendations. If the background in the frame differs significantly in brightness from the scene-important object, then the exposure parameters of the shooting should be selected either in manual mode, or in order to avoid errors in semi-automatic mode using the spot metering method. When photographing scenes with a high-brightness color background (such as an autumn or spring landscape with a large plane of yellow leaves or greenery, commercial subject matter photography), you should definitely use the partial or spot metering method, which will provide satisfactory gradation and automatic color balance.

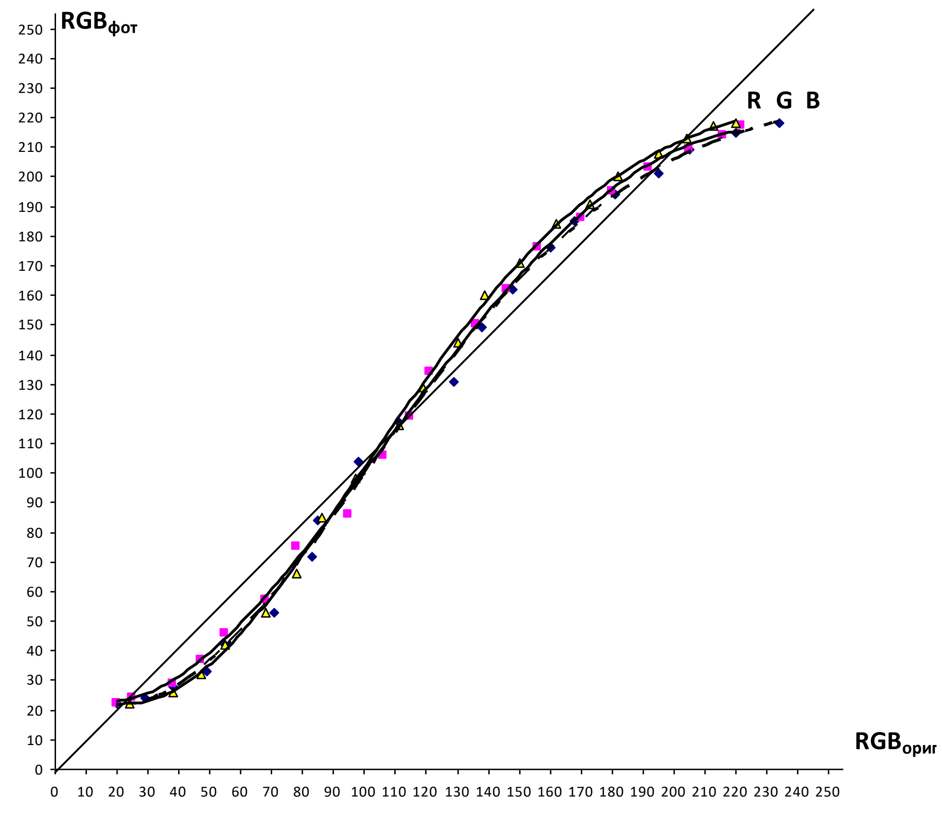


a)

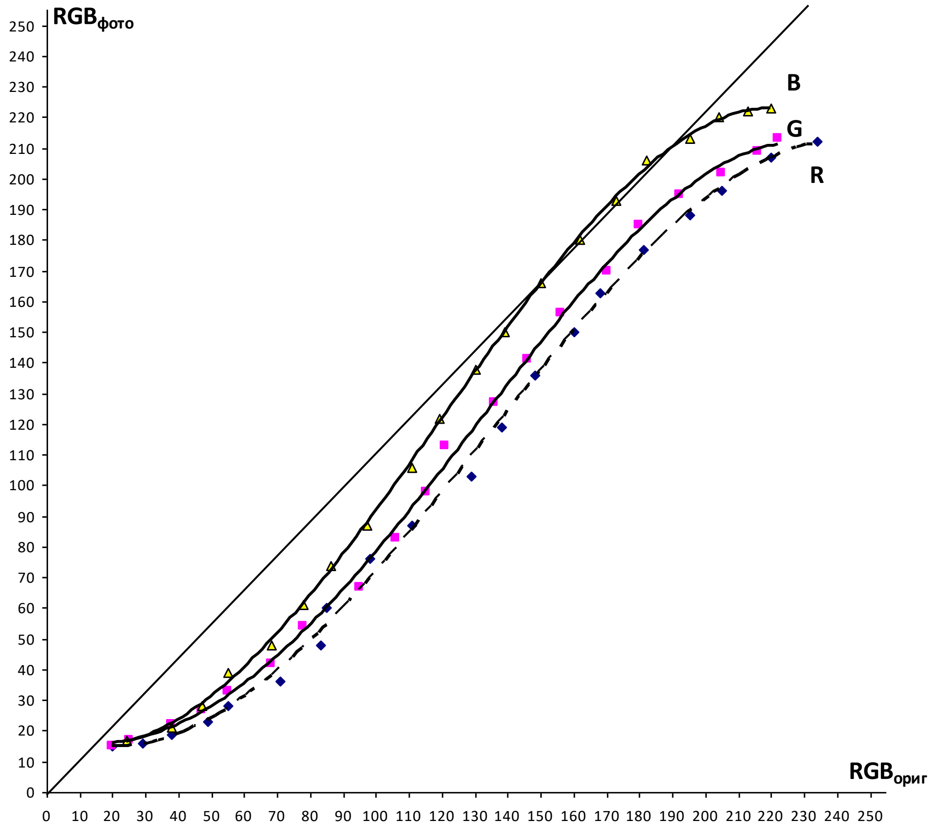


b)

Figure: 8. Color characteristics of the photo image obtained in the automatic white balance mode and the segment metering method (a – green background, coordinates Lab 67,54;-47,17; 33,85), b - yellow background, coordinates Lab 96,63;-4,07; 68,65)



a)



a

b)

Figure: 9. Color characteristics of a photographic image obtained in the auto white balance mode and by the spot metering method (a - green background, coordinates Lab 67,54;-47,17; 33,85), b - yellow background, coordinates Lab 96,63; -4,07; 68,65)

The central focus point, within which the illumination is measured, should be aimed at a scene-weighty object.

Segment or center-weighted exposure metering method is appropriate to use when objects in the frame are diverse in brightness and color without a predominance of a certain color or brightness.

The relationship between the format of digitizing a photographic image and the balance of colors

Since the presented information model showed a significant influence of the digitization format on the degree of color balance, we will study what color characteristics are formed in photographic images when digitized in jpeg and raw formats and when using various white balancing algorithms.

The following graphic dependencies represent the color characteristics of photographic images digitized in jpeg format and processed with white balance tools from the camera software (Fig. 10), digitized in raw format (Fig. 11) and digitized in raw format, followed by color balance in RAW-converter (Fig. 12). In all cases, the exposure was carried out under the light of a warm LED lamp, the spectrum of which is dominated by the red zone of the spectrum.

According to the mutual arrangement of the curves in Figs. 10, we can come up with unambiguous conclusions about the degree of color balance.

Achromatic shades on a perfectly balanced color image should be formed by the same color content of additive synthesis, which in turn should be displayed on graphic dependencies by the location of the content curves of red, blue and green colors close to each other.

If the curves on the coordinate plane are located in any other way, this indicates an imbalance in colors.

Yes, fig. 10a shows the color characteristics of the photographic image with automatic white balance, which demonstrate the imbalance of colors: an increased content of the red component. At the same time, a photographic image processed by manual white balance using an achromatic color sample demonstrates an ideal color balance (Fig. 10 (b)).

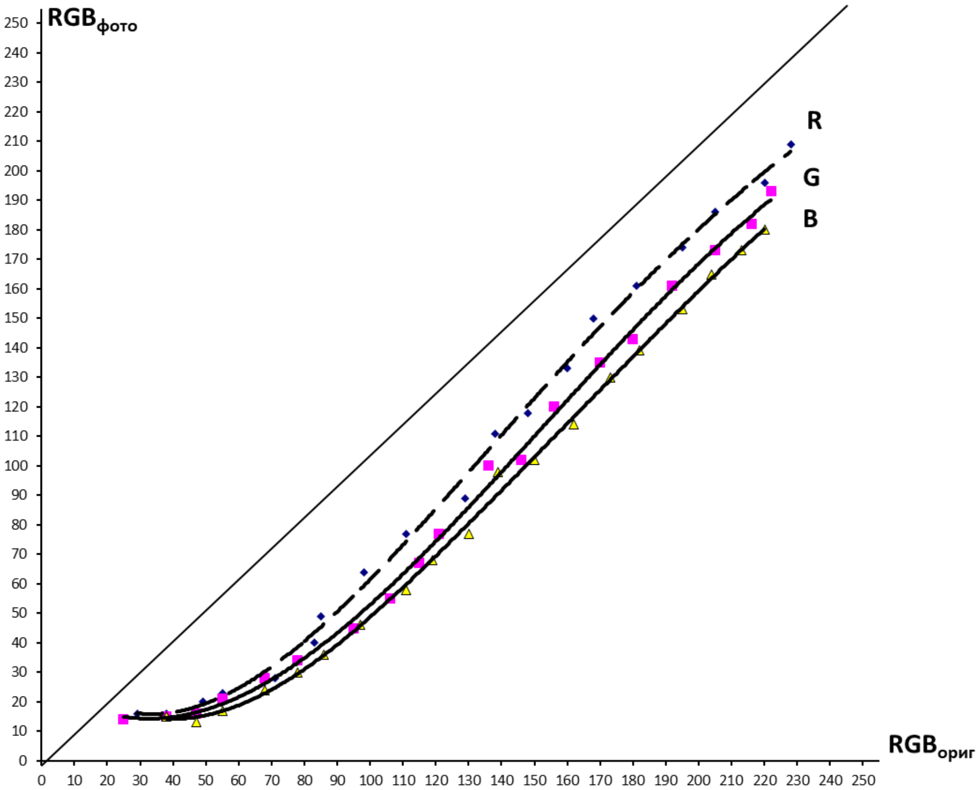
On fig. 11. Graphical dependences of the color content of additive synthesis on a gray scale of raw photographic images in RAW format are shown.

The degree of color balance in these raw photos is similar to the corresponding JPEG photos: the best color balance is in the photo obtained by manual white balancing on an achromatic pattern (Fig. 11(b)). It is appropriate to note that the color balancing on the analyzed RAW photographs is different. That is, the color balance algorithm at the stage of data processing by the camera software, contrary to what is common in some information sources of data, has a certain effect on the data digitized in the RAW format.

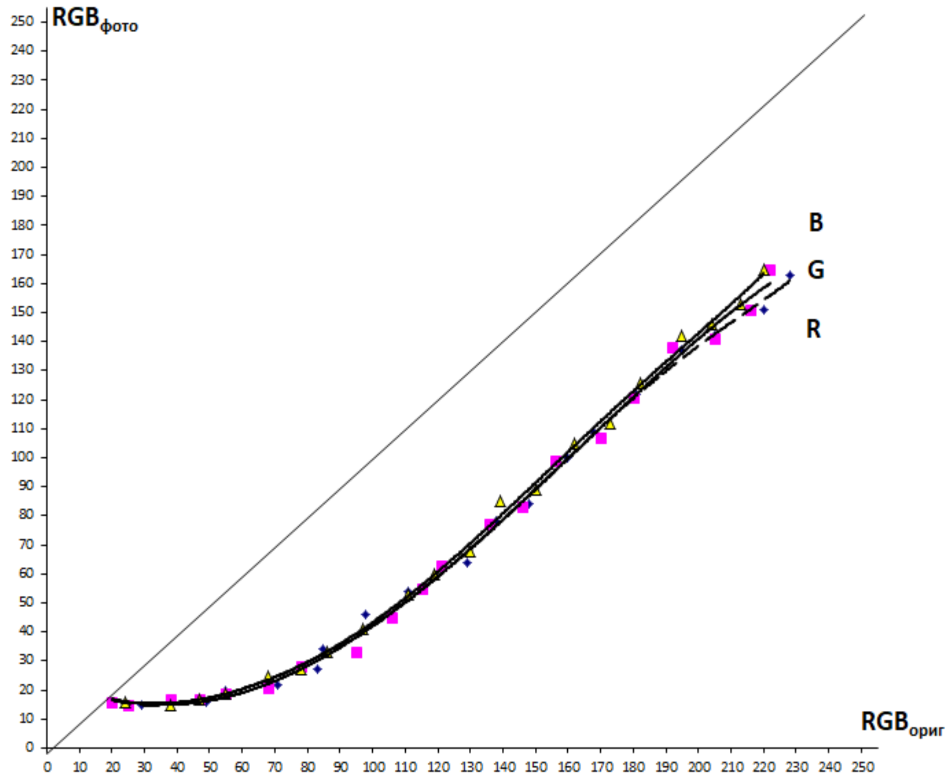
Reproduction of gradation, which can also be evaluated on the obtained graphic dependencies, also differs for photographic images in RAW and JPEG formats. If a photo in JPEG format has significant loss of gradation in the shadow range, then in RAW format it is characterized by smooth reproduction of gradation over the entire range of tones.

After processing in the RAW converter, all photographic images received a satisfactory color balance (Fig. 12). The result of the white balance, made in the RAW converter, does not depend on the conditions under which the white balance was taken, but only on the choice of the neutral area of the photo image as a sample for color balance.

This method of achieving color balance provides good results and is not difficult to implement, since it does not require the use of any additional tools (neutral color standards, in particular), does not complicate the technological process with lengthy adjustments and additional exposure to adjust the custom white balance.

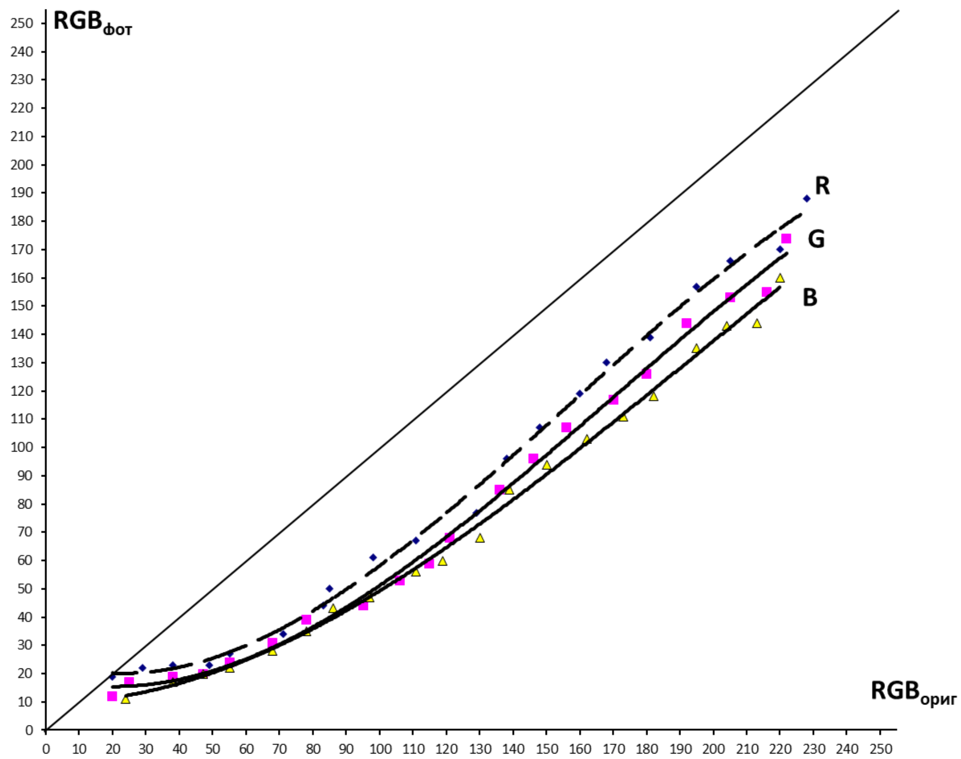


a)

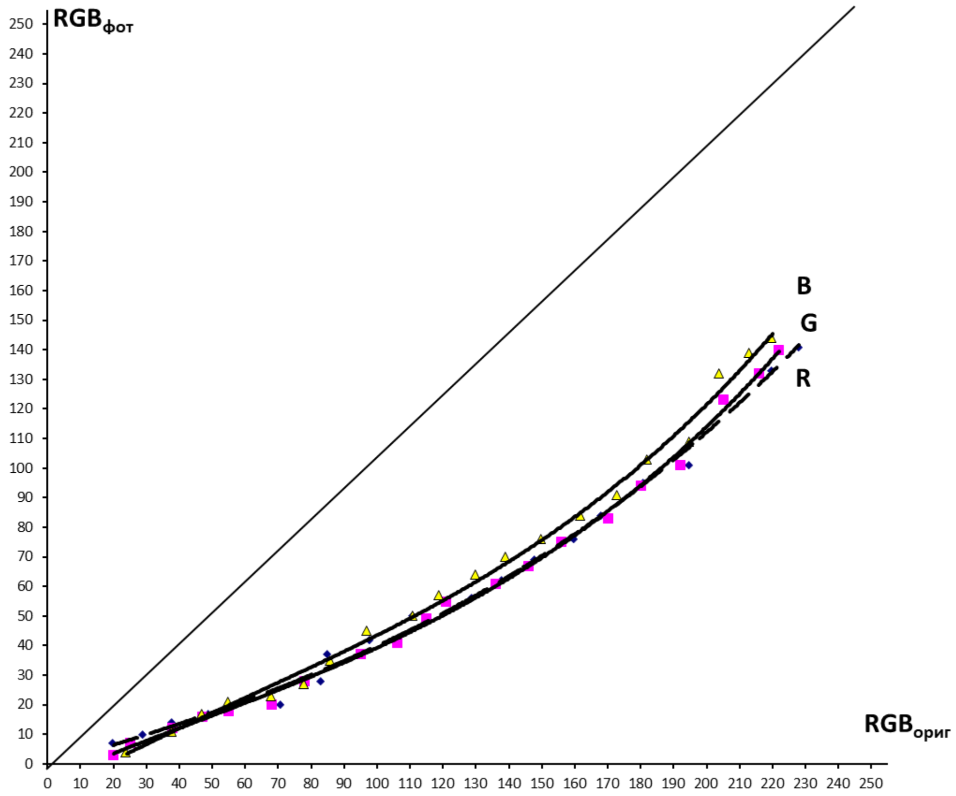


b)

Figure: 10. Color characteristics of photographic images processed by means of the camera software white balance (a – automatic white balance; b – manual white balance (by achromatic pattern))

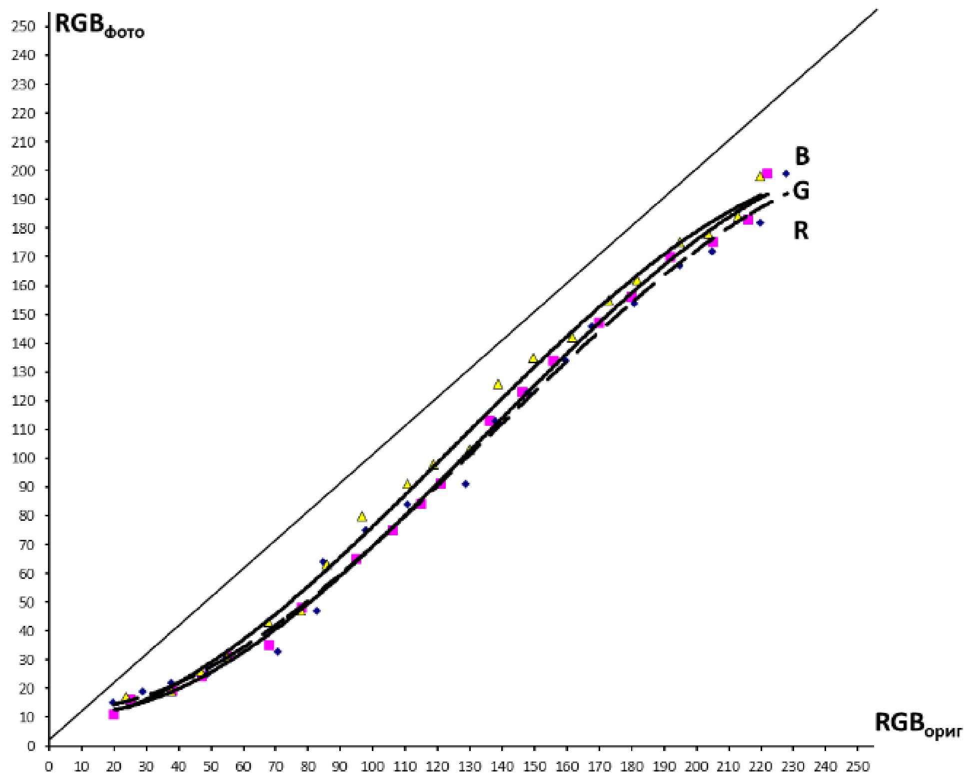


a)

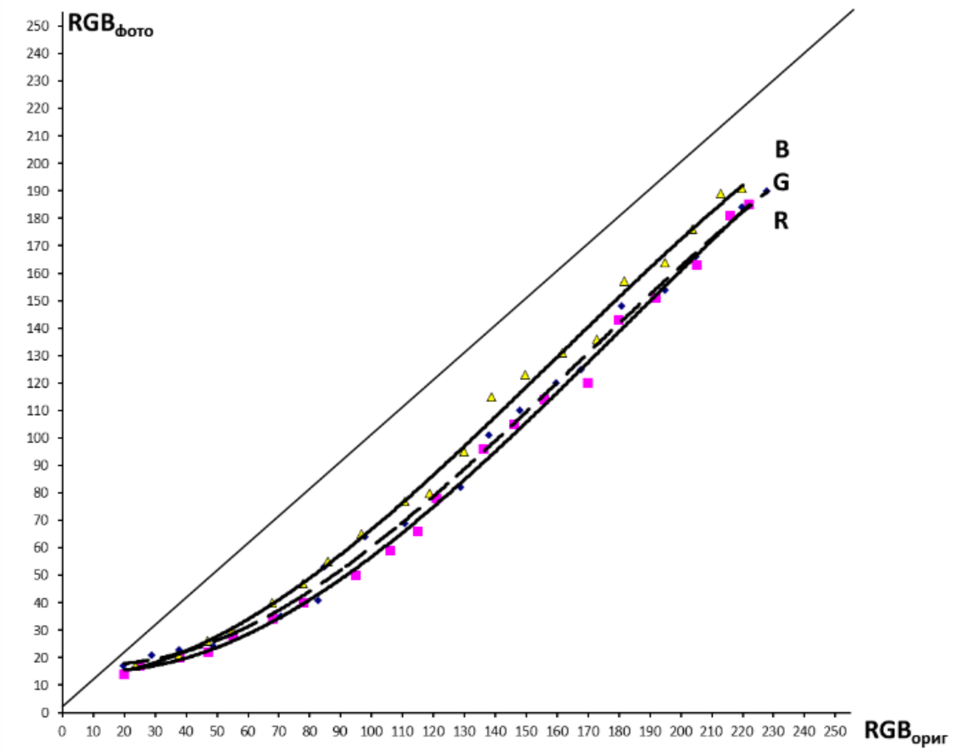


b)

Figure: 11. Color characteristics of photographic images in RAW format without processing (a - automatic white balance; b - manual white balance (according to an achromatic sample))



a)



b)

Figure: 12. Color characteristics of photographs processed in the RAW converter (a - automatic white balance; b - manual white balance (according to an achromatic sample))

Conclusions

The following conclusions can be drawn from the conducted research. Since there are a large number of light sources with an unbalanced spectral composition, there will always be a need to use color balancing tools designed to eliminate excess color cast. The consumer has several white balance algorithms that can be applied both at the time of processing data from the photosensitive matrix by the camera software, and at the stage of post-photo processing. Among all the white balance methods at the stage of photography, the best result was provided by manual white balance. However, studies show that this mode requires the use of additional material support, and the result of color balancing is no better than the balance obtained using the RAW converter. In this case, the qualitative characteristics of the processed images do not depend on the characteristics of the original image, but only on the selected neutral tone sample, according to the color characteristics of which the white balance is realized. In the course of the described studies, another interesting fact was revealed: despite the fact that the RAW format is described as a format without data processing by the camera software, the use of various white balance tools during photography leads to different color gamuts and the degree of color balance in photographic images. RAW format.

When using the automatic white balance tool, be sure to take into account that the metering method affects the final result, so it is appropriate to use a point or partial method of measuring lighting in the frame and set the central point on a plot-weighty object. Since, in addition to improving the color characteristics of the photo image, the RAW format provides better gradation characteristics, and the implementation of the white balance function does not require the use of cost test objects, therefore, the optimal solution would be to take photographs in the following sequence: under appropriate scene lighting, perform an exposure test about neutral gray colors, to shoot with automatic white balance and digitize photo images in RAW format and then batch work out the color balance of all photo images in the RAW converter environment. If there are objects of neutral color (white, gray or black) in the frame, the test object (gray card, etc.) can be omitted. Such a sequence of implementation of the technological process will reduce its complexity and ensure high quality indicators of the photographic image.

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