В ходе проведенных исследований установлено, что подтверждается стабильность поддержания скорости воздушного потока по результатам поученным в 2015, 2016 и 2017 годах.

Данный комплект оборудования для измерения скорости воздушного потока утвержден в качестве Национального эталона единицы скорости воздушного потока Постановлением Госстандарта Республики Беларусь № 3 от 17.01.2018.

В настоящее время при помощи созданного Национального эталона выполняются работы по метрологическому контролю средств измерений скорости воздушного потока различных типов и принципов действия (testo, ТКА-ПКМ, ИСП-МГ4, АСЦ-3, МЭС-200А, ТТМ-2, трубки напорные ПИТО и НИИОГАЗ).

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УДК 535.3

THE MAIN PROVISIONS OF THE HIGH-RESOLUTION COLORIMETRY

Saukova Y.

Belarusian National Technical University, Minsk, Belarus

According to [1] colorimetry is a measurement of colour performed in accordance with an accepted system of conventions (international agreements). Since color is defined as sensation [1] and a measurable value [2] it can be evaluated qualitatively (subjective methods) and measured quantitatively (objective methods). Subjective methods are based on the equalization of colours before the disappearance of their visual differences with the help of visual additive and subtractive colorimeters, color scales and atlases. N.D. Nyuberg proposed to divide the process of research and interpretation of color effects on the organs of vision into three levels [3]:

– physical (optical phenomena arising from the interaction of light radiation with objects in different environments and conditions of observation);

– physiological (effects of optical radiation on the visual analyzer, including light and color sensations);

– psychological (psychological sensations caused by the influence of radiation with certain physical characteristics, including the environment).

Objective methods involve the use of measuring instruments to obtain spectral distribution functions of primary and secondary emitters and on their basis to determine the coordinates of color and chromaticity [2, 4]. Basic colorimetry is based on standardized models of observation conditions and is used in the control of products in medicine, chemical, paint industry, printing. The highest colorimetry according to Vyshetsky «includes methods for assessing the perception of color stimulus presented to the observer in a complex environment that we observe in everyday life» [5] that is, in real conditions of observation. The problem of correct colour reproduction and colour perception becomes more complicated when reproducing a color image (reproduction, color photography, the image on the screen of the TV, computer) because it increases the amount of information and the accurateness of color people can judge, mainly relying on their memory (provided that in this moment he didn't see the original). Therefore, in this case it is necessary to ensure the process of hardware independent color reproduction [6]. The technologies of color information transmission of images in telecommunication systems are based on the use of the highest colorimetry principles. Taking into account the characteristics of visual perception and observation conditions including colorimetric parameters of the environment is an important trend for further improvement of these systems. D. Fairchild introduced the concept of «absolute» and «relative» colorimetry in terms of capabilities of the color reproduction technical means. If the output device has a wider spectrum than the original profile, that is, all colors at the input can be displayed at the output visualization using absolute colorimetry is used and colors outside the boundaries of the reproduced color will be transferred to the edge of the color spectrum of the output device while preserving the «white point» [6]. Relative colorimetry takes place in color transformations of colour rendering systems allowing to shift colours with the movement of the «white point» to a new position taking into account the limitations of the technical devices colour gamut [6].

The prerequisites for the development of high-resolution colorimetry are colour television and digital photography, integrated control of the light environment, information and advertising industry as well as the development and cheapening of digital technology. Under the High-Resolution Colorimetry, the author implies a methodology of multiparameter measurements and an interdisciplinary field of research covering methods and means of measurement, control and testing of self-luminous and non-self-luminous objects at all stages of their life cycle, based on the use of technologies of digital registration of objects with high spatial resolution and processing of their images, allowing a given level of reliability to provide reliable results of measurement, control and testing. The High-resolution Colorimetry is based on the following provisions.

1. According to the physical implementation of the digital image is a non-point primary emitter at the macro level and an ordered set of elements (pixels) at the micro level. It is the final link of the information channel including the recording device (digital camera, scanner), data conversion channel and display device (display, video terminal). Any extended surfaces and each of the elements of the information channel (scanner, camera, display, software) can be the objects of research based on the analysis of digital images. The validation model of the information-measuring channel developed by the author is based on the fact that the digital image is the result of convolution of the functional spaces of the properties of these elements and the information model of any of them provided that all other elements are validated. Each element of the information-measuring channel can also have a large number of implementations on the basis of" the investigated element": 1) illuminator when measuring color; 2) illuminated surface; 3) digital camera when it is calibrated; 4) software for testing measuring systems; 5) display device when it is calibrated. Definition uncertainty of the colours in the software and hardware environments there is a parameter associated with the measurement result which characterizes the least in a multidimensional functional space area of dispersion of values is due to the limited detail in the definition of the color as subjective feelings and affine vector quantities measured by averaging the signals of the digital image in the context of the interaction of factors, «space-time», the principle of statistical redundancy, quantization effects and metamerism in the discrete vision systems with an unlimited number of input and output variables.

2. Principles and methods of measurement of brightness and color of self-luminous and non-self-luminous extended objects are based on optical-electronic transformations in the information-measuring channel at digital registration of the object and certified reference samples by the matrix photodetector and processing of the received digital images for construction of calibration dependences of intensity of color channels on brightness of reference samples and time of exposure and determination of brightness and color of the object at the control point with the expanded uncertainty not exceeding 10 %. The intensity and chromaticity in the coordinates of the standard color spaces for each (red, blue, and green) color channel are determined by the formula:

$$L = K\eta\left[(N - N_0)\frac{(L_{02}k_2 - L_{01}k_1)}{N_{02} - N_{01}} + L_1 k_1\right], \qquad (1)$$

where K – scaling factor;

η – coefficient taking into account the registration parameters (aperture and the transmittance of the lens);

N – the output signal of the CCD matrix corresponding to the brightness of the reference point on the image of the object for this channel;

L_{01}, L_{02} – the reference brightness in a given color channel, cd/m^2;

k_1, k_2 – coefficients wich depend on the distribution of the reference radiation;

N_{01}, N_{02} – the output signals of the CCD matrix correspond to the brightness of the reference brightness image on the object in this colour channel.

3. The principle of constructing a conditional multi-dimensional scale for colour measurements is to create a set of certified reference samples-non-point emitters belonging to a certain sector of the color palette forming a digital registration with a step-by-step increasing exposure time vectors in the color space XYZ, originating from the zero reference point of space and intersecting the plane of the color locus of the color chart forming on it a geometric place of color points, allowing to ensure the condition of uniformity of measurements.

4. A method for expanding the dynamic range of colorimetric measurements based on registration with step-by-step increasing exposure time of the reference point of the object and certified reference samples by a matrix photodetector and processing of the obtained digital images, in which the calibration dependences of the intensity on the brightness of the reference samples and the exposure time for the three color channels are constructed and the coordinates of the control point color are determined by pairing the calibration dependencies corresponding to different digital images, which allows to measure the brightness and chromaticity in the range of 60 dB.

5. A method of the methodological uncertainty reducing in the colorimetric measurement hardware and software environments is based on a digital image processing in which the coordinates define the color of an area of the digital image in the RGB color space klassificered and identificered their place, the circulation in the color space XYZ, build the calibration dependence of the intensity of the color channels of luminance and exposure time determine the chromaticity coordinates. This method allows to reduce the risks of the first and second kind errors in the control and to increase the resolution of color measurement by fixing the nominal quantization steps in the color channels of images.

6. A complex model of the results of multiparameter measurements in discrete systems with an unlimited number of input and output quantities based on the use of modular ascending and descending approaches in the construction of models of mathematical expectations of measurement results and models of their scattering (uncertainty and covariance), combining the components of uncertainty with entropy allowing to formalize the description o measurement results in software and hardware environments.

Regression analysis allowed to determine the optimal area of the image for research in pixel graphics providing the lowest dispersion equal to 128 by 128 pixels or 0.068 % of the total number of pixels.

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QUANTITATIVE RESEARCHES IN THE VISION TECHNICAL SYSTEMS WITH UNLIMITED NUMBER OF ENTRANCE AND OUTPUT MAGNITUDES

Saukova Y., Alkhimovich M.

Belarusian National Technical University, Minsk, Belarus

Quantitative researches in the vision technical systems are based on processing of digital images at measurements and modeling of objects properties. In this regard a method of the correlation and regression analysis described in [1] is the convenient instrument of results displaying. The method allows to reveal significant factors of influence and to define interrelations between them (or their absence) [2]. The usage of 3D technologies gives the chance to display triads of magnitudes and to represent the results of multiple parameter researches as a vector columns and sets of covariation matrixes. The review of sources [1-4] has shown that for covariance assessment most often use coefficient of linear correlation of $r_{x,y}$ and a correlation ratio η^{ϵ}_{yx} (for nonlinear dependences) and also a method of the smallest squares and confidential intervals.

1. The Pearson coefficient of linear correlation expresses degree of narrowness of linear communication between two random variables and is calculated according to selective data on a formula:

$$r_{x,y} = \frac{\sum_{i=1}^{n}[x_i - \bar{x}) \cdot (y_i - \overline{y)]}}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}}, \qquad (1)$$

where x_i, y_i the values of variables x, y respectively, n – number of observations.

The coefficient of correlation can accept values from -1 to +1 and the direction of change of characteristics is reflected by the signs «+» or «-» before it. This coefficient shows communication «force» i. e. synchronism of change of two variables.

According to Fischer the statistical importance of Pearson correlation coefficients in a case of their normal distribution is checked on the basis of Student's t-distribution with the set of the probabilistic importance level α and the known factors number in a model [3]. We find the value of t-criterion on a formula:

$$t_{calc} = r_{xy}\sqrt{\frac{n-k-1}{1-r_{xy}^2}}, \qquad (2)$$

from here

$$r_{xy} = \frac{t_{calc}}{\sqrt{n-k-1+t_{calc}^2}}, \qquad (3)$$

where k – number of factors in the model. It is necessary to compare the value of the criterion t_{calc} with the theoretical value t_{tab} specified in statistical tables. If $t_{calc} > t_{tab}$, the correlation coefficient is considered to be statistically significant, and this coefficient is insignificant when $t_{calc} \leq t_{tab}$. If the probability distribution is not normal then the Fisher's Z-criterion is used as a criterion of their significance. For paired correlation coefficients an interval estimate [c_{min}; c_{max}] can be constructed using the Fisher Z-transform with a given reliability [4]. Using the Fisher's Z-transform and the selective correlation coefficient *r* we find the corresponding value of Z which is the hyperbolic arctangent of *r* [4]:

$$\mathrm{Z} = \frac{1}{2}\ln\left(\frac{1+r}{1-r}\right) = \operatorname{arctanh}(r).$$

Further we find the value of *dZ* corresponding to the confidence level p = 0,95 (the value of the Laplace function). We calculate the values of Z_{min} and Z_{max} by the following formulas:

$$Zmin = Zr - dZ, \qquad (4)$$

$$Zmax = Zr + dZ. \qquad (5)$$

Finally using the inverse Fisher transform we find the lower and upper bounds for the general correlation coefficient c_{min} and c_{max} which are hyperbolic tangents of Z_{min} and Z_{max}:

$$r = \frac{\exp(2z)-1}{\exp(2z)+1} = \tanh(z).$$

2. The empirical correlation relation η^{ϵ}_{yx} is used to estimate the tightness of the nonlinear coupling between random variables and calculated using the common σ_Y^2 and the intergroup $\sigma_{\bar{Y}_x}^2$ dispersions the formulas of which are indicated in [3]. After all the additional calculations, we find the empirical correlation relation according to the formula [3]:

$$\eta^{\epsilon}_{yx} = \sqrt{\frac{\sigma^2_{\bar{\mathrm{Y}}_{\mathrm{x}}}}{\sigma^2_{\mathrm{Y}}}}. \qquad (6)$$