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SPECIFICS OF METHODS FOR ASSESSING THE ACCURACY OF PARAMETER DETERMINATION WHEN IMPROVING COMPUTER-INTEGRATED TECHNOLOGY FOR ANALYSIS OF GAS-DISCHARGE RADIATION IMAGES

The article is devoted to the consideration of the features of methods for assessing the accuracy of determining image parameters. Existing problems associated with the specifics of methods for obtaining measurement information based on image processing and assessing the accuracy of determining geometric and brightness parameters of images are analyzed.

The task of improving modern computer-integrated technologies, an integral part of which is the image registration and processing subsystem, is associated with ensuring increased accuracy and reliability of measurement results.

The implementation of computer-integrated technologies that include image processing procedures requires an analysis of the components of measurement uncertainty that arise at different stages of the implementation of information measuring technology.

The article provides a comparative analysis of the specifics of image registration and processing methods, which allowed us to determine the specifics of methods for assessing the accuracy of parameter determination when improving computer-integrated technology for analyzing gas-discharge radiation images. Compared with other measurement conditions and models used in measurement methods with visual measurement information, the gas-discharge radiation method can be characterized by two specific features: the absence of fluctuations in the external illumination level, which is provided at the hardware level in accordance with the requirements of the measurement experiment; the presence of requirements for determining and setting the parameters of the hardware and software complex for image registration.

To compare different modifications of hardware and software complexes for recording images of gas-discharge radiation, it is proposed to use a test object and the corresponding methodology for experimentally assessing the random dispersion of geometric parameters of images based on the assessment of the mean square deviation for individual series of observations made at different time intervals. To substantiate the possibility of combining individual series of observations into a sample when processing experimental data, the Student and Fisher criteria were used, based on which the hypothesis of equal accuracy of the performed series of observations was confirmed.

Keywords: *computer-integrated technology, image processing, gas-discharge radiation, measurement uncertainty*

Formulation of the problem. When developing modern computer-integrated technologies, it is necessary to pay attention to the improvement of hardware and software. The corresponding improvement consists both in the positive dynamics of qualitative changes in the technology of obtaining and processing experimental data, and in ensuring the improvement of quantitative indicators. Qualitative changes may consist in expanding the list of studied parameters and improving the methods of processing experimental data used in computer-integrated technology.

Improving quantitative indicators, which together determine the quality of modern computer-integrated technology, consists primarily in increasing the accuracy and reliability of the results obtained during the registration and processing of experimental data.

Analysis of recent research and publications.

The vast majority of modern automated systems and computer-integrated technologies imply the registration of data in quantitative form. In this case, methods are used both for measuring individual parameters of research objects, and more complex methods for an



integral assessment of the state of various objects or processes, which may be based on obtaining images. In both the first and second cases, quantitative values are obtained as a result of the application of certain measurement methods and information-measuring technologies.

In accordance with modern requirements for the quality of measurements, their accuracy should be assessed in the form of measurement uncertainty. If the uncertainty is calculated when measuring individual physical quantities obtained using appropriate measuring instruments or transducers, then today the methods have been developed that are regulated in the relevant standards [1].

In cases where the computer-integrated technology includes components (subsystems) designed to record, convert, process and analyze images, their use requires appropriate procedures for assessing the accuracy of parameters determined on the basis of image analysis. Due to the development of computer-integrated technologies, images are increasingly used as measurement information, including for measurements in laboratory conditions, in scientific research and in industry.

It should be taken into account that the general statement of the measurement task, the measurement goal and the implementation of the measurement experiment assume the presence of a model of the measurement object. In the case of using images as measurement information, it is first necessary to determine which features of the images will be used as measurement results, whether it is planned to determine their quantitative value and perform an accuracy assessment. When solving this issue, problems may arise that depend on the specifics of the object under study.

In [2] it is noted that there are no general models for the analysis of images or their parts, characteristics, and relationships. Variants of such models are known, but they are created for individual image processing tasks or objects of a certain class. Also, according to the conclusions made in [2], there are a number of problems associated with the development of universal methods for assessing the accuracy of measurements, which are implemented on the basis of image analysis.

The process of obtaining measurement information in the form of images is significantly different from measurement procedures and methods for performing measurements of one individual physical quantity, so it always includes several stages, in particular, registration, processing and analysis of the image. Thus, the sources of measurement uncer-

tainty and the corresponding uncertainty components should be analyzed and calculated separately for each of these stages. The authors of the article [3] proposed to allocate three separate steps at which the measurement uncertainty components should be analyzed. In the article [4], the use of calibration is proposed to assess the accuracy of image parameters, which provides an estimate of the uncertainty of the dimensions in the image.

From the analysis of literary sources, it can be concluded that the vast majority of scientific research related to the assessment of the uncertainty of quantitative characteristics of images is aimed at tasks that arise when studying images of real objects in industry, in particular in the fields of machine vision systems and robotic systems. For these industries, the tasks of assessing the uncertainty components caused by changes in the illumination of the object of research; changes in the geometric dimensions, shapes, contours of objects; changes in the image background are relevant. But not all tasks of image registration and processing are concentrated in these areas.

When using the gas-discharge radiation method, the image acquisition and registration are significantly different from similar procedures common in machine vision systems. The gas-discharge radiation method involves performing an active measuring experiment under the influence of a pulsed electromagnetic field on the liquid sample under study. As a result, an image of a corona gas discharge is formed, which is a superposition of a spatial structure consisting of a set of gas-discharge tracks [5, 6].

Task statement. Since the procedure for generating gas-discharge radiation images and possible methods for their registration is characterized by significant differences from the objects of research in machine vision systems and the specifics of the measurement model, it requires the development or modification of existing methods for assessing the uncertainty of image parameters.

The task of the research is to determine the specifics of methods for assessing the accuracy of image parameters when improving computer-integrated technology for analyzing gas-discharge radiation images.

Outline of the main material of the study. When studying the properties of liquid-phase objects by the method of gas-discharge radiation, the stage of formation of a corona gas discharge in the form of a set of gas-discharge tracks should be considered as a probabilistic process. The complex physical processes of the emergence and existence of gas discharges underlie the stochastic dynamic model of the object

of research. Thus, the model of the measured object turns out to be quite complex, so the determination of its parameters should be based on the methods of probability theory and mathematical statistics.

The hardware and software complex used to perform experimental studies involves the formation of experimental liquid samples, while the liquid samples have a certain measured volume, which is provided on the basis of the use of a metal conical funnel. As a result, the liquid sample enters the space between the two electrodes of the high-voltage pulse generator: the first passive output of the generator is electrically connected to the conical funnel and, accordingly, to the sample of the liquid under study; the second high-voltage output is connected to an optically transparent electrode on the lower surface of the glass plate [6]. Due to this design, in each individual experiment, the uniformity of the shape and volume of the samples under study is ensured within the permissible range.

As a result, the registered variants of corona gas discharge for different samples of liquid-phase objects are characterized by the similarity of the general characteristics of the image. Among the general characteristics of the images, the following can be noted: the central part contains a fragment of a round shape, which corresponds to the studied liquid sample; the image of corona gas discharge in the form of a superposition of individual gas discharge tracks, which are directed from the sample contour outward with a gradual decrease in intensity and thickness as they move away from the sample; the background area of the image.

The method of corona gas discharge registration involves conducting experimental studies indoors without external lighting or separating a part of the space to which external lighting is limited. Thus, all images of gas discharge radiation are characterized by a background with an almost uniform color and separate procedures for determining, processing or adjusting the illumination level at the stages of image processing are not required, since illumination fluctuations are eliminated at the hardware level during image registration. Accordingly, the measurement uncertainty component associated with systematic or random fluctuations in the illumination level of the research object is absent for this method.

The use of the hardware-software complex [6] with additional consideration of the characteristics of image histograms proposed in [7] allowed to increase the accuracy of determining the parameters of corona gas discharge images. To compare the accuracy characteristics obtained at the previous stages of research with new modifications of the hardware-software complex, a test object was used. Since corona gas discharge images of liquid-phase objects are charac-

terized by uniformity of shape, a round metal object was used for testing.

To study the characteristics that describe the random dispersion of corona gas discharge parameters, samples consisting of 100 and 120 images of the test object were obtained for each of the modifications of the software and hardware complex, respectively. To assess the uncertainty of the geometric parameters of the images, a technique was used, according to which the quantitative value of the diameter of the test object was estimated by constructing six brightness profiles for each image.

To confirm the stability of the parameters of the hardware and software complex, several series of observations were performed at different time intervals. Therefore, to substantiate the possibility of combining individual series of observations into appropriate samples, it was necessary to test the hypotheses about the statistical equality between the values of the experimental estimates of the mean values and the variance. From a metrological point of view, this indicates that the measurements in individual series of observations were performed with the same accuracy.

To confirm the hypotheses about the statistical equality of the values of the estimate of the mathematical expectation and the estimate of the variance when solving a wide range of data processing tasks, it is usually recommended to use the parametric criteria of Student and Fisher [8].

When performing experimental studies using the gas-discharge radiation method, both statistical hypotheses were confirmed by the Student criterion and the Fisher criterion, respectively: 1) the difference between the experimental estimates of the mean value of the size of the test object in individual series of observations was insignificant; 2) the ratio of experimental estimates of dispersions of geometric dimensions in images turned out to be insignificant.

For both data samples (for the first version of the device for recording images of gas-discharge radiation and for the improved version of the hardware-software complex [6]), a combination of separate series of observations was performed into two corresponding groups, for which experimental estimates of the diameter of the applied test object are calculated as follows:

$$\bar{D}_1 = \frac{1}{L} \sum_{i=1}^L \bar{d}_{1i},$$

$$\bar{D}_2 = \frac{1}{M} \sum_{j=1}^M \bar{d}_{2j},$$

where \bar{D}_1 is the experimental assessment of the most probable value of the test object size when using the first version of the image registration device; \bar{D}_2 is the experimental assessment of the most probable value of the test object size when using the second modification of the hardware-software complex for recording gas-discharge radiation images; \bar{d}_{1i} are the estimates of the average values for the i -th series of

observations for the first version of the device; \bar{d}_{2j} are the estimates of the average values for the j -th series of observations for the second version of the device; L , M are the volumes of observation series for the first and second variants of devices, respectively.

To calculate experimental estimates of the spread of values within the samples, the standard deviation was estimated:

$$s\left(\bar{D}_1\right)=\sqrt{\frac{n-1}{N(N-1)}\sum_{i=1}^L S_i^2+\frac{1}{L(N-1)}\sum_{i=1}^L\left(\bar{d}_{i1}-\bar{D}_1\right)^2},$$

$$s\left(\bar{D}_2\right)=\sqrt{\frac{n-1}{N(N-1)}\sum_{j=1}^M S_j^2+\frac{1}{M(N-1)}\sum_{j=1}^M\left(\bar{d}_{j2}-\bar{D}_2\right)^2}.$$

To select images of the test object obtained when using the first modification of the device, $s\left(\bar{D}_1\right)=0,24327$ mm. For the second sample, the corresponding standard deviation was $s\left(\bar{D}_2\right)=0,16125$ mm.

The values calculated in this way can serve as a basis for estimating the standard uncertainty according to type A. When using the gas-discharge radiation method, this uncertainty component can be due primarily to the probabilistic physical nature of the gas discharge and the formation of different patterns of superposition of gas-discharge tracks for uniform research objects. Also, in the generalized experimental assessment of the scatter of geometric parameters of the image in the form of the standard deviation, other random factors of a probabilistic nature can be taken into account.

When determining the accuracy characteristics of gas-discharge images, it is also necessary to take into account the uncertainty of type B, which in this case will characterize the components of uncertainty that appear when obtaining digital images. When using an analog form of gas-discharge image registration, analog-to-digital conversion is used as a separate operation to convert images into a form suitable for computer processing and analysis. When using a digital camera for registration, this component will be due to its limited resolution.

If not only geometric, but also pixel brightness characteristics are used in image analysis, this requires the use of additional techniques that allow assessing the accuracy of their determination.

Often, the brightness characteristics of images are used to study objects, in particular, this occurs when constructing image histograms, spectral analysis, determining texture features, etc. When analyzing gas-discharge radiation images, methods have been proposed that use the construction of histograms or spectral analysis of images [9, 10].

In this case, in addition to the considered approach to assessing the accuracy of geometric features of images, it is necessary to apply methods for assessing the accuracy of reproduction of brightness characteristics. The accuracy of determining brightness characteristics can be determined using a test object,

which can be a harmonic periodic lattice of different brightness values for a halftone image, for example, in the manner described in [11].

In the general case, in addition to the diameter of the test object, other parameters can be used, which constitute a set of values $\{x_{0,i}\}$, which are used to assess accuracy. If the measurement channel consists of several components or the components of measurement uncertainty are estimated at separate stages of the measurement procedure, then they must be calculated separately as a set of components $\{u_i\}$ – standard uncertainties for each individual i -th component of the measuring channel or stage of image registration and processing, including the uncertainty of computational algorithms. The result of determining the quantitative parameters of images with an assessment of their accuracy will be sets of values $\{x_i, u_{xi}\}$, which are the studied parameters of the test object, the values of which are registered at the output of the measuring channel of image registration with an assessment of their accuracy in the form of a combined standard measurement uncertainty.

Conclusions. The vast majority of known methods for estimating the uncertainty of geometric and brightness characteristics of images have been developed within the framework of the tasks of studying physical objects, the images of which are recorded by a digital camera in natural or industrial conditions. In this case, much attention is paid to such factors as illumination, the influence of external conditions.

The specifics of the procedures for recording, processing and analyzing images of gas-discharge radiation is that they are recorded in conditions without external lighting, but require the use of appropriate hardware for conducting an active measuring experiment. To solve the problem of selecting the parameters of the pulse voltage generator, determining the optimal modes of gas discharge formation, methods are needed that allow assessing the accuracy of reproducing geometric and brightness parameters of gas-discharge radiation images.

To compare the quality of obtaining measurement information in the form of images of gas-discharge radiation, methods based on the use of test objects were proposed. Comparative analysis of the parameters of various modifications of hardware and software complexes was implemented on the basis of the assessment of the standard uncertainty of type A.

A comparative analysis of the obtained results confirmed the feasibility of modifying the hardware and software complex for studying the properties of liquid-phase objects, an integral part of which is computer-integrated technology that provides the construction of histograms and the determination of the amplitude of extrema for envelope histograms.

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Глухова Н.В. СПЕЦИФІКА МЕТОДІВ ОЦІНКИ ТОЧНОСТІ ВИЗНАЧЕННЯ ПАРАМЕТРІВ ПРИ УДОСКОНАЛЕННІ КОМП'ЮТЕРНО-ІНТЕГРОВАНОЇ ТЕХНОЛОГІЇ ДЛЯ АНАЛІЗУ ЗОБРАЖЕНЬ ГАЗОРОЗРЯДНОГО ВИПРОМІНЮВАННЯ

Стаття присвячена розгляду особливостей методів оцінки точності визначення параметрів зображень. Проаналізовано існуючі проблеми, пов'язані зі специфікою методів отримання вимірювальної інформації на базі обробки зображень і оцінкою точності визначення геометричних і яскравісних параметрів зображень.

Завдання удосконалення сучасних комп'ютерно-інтегрованих технологій, складовою частиною яких виступає підсистема реєстрації і обробки зображення, пов'язано з забезпеченням підвищення точності та достовірності результатів вимірювань.

Впровадження комп'ютерно-інтегрованих технологій, які включають процедури обробки зображень потребує аналізу складових невизначеності вимірювань, які виникають на різних етапах реалізації інформаційно-вимірювальної технології.

У статті виконаний порівняльний аналіз специфіки методів реєстрації та обробки зображень, який дозволив визначити особливості методів оцінки точності визначення параметрів при удосконаленні комп'ютерно-інтегрованої технології для аналізу зображень газорозрядного випромінювання. У порівнянні з іншими умовами та моделями вимірювань, які застосовуються у методах вимірювань з отриманням візуальної/вимірювальної інформації, метод газорозрядного випромінювання можна охарактеризувати двома специфічними особливостями: відсутністю коливань зовнішнього рівня освітленості, що забезпечується на апаратному рівні відповідно до вимог проведення вимірювального експерименту; наявністю вимог щодо визначення і налаштування параметрів апаратно-програмного комплексу для реєстрації зображень.

Для порівняння різних модифікацій апаратно-програмних комплексів для реєстрації зображень газорозрядного випромінювання запропоновано використання тест-об'єкту і відповідної методики для експериментальної оцінки випадкового розкиду геометричних параметрів зображень на базі оцінки середньоквадратичного відхилення для окремих серій спостережень, виконаних у різні часові проміжки. Для обґрунтування можливості поєднання окремих серій спостережень у вибірки при обробці експериментальних даних використано критерії Стьюдента та Фішера, на підставі застосування яких було підтверджено гіпотезу щодо рівноточності виконаних серій спостережень.

Ключові слова: комп'ютерно-інтегрована технологія, обробка зображень, газорозрядне випромінювання, невизначеність вимірювань.

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