UDC 004.92+519.674

A.I. Ivon, Y.A. Ivon, R.I. Lavrov

APPLICATION OF BITMAPS FOR INCREASING DATA PROCESSING ACCURACY IN PHYSICAL EXPERIMENT

Abstract. Application of bitmaps obtained by a digital photocamera for increasing measurement accuracy was investigated. As it was shown, the processing of such images in graphic editors allows measuring sizes of planar objects with the absolute error no more than ± 31 μm. The relative error of voltage measurement by means of the bitmaps of analog oscillograms does not exceed ±1.5%.

Keywords: pixel, bitmaps, graphic editor, measurement error.

Introduction. It is known that a bitmap is a two-dimensional array of points called pixels. Every pixel has coordinates and color [1]. Since pixels have the discrete nature, their coordinates are discrete values, usually integer numbers which are represented by binary codes in a computer. Pixel color is represented by a binary code too. Therefore, a bitmap is the method of image representation in a computer in the form of a bit array. Depending on a coding method of a color there are different formats of graphic files for storing bitmaps. The widest spectrums of a color rendering have the graphic files which use 24 bit RGB code for coding the pixel color (~ 16 millions of color tints). For example, these are files of the TIF and JPG formats.

Digital photography gives wide possibilities of creating bitmap files. Such files can be obtained with a digital camera. After input into a computer a bitmap file can be opened in a graphics editor, for example, in the Adobe Photoshop. Graphics editors allow increasing bitmaps and allow performing scanning for obtaining the information about the coordinates of any pixel. These possibilities can be used for increasing data processing accuracy in physical experiment, for example, at determining sizes of small objects or at extracting information from oscillograms of analog oscillograph.

Problem definition. The aim of this work is the investigation of application of bitmaps for determining sizes of planar objects and for increasing accuracy the analog oscillograms processing.

Major part. Physical object or oscillogram must be photographed with a digital camera to create a graphics file. To determine the size it is necessary to photograph measurement object together with a length standard, for example, together with the scale of a ruler. It is necessary for binding coordinates with the length unit. With the same aim, for analog oscillograms it is necessary to photograph oscillograms of the calibrating signals which define the standard intervals for voltage and time.

Adobe Photoshop graphics editor can be used to process bitmaps. The “Actual Pixels” option in the “View” option can be used for obtaining of the initial image size. The “Info” option gives information about coordinates of a pixel. Adobe Photoshop allows scanning coordinates in different length units according to the settings of the “Info” option. Further we will use the coordinates n_x, n_y defined in pixels.

The standard length interval L_S is used for determining the scale parameters γ_x, γ_y along the axis x and y. This interval must be situated parallel to the x-axis for determining the γ_x value. In this case the coordinates n_{xS1}, n_{yS1}; n_{xS2}, n_{yS2} of the ends of L_S interval must be defined at $n_{yS1} = n_{yS2}$. Then the γ_x value is equal $\gamma_x = |n_{xS1} - n_{xS2}|/L_S$. The standard interval of length must be situated parallel to the y-axis for determining the γ_y value. In this case the coordinates must be found at $n_{xS1} = n_{xS2}$ and the γ_y calculated as $\gamma_y = |n_{yS1} - n_{yS2}|/L_S$. Usually $\gamma_x = \gamma_y = \gamma$.

When the γ value is known, the sizes of any bitmap object along the axis x (l_x) and the axis y (l_y) can be determined by scanning coordinates on the edges of object n_{x1}, n_{y1}; n_{x2}, n_{y2} using the following relationships:

$$l_x = |n_{x1} - n_{x2}|/\gamma \text{ at } n_{y1} = n_{y2}, \quad (1)$$

$$l_y = |n_{y1} - n_{y2}|/\gamma \text{ at } n_{x1} = n_{x2}. \quad (2)$$

The resolution of a bitmap is $\Delta n = 1$ pixel. Therefore, from the Eqs. (1), (2) it follows that absolute error of length determination for such images is equal:

$$\Delta l = \pm 1/\gamma. \quad (3)$$

The bitmap for specimen of the varistor ceramics with small silver electrodes is shown in the Fig.1. Graphic file of this image was created with the digital camera OLYMPUS C-765. File is opened in Adobe Photoshop editor with using the “Actual Pixels” option. The scanning of the ruler scale at $n_{x01} = n_{x02}$ allows to determine the value of the scale parameter $\gamma = 32$ pixel/mm. Thus, in accordance to (3) the absolute error of the length determination is ± 0,031 mm = ± 31 μm.

Such value of the absolute error is close to the absolute error of length measurement by means of the micrometer ± 10 μm and three times lower than the absolute error of length measurement for the vernier calipers ± 100 μm. It should be noted that micrometer and vernier calipers do not allow measuring the sizes of planar objects precisely (electrodes in the Fig. 1). Bitmaps give the possibility to determine sizes of planar objects by the method described above. Thus, for example, the electrode 2 in Fig. 1 has the sizes along x and y axis d_x = 1,75±0,03 mm, d_y = 1,72±0,03 mm, correspondingly. The electrode area calculated by the formula of ellipse area is equal 2,36±0,06 mm^2. The relative error of sizes determination is ± 1,7 % and the relative error of area determination is ± 2,5 % for electrodes in the Fig. 1.

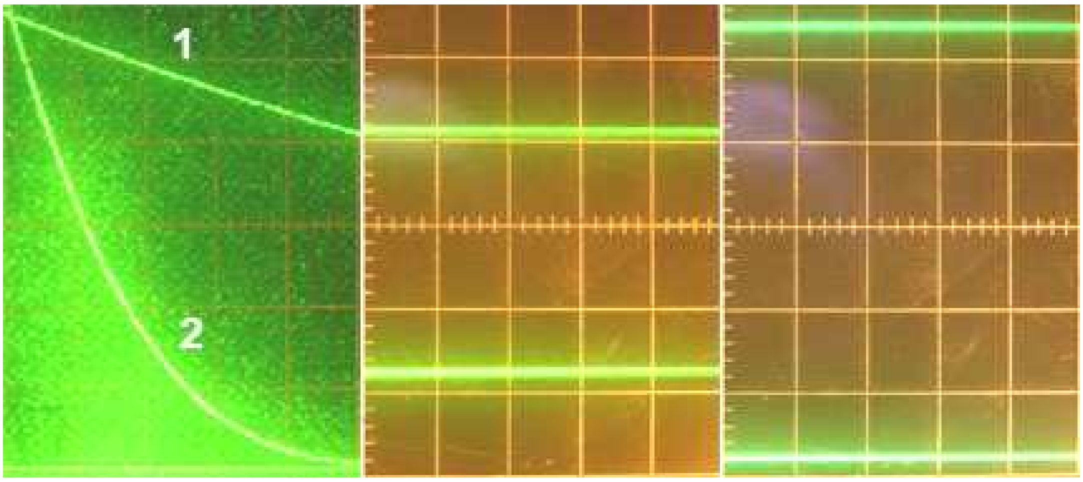
Figure 1 – Bitmap of varistor ceramics specimen

Consequently, the bitmaps obtained with a digital camera ensure a high accuracy for sizes determination of the planar objects at processing of such images in the graphic editors. This accuracy can be increased if using a camera with higher resolution.

It is known that the relative error of determining instantaneous values of voltage $u(t)$ is close to ± 5–8% for analog oscillographs [2].

Let's analyze the possibilities of using bitmaps for increasing processing accuracy of analog oscillograms.

Oscillograms of voltage and electric current recorded in a memorization mode for zinc oxide varistor with small electrodes are shown in the Fig. 2 (for electrode 2 in Fig. 1). Oscillograms were obtained at the application of exponential pulse with the time constant of 100 μs to the specimen. Oscillograms of the calibrating signals, recorded in usual time sweep mode at the same amplification as oscillograms in Fig. 2a are shown in the Fig. 2b and the Fig. 2c. The rectangular pulses with the cycle of 1 ms and with the amplitudes of 100 *V* and 5 *V* were used for calibration. Electric current was measured as a voltage drop on the precision resistor connected in series with the specimen. Therefore, the calibrating current is $I_C = 5\ A$. Oscillograms in the Fig. 2 were recorded by means of the analog double-beam storage oscilloscope C8-11. Bitmap files of oscillograms in the JPG format were created with the digital camera OLYMPUS C-765.



a b c

Figure 2 – Oscillograms: a – voltage (1) and current (2) for specimen of varistor ceramics; b – calibration voltage of 100 *V*;
c – calibration current of 5 *A*.
The scale of the time sweep T_C = 5 μs/division

The scale parameters for voltage γ_U and current γ_I can be determined from the oscillograms of calibration signals using the calibration voltage U_C and the calibration current I_C. To do this it is necessary to scan bitmaps of the calibration signals at $n_{xC1} = n_{xC2}$ in two points corresponding to upper line and bottom line in the Fig. 2b and in the Fig.

2c. From the obtained values of the coordinates n_{xC1}, n_{yC1}; n_{xC2}, n_{yC2} the scale parameters can be calculated as

$$\gamma_U = |n_{yC1} - n_{yC2}|/U_C,\ \gamma_I = |n_{yC1} - n_{yC2}|/I_C. \tag{4}$$

The γ_T scale parameter of time can be obtained from the value of time sweep scale T_C by scanning the scale grid of oscillograph at $n_{yC1} = n_{yC2}$.

The systematic error related to the determination of the scale parameters can be reduced at measuring values of $u(t)$ and $i(t)$. To do this it is necessary to determine the values of γ_U and γ_I for several points on the bitmap of the calibration signal and calculate the average values of these parameters.

It is necessary to use the $n_{0x}(t)$, $n_{0y}(t)$ coordinates of the reference line at determining instantaneous values of $u(t)$ and $i(t)$ by means of bitmaps of the oscillogram. The reference line is registered at zero voltage applied to the inputs of a storage oscilloscope (bottom straight line in Fig. 2a). Scanning of pixels of oscillogram bitmap is performed at $n_{0x}(t) = n_{Ux}(t) = n_{Ix}(t)$. The instantaneous voltage $u(t)$ and current $i(t)$ can be calculated from the coordinates $n_{Ux}(t)$, $n_{Uy}(t)$; $n_{Ix}(t)$, $n_{Iy}(t)$ as

$$u(t) = |n_{Uy}(t) - n_{0y}(t)|/\gamma_U\ , \tag{5}$$

$$i(t) = |n_{Iy}(t) - n_{0y}(t)|/\gamma_I\ . \tag{6}$$

If the initial moment of time is selected in the reference line (point with coordinates $n_{0x}(0)$, $n_{0y}(0)$) then the running time in Eqs. (5) and (6) is equal:

$$t = |n_{Ux}(t) - n_{0x}(0)|/\gamma_T\ . \tag{7}$$

The error of voltage determination by bitmaps of analog oscillograms depends not only from the resolution of the bitmap itself, but also and first of all from the blurriness of lines in oscillogram. The value of this blurriness Δ can be found by determining the coordinates of the edges of the line at $n_{x1} = n_{x2}$. If these coordinates are n_{x1}, n_{y1}; n_{x2}, n_{y2} then $\Delta = |n_{y1} - n_{y2}|$. The cursor should be positioned in the middle of oscillogram line at the scanning of coordinates in this line. Therefore, blurriness of the line gives the absolute error of coordinate's determination close to $\Delta/2$. Then the absolute error $\Delta u(t)$ of the voltage determination from a bitmap of oscillogram is equal

$$\Delta u(t) = \pm\ \Delta/(2\gamma_U). \tag{8}$$

 ISSN 1562-9945

Taking into account the Eq. (5) and (8) the relative error of voltage measurement δ is calculated by the expression:

$$\delta = \pm \frac{\Delta}{2\left|n_{Uy}(t) - n_{0y}(t)\right|} \cdot 100\% . \quad (9)$$

As evident from the Eq. (9), the value of δ is decreasing when modulus of coordinate difference $|n_{Uy}(t) - n_{0y}(t)|$ is increasing and when the blurriness parameter of oscillogram Δ is decreasing. The Δ value can be controlled by changing focusing, astigmatism and brightness of the oscillograph beam.

A blurriness of lines in oscillogram (Fig. 2, the curve 1) is $\Delta = 10$ pixels. The value of modulus for difference $|n_{Uy}(t) - n_{0y}(t)|$ changes from 1600 to 1100 pixels. Taking into account the Eq. (9), the accuracy of the voltage determination at using the bitmap from Fig. 2a is $\delta = \pm(0{,}3\text{-}0{,}5)\%$. Consequently, at using bitmaps of analog oscillograms for the measurement of instantaneous voltages the relative error is close to the values typical for the digital voltmeter $\delta = \pm 1\text{-}1{,}5\%$ [2].

Adobe Photoshop is not right for scanning large pixel arrays in bitmaps, because it does not allow memorizing these arrays for a further processing. We developed a program for scanning of bitmaps. This program can be opened in any modern browser. The window of the program opened in the Opera browser is shown in Fig. 3.

Any bitmap file can be opened in a window using the "Open file" option of the program. Coordinates of a pixel corresponding to the cursor location are displayed in the upper left corner of the screen. Click on the left mouse button records the current coordinates to the table. As shown in the Fig. 3 (see the table), the array of pixel coordinates can be obtained when the cursor at scanning goes with the specified step along the oscillogram line and then it goes with the specified step along the reference line (the line at the bottom of screen). This array can be copied and then opened for a further processing, for example, in Microsoft Excel.

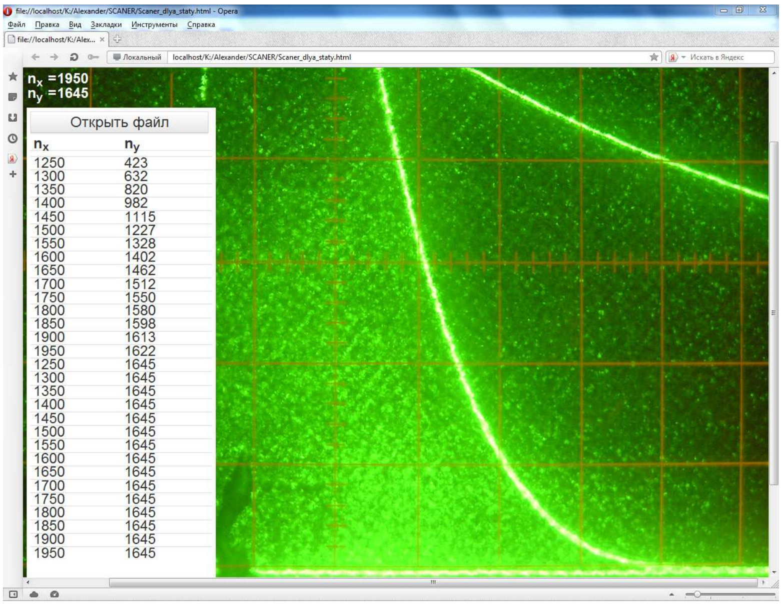


Figure 3 – Window of program for scanning of the bit images

Conclusion. The bitmaps obtained with a digital camera allow increasing the measurement accuracy of physical values at their processing in a graphics editor. The application of bitmaps for determining sizes of planar objects ensures the absolute error no more than ± 31 μm. The relative error of voltage measurement by means of bitmaps of analog oscillograms does not exceed ± 1.5%.

REFERENCES

1. Солоницин. Ю. Photoshop CS2 и цифровая фотография [Текст] / Ю. Солоницин. – СПб.: Издательский дом „Питер”, 2006. – 347 с.

2. Дедюхин А.А. Основные характеристики современных осциллографов [Электронный ресурс]. – Режим доступа: http://www.prist.ru/info.php/articles/general_ch_modern_oscilloscopes.htm – Загл. с экрана.