UDC 004.424+53.087.7

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SOFTWARE FOR DATA PROCESSING of ELECTRON MICROSCOPY

Abstract. Program for the data processing of electron microscopy is described. On a basis of the scan data for digital images of microstructure, a program allows to measure the geometric parameters of microstructure objects (size, area), as well as to obtain information concerning their statistical characteristics: distribution law, mathematical expectation and variance. The programme can be opened and executed in any Internet browser.
Keywords: digital image, software, electron microscopy, statistical analysis.

Introduction. The experimental data can be obtained in a visual form as an image. Satellite images, electron microscope photographs, oscillograms of electrical signals and others are such data. For obtaining the quantitative data on a basis of visual information the scaling of image is necessary. Interval LM usually defines the scale of the image and corresponds to the calibration interval of length, time, voltage or other physical quantity associated with the image.

The raster (digital) images provide significant opportunities for digitization and computer processing of visual information. Digital images, in the form of a graphic file, can be obtained by a digital camera or scanner. This file after loading into computer allows to process the image by any specified program. As was shown in [1], the digital images of oscillograms of an analog oscilloscope allow to determine the signals parameters with the accuracy of the digital frequency meter. Since the absolute error in scanning digital images is 1 pixel, the measurement accuracy increases with increasing of the resolvability of instruments used to obtain such images.

For processing of the digital images is demanded software allows downloading images in computer, scaning them and obtaining information on a basis of scan data.

Good capabilities for a creating of such software provide the means for presentation of information in Internet. HTML and CSS formatting languages allow creating of a comfortable interface in the form

of a web page. JavaScript programming language has the tools are necessary for download and scanning of digital images. It allows processing of the scan data and to use the vector graphics supported by Canvas technology for display of the processing results. Any Internet browser is the software environment for programs created by the means described above.

Problem definition. Creation of a program for measuring and statistical analysis of the microstructure objects parameters in digital images of electron microscope is the aim of the present work.

Major part. The most complete information about microstructure that characterizes the internal structure of material can be obtained using the electron microscope. Such information is visual and usually presented as the graphic files, which can be displayed on the computer screen as raster images. These images contain the information about parameters and characteristics of the objects in microstructure of material: grains, pores, intergranular boundaries, phase inclusions, etc. The digital images of electron microscope usually contain a scale in the form of interval with the given length LM. It allows measuring the geometric parameters of objects in microstructure, such as a length and an area. The information concerning the statistical characteristics and parameters of the microstructure objects can be obtained at measuring of their parameters for a sufficiently large number of these objects.

Measurement of the geometric parameters for objects in the digital image can be performed by means of the scan coordinates corresponding to the boundaries of these objects. The x and y coordinates are given relative to the upper-left corner of image in the pixels. According to the determining method of geometric parameters of the objects in a raster image [2], the object size L in given direction can be determined over coordinates of its edges x1, y1, x2, y2 as

$$L = M\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \ . \tag{1}$$

The area S for objects of polygon form can be calculated over the coordinates of their K-angles as

$$S = \frac{M^2}{2}\left((y_K + y_1)(x_K - x_1) + \sum_{i=1}^{K-1}(y_i + y_{i+1})(x_i - x_{i+1})\right), \tag{2}$$

where M is the scale of the digital image. The scale was calculated over the scan data for the ends of interval LM.

In program the equations (1), (2) were used for calculating of the geometric parameters of objects in the digital image of electron microscope. At the microstructure analyzing of materials, the information about statistics of the geometric parameters of microstructure objects is interesting. The program presented in this work performs the statistical analysis using a sample of N values of parameters. For this aim a program forms an array of sizes Li(1 ≤ i ≤ N) on the base of array of scan coordinates for N objects in a digital image of microstructure. Programme calculates the mean Lav and the standard deviation σL using the sample N by formulas [3]:

$$L_{av} = \frac{1}{N} \sum_{i=1}^{N} L_i, \quad \sigma_L = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (L_i - L_{av})^2} . \tag{3}$$

The same algorithm of statistical analysis was used for S parameter too.

For the construction of histogram and the testing of distribution normalcy in a program applies the statistical sample consisting from N random values of Li or Si(1≤ i≤N).The testing of distribution normalcy is performed using the coefficients of skewness and excess for a distribution law [3]. Program calculates the number of intervals k at histogram construction according to Sturges rule [4]: is integer part of the logarithm

$$k = 1 + \lfloor \log_2 N \rfloor, \tag{4}$$

where $\lfloor \log_2 N \rfloor$ is the integer part of logarithm.

Program performs the following stages of processing for the digital image of electron microscope: 1) Image load in the program window; 2) Determination of the image scale; 3) Choice of geometric parameter (length, area), which will be measured for the objects of microstructure; 4) Scanning of the objects coordinates of microstructure for obtaining the certain sample size N; 5) Calculations on the base of scan data; 6) Display of the outcomes.

The program interface consists of three menu blocks that support the processing stages described above. Main "Tools" block contains the form fields for input of the initial data and output of the processing results. This block contains the button which allows activation of scripts for the different stages of processing. To make the work with program easier, "Tools" block contains user instruction for every stage. Current

coordinates of cursor are showing in the fields of form "X =", "Y =" of the display unit. A program script supports the functioning of this display unit by means of the event "mousemove". The third block is intended for download of files and for display of scan data. It contains: the file type field with the button "Выберите файл"; the button "Remove the last line"; the headers of the table "N X Y". Script that uses the FileReader object is activated at pressing of the button "Выберите Файл". This script gives possibility to select any graphic file that is stored in computer and to load it into the browser window. Scaning of coordinates occurs at the click in given point of the digital image. In this case will be executed a script that transmits the coordinates to variables and arrays of the program for their subsequent processing in accordance with formulas and algorithm that was presented above. This script records the scan data to the table contained in block. The button "Remove the last line" allows deleting data from the last row of the table. This gives possibility for correction of the scan data.

The program uses the Draggable widget of the iQuery UI plugin to move the menu blocks of program to any place in the browser window.

The Fig. 1 shows the window of program at the stage of scale determination for image of electron microscope. For this stage "Tools" interface has the radio buttons for choice the unit of length, the "L0 =" entry field for LM scale parameter and the "ML =" field for display of the image scale. If the LM scale parameter was entered into the "Lo =" field and scanning of the length LM was performed, then program calculates the scale M of a digital image at the pressing of button "Scale". The scale of a digital image will be appropriated to the corresponding variable of program and be shown in the «ML =» field. Script that serve this block contains the means for checking the filling of the "L0 =" field and for control the completion of scanning the ends of scale interval. If the "L0 =" field is not filled or the scanning is not completed, a program displays a corresponding message.

At pressing of the button "Continue" a transition to following stage of processing takes place. After stage of scaling, a user has possibility to choose what parameters of objects in microstructure will be measured (size or area).

The minimum sample size N that program uses is N = 100. That guesses the scanning not less 100 objects for the digital image of electron microscope. The scanning can be stoped by pressing of the button "Finish scanning". When this button is pressed and a sample size N is smaller than 100, the program informs about deficiency of a sample size. The calculation of objects parameters Li or Si ($1 \leq i \leq N$) on a basis of scan data occurs at pressing of the button "Calculation".
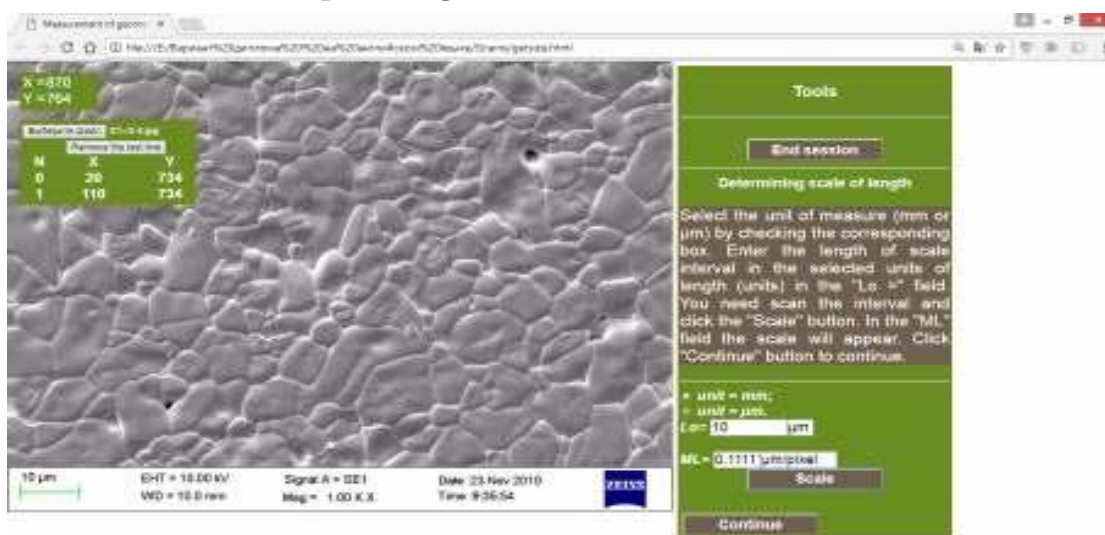

Figure 1 - Window of program at the stage of scaling

The window of program at the final stage of execution is shown in the Fig. 2. At this stage, the program performs statistical analysis and displays the results of processing on the computer screen. At pressing of the button "Create histogram", histogram building on the basis of a statistical sampling for the parameters of microstructure objects occurs. In this case, script is activated that performs the corresponding calculations and construction. This script uses canvas methods for the building of histogram. For carrying out the lines between the points on the opposite ends of object (Fig. 2) these means were used too. The lines connect points where coordinates were scanned.

Test for normality will be executed at clicking the «Distribution» button. In this case script is activated that calculates the coefficients of skewness and excess on the basis of obtained statistical sampling. Program uses these coefficients for the analysis of distribution law of random variable on the basis of known criteria [3] and forms a message about the most probable distribution. Such message can be seen in Fig. 2 for distribution of grain sizes in the microstructure of ceramics on the basis of SnO_2.
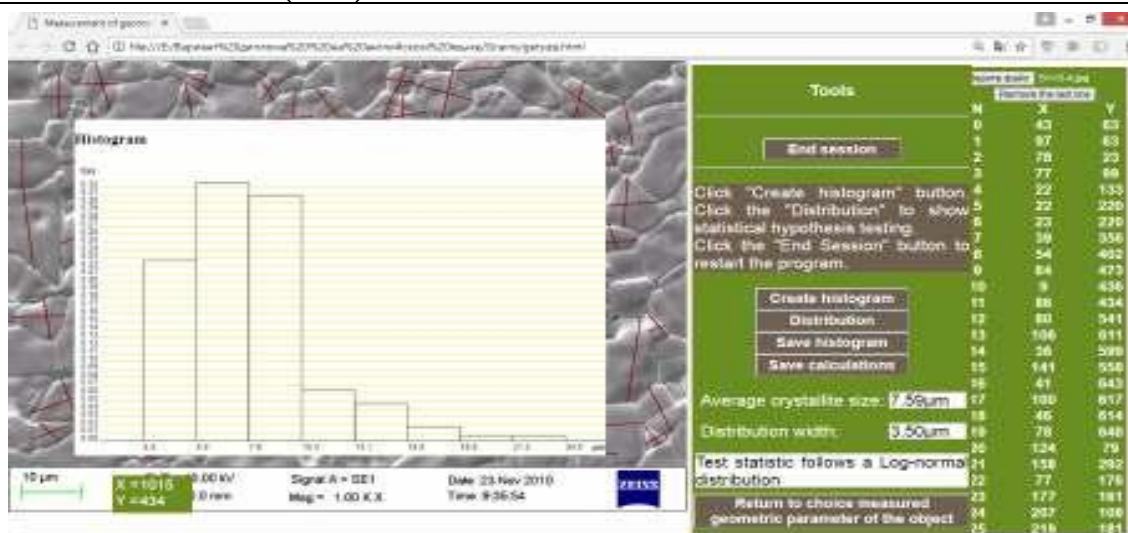
Figure 2 - Window of programme for the final stage of executing

Program allows saving the scan data and results of calculation to the file with extension ".txt". It occurs at the pressing of the button "Save calculation". For histogram memorization in format of ".png" the button «Save histogram» is used. For type change of geometric parameter (length or area) that will be measured, the button "Return to choice measured geometric parameter of the object" is used. The button "End session" provides completion of a current work with program.

Conclusion. Program for the processing of electron microscopy data was created by means of languages for the creation of client web-applications. The program can be opened and executed in any Internet browser. On a basis of the scan data for digital images obtained by electron microscope, program allows to measure parameters (size, area) of microstructure objects, as well as to obtain information about their statistical characteristics: distribution law, mathematical expectation and variance.

ЛИТЕРАТУРА

1. Ivon A.I. Digitization of oscillograms by raster images for rising of accuracy at signal parameters determination / A.I. Ivon, V.F. Istushkin // Системні технології. – 2017. – вип. 1 (108). – С. 37-40.

2. Ivon A.I. Measurement of geometric parameter of plane figures in raster image / A.I. Ivon, V.F. Istushkin, A.A. Lischenko // Системні технології. – 2016. – вип. 1 (102). – С. 24-28.

3. Кобзарь А.И. Прикладная математическая статистика / А.И. Кобзарь – М.: Физматлит, 2006. – 816 с.

4. Sturges H.A. The choice of a class interval / H.A. Sturges // J/ Amer. Statist. Assoc. – 1926. – V. 21, № 153. – P. 65-66.