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MEASUREMENT OF GEOMETRIC PARAMETERS OF PLANE FIGURES IN RASTER IMAGES

Abstract. Method for measurement with the high precision of geometric parameters of plane figures in raster images is presented. The length and the area of such objects are defined from scan data of their coordinates. Programme for method realization was created. Internet browsers are the software environment for its using.

Introduction. Data of electron microscopy usually presents as the raster images. Such images have the scale interval of known length L_0. This interval allows defining the scale of raster image. It gives possibility to measure the length and the area of objects in photomicrography of electron microscope.

Geometric parameters for the small objects of plane surface can be measured with the high precision if to use raster images. It is important, because for such objects the precise measurement of size by micrometer is impossibly. However, as shown in [1], if we obtained the raster image of surface by means of digital photocamera with a high resolution, the sizes of surface objects can be defined with absolute error is close to micrometer errors, which have the values from 2 μm to 50 μm for different accuracy classes of micrometers.

Problem definition. Development of the measurement method of geometric parameters of plane figures in raster images and the creation of program for method realization is the aim of present work.

Major part. Upper left corner of raster image is the origin of coordinates for any its point. Relatively origin of coordinates, x coordinate is the point offset in horizontal direction; y coordinate is the point offset in vertical direction. Coordinates x, y in pixels for any point of raster image can be obtained at the scan of image in graphics editors.

For measurement of geometric parameters (length and area) for objects of raster image it is necessary to define the scale Ml using the scale in-

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terval L_0. At scan of this interval coordinates (xm_1, ym_1 and xm_2, ym_2) in pixels can be obtained. Then $Ml=L_0/|xm_1-xm_2|$ for the scale interval with horizontal disposition and $Ml=L_0/|ym_1-ym_2|$ for such interval with vertical disposition. Ml value actually determines the absolute error of length measurement, since the scan error is ±1 pixel. This error decreases with increasing a resolution of digital photocamera used for obtaining of the raster image. The dimensions and the area of object in raster image can be measured by the scan of object. For objects with arbitrary shape the calculation of area S can be reduced to calculation of area for ellipse and polygon.

For the length measurement of any object in raster image it is necessary to perform a scan of two points in the edges of object in given direction. It gives coordinates x_1, y_1 and x_2, y_2. The value of object length is determined by formula:

$$l = Ml\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}\,. \qquad (1)$$

The length measurement is indirect, since l is calculated by formula (1). This formula uses coordinates x_1, y_1 and x_2, y_2 obtained by the direct measurements with error of scan Δ = ±1 pixel. As is well known [2], the absolute error Δl of indirect measurement is defined by the modules of partial derivatives. Then on the base of equation (1) can be calculated Δl and the relative error of length measurement δ as

$$\delta = \pm\frac{\Delta l}{l}100\% = \pm 2\Delta\frac{|x_1 - x_2| + |y_1 - y_2|}{(x_1 - x_2)^2 + (y_1 - y_2)^2}100\%. \qquad (2)$$

For the plane figures of raster image in shape of circle or ellipse, the area S_e can be calculated by known formula:

$$S_e = \frac{\pi}{4}ab\,, \qquad (3)$$

where a and b are lengths of the major axises of ellipse. Scan of points in the edges of major axises it is necessary to perform for measurement of their length. It gives coordinates $(x_{a1}, y_{a1}, x_{a2}, y_{a2})$ and $(x_{b1}, y_{b1}, x_{b2}, y_{b2})$. On the base of these coordinates and formulas (1), (3), the area of elliptical object S_e can be presented as

$$S_e = \frac{\pi}{4}Ml^2\sqrt{((x_{a1} - x_{a2})^2 + (y_{a1} - y_{a2})^2)((x_{b1} - x_{b2})^2 + (y_{b1} - y_{b2})^2)}\,. \qquad (4)$$

As it follows from the equation (3), relative error of area definition δ_{Se} for the elliptical objects is equal

$$\delta_{Se} = \frac{\Delta S_e}{S_e} 100\% = \left(\frac{\Delta a}{a} + \frac{\Delta b}{b} \right) 100\% \qquad (5)$$

At using of the equations (5), (4) and (3) relative error δ_{Se} can be calculated as

$$\delta_{Se} = \pm 2\Delta \left(\frac{|x_{a1} - x_{a2}| + |y_{a1} - y_{a2}|}{(x_{a1} - x_{a2})^2 + (y_{a1} - y_{a2})^2} + \frac{|x_{b1} - x_{b2}| + |y_{b1} - y_{b2}|}{(x_{b1} - x_{b2})^2 + (y_{b1} - y_{b2})^2} \right) 100\% \qquad (6)$$

The area of plane figures in a shape of polygon can be defined from the coordinates for vertex of angles. Fig.1 shows polygon in the coordinate system of raster image. Scan of angles should be performed in series clockwise beginning from any angle of polygon. As can see from the Fig.1, the areas of trapeziums (S_{12}, S_{23}, S_{34}, S_{45}, S_{56}, S_{67}, S_{71}) are related to the area of polygon S_{pol} by expression:

$$S_{pol} = S_{12} + S_{23} + S_{34} - S_{45} - S_{56} - S_{67} - S_{71}. \qquad (7)$$

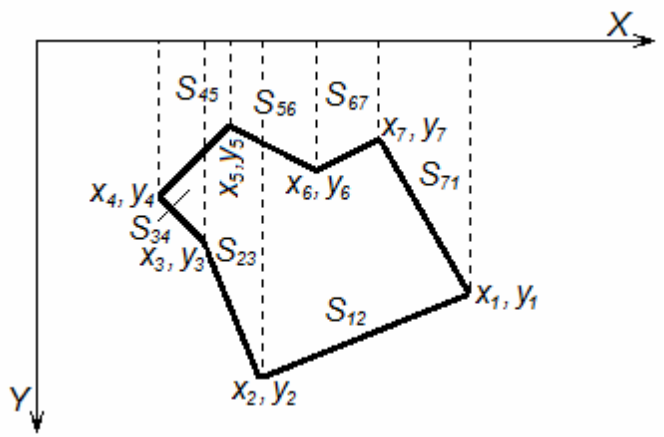

Figure 1 - Polygon in coordinate system of raster image

When a quantity N of polygon angles is arbitrary, the equation (7) has a view:

$$S_{pol} = \sum_{i=1}^{N-1} S_{i(i+1)} + S_{N1}, \qquad (8)$$

where the area of trapeziums $S_{i(i+1)} = Ml^2(y_i + y_{i+1})(x_i - x_{i+1})/2$ in the range $1 \le i \le N\text{-}1$ and $S_{N1} = Ml^2(y_N + y_1)(x_N - x_1)/2$.

Length of the base of trapeziums is defined as differences of coordinates $(x_i - x_{i+1})$ and $(x_N - x_1)$. In the sum of equation (8) these differences ensure the correct sign for $S_{i(i+1)}$ and S_{N1} when scan of angles is performed clockwise in series.

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Thus the area of plane figure in shape of polygon having N of angles can be found from the coordinates of angles x_i, y_i ($1 \le i \le N$) by formula:

$$S_{pol} = \frac{Ml^2}{2}\left((y_N + y_1)(x_N - x_1) + \sum_{i=1}^{N-1} (y_i + y_{i+1})(x_i - x_{i+1}) \right). \quad (9)$$

Taking into account the absolute error of coordinate scan $\Delta = \pm 1$ pixel, on the base of equation (9) can be obtained the expression for relative measurement error of the area for object having a polygonal shape:

$$\delta_{pol} = \frac{\Delta S_{pol}}{S_{pol}} 100\% = \pm 2 \frac{|x_N - x_1| + \sum_{i=1}^{N-1} |x_i - x_{i+1}|}{(y_N + y_1)(x_N - x_1) + \sum_{i=1}^{N-1} (y_i + y_{i+1})(x_i - x_{i+1})} 100\%. \quad (10)$$

On the base of presented above results, programme for the measurement of geometric parameters of objects in the raster images was created by means of the languages HTML, CSS, JavaSckript and jQuery library.

Programme allows measuring the length and the area of objects in raster image and calculates the errors of such measurements. It performs the processing of raster image using the following stages: 1) image loading in window of programme; 2) determination of the image scale by scan of coordinates for the scale interval L_0; 3) choice of measurable object (straight line, ellipse, polygon); 4) scan of measurable object; 5) calculation of geometric parameters and measurement errors; 6) display of the measurement results.

At beginning of every stage the window with user instruction is opening. Current coordinates of cursor are recorded in a script by means of the event “mousemove”. They display in the left top angle of browser window (Fig. 2). Programme script performs coordinate scan by means of the event “click”, when click in a given point of raster image takes place. Scan data are used for calculation according the formulas presented above. Fig. 2 shows window of programme for the final stage of its performance. Programme is opened in the Google Chrome browser.

Raster image can be loaded to the browser window at using of menu option “Выберите файл” (Fig. 2). In Fig. 2 the image scale 0.60 μm/pixel was defined at scan of interval L_0 = 50 мкм in a bottom of image. These scan data are presented in the table below the word “Линейка”. The button “Многоугольник” was set for area measurement of crystallites on a surface shown in

raster image. A scan of the chosen objects can be performed after a pressing of the button “Начать измерение”. The scan data are presented in the table below the word “Объект”. In the course of scanning, after three clicks in points of raster image, the button “Завершить” appears in place of the button “Начать измерение”. Pressing of this button ensures the data transmission to script for calculation of the area and the error by formulas (9), (10). Results of measurement are displayed below the word “Результаты” (Fig. 2). The button “Прямая” is set at measurement of the length. The buttons “Эллипс” or “Многоугольник” are set at measurement of the area.

Conclusion. Method for the measurement of geometric parameters of plane figures in the raster images was developed. The length and the area of such objects are defined with high precision from the scan data of their coordinates. Programme for method realization was created by means of the languages HTML, CSS, JavaScript and jQuery library. Internet browsers are the software environment for this programme.

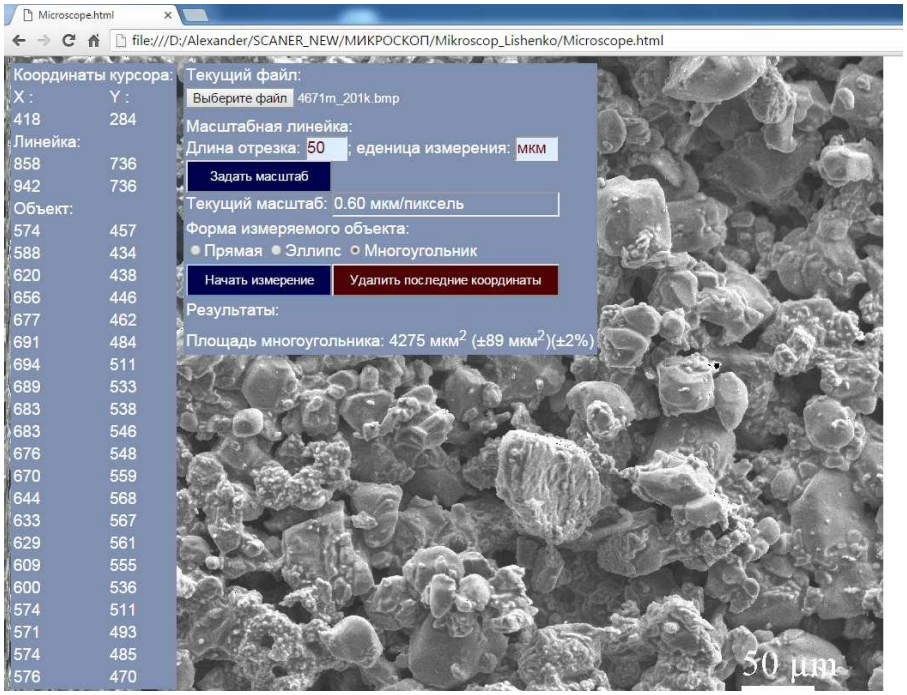

Figure 2 - Window of programme at final stage of the measuring process

REFERENCES

1. Ivon A.I. Application of bitmaps for increasing data processing accuracy in physical experiment [Text] / A.I. Ivon, Y.A. Ivon, R.I. Lavrov // System technologies: coll. articles.–Dnepropetrovsk, 2014. – Issue 1 (90).–P.10–17.
2. Новицкий П.В. Оценка погрешностей результатов измерений [Текст] / П.В. Новицкий, И.А. Зограф – Л.: Энергоатомиздат, 1991. – 304с.