AUTOMATION OF MEASUREMENT OF OBJECTS GEOMETRICAL PARAMETERS

Yury Megel, Ivanka Kalimanova, Antonina Rybalka, Sergej Kovalenko, Svetlana Kovalenko

Abstract: The issues of automation of measurement of the basic physical and geometrical parameters of biological object and possibility to obtain quantitative characteristics by optical methods are considered in the article. The prospects of the method of pattern recognition to distinguish the contour of the object in order to increase descriptiveness and precision measurement are shown.

Keywords: measurement, automation, biological object, pattern recognition, optical system, pixel.

1.Introduction

The evaluation of the geometric and physical characteristics of objects in the field of view of the optical system reduces to measuring the coordinates, the length of rectilinear and curvilinear segments, and areas. These measurements are associated with the need to fix the levels of optical density or brightness of image fragments.

The image of the biological object in the field of view of the optical system is represented on the monitor screen (Fig. 1) as brightness (reflection, transparency or absorption) dependence as a function of the coordinates. The embryo model, which reflects the nature of the distribution of illumination in the image field, has the form close to the Gaussian function $\rho(x, y)$. Interpretation of the dependence $\rho(x, y)$ is the subject to measurement in quantitative analysis [1].

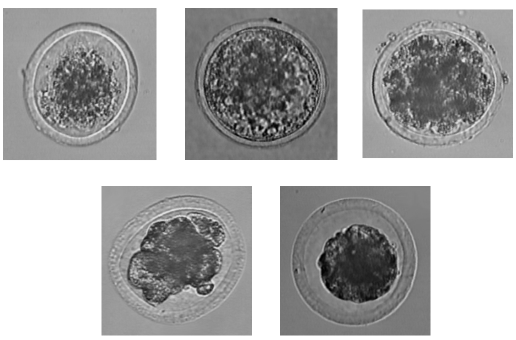

Fig. 1. Examples of images of microbiological objects under a microscope

2. Statement of the problem

The measured parameters of the embryo studied images are the diameter d_ρ, the area S_ρ, the perimeter P_ρ, and the shape factor P_ρ / S_ρ of the object.

To control the size of the embryo, it is necessary to evaluate the influence of the characteristics and parameters of the CCD on the accuracy of determining the coordinates.

3. Solution of the task

To implement an automatic measurement of the geometric parameters of an object, a structural diagram, shown in Fig. 2, is used.

For the purpose of control and installation of the embryo in the focal plane, the image is displayed on the monitor. To process the resulting image, the television signal is digitized and inputted to the PC via the interface.

The main characteristic of a television system is the resolving power. There are two quantitative estimates of the resolving power in television and optical lines [2].

In both cases, the resolving power is determined by the number of photosensitive elements and by the sizes of these elements, both in the vertical and in the horizontal direction

As follows from the principle of television scanning and obtaining an image of the object on the monitor (vertically and horizontally), the coordinate x_{1i} of the left boundary of the object in i row is strictly related to the time position t_{1i} of the front of signal corresponding to this row of the raster, by the relation $x_{1i} = \text{н}_x \cdot t_{1i}$, (where ν_x is the speed of movement of the scanning element in the image plane in the x-direction). Correspondingly, the coordinate of the right boundary $x_{2i} = \text{н}_x \cdot t_{2i}$, and the size of the object in this row (chord size)

$$l_i = x_{2i} - x_{1i} = v_x \left(t_{2i} - t_{1i}\right) = v_x \ \tau_i ,$$

where τ_i is the duration of the pulse generated in the raster line.

Thus, measuring the duration of the time interval τ_i allows us to determine the lengths of the segment l_i at a given scanning speed v_x and the optical system magnification factor. It follows [3] that the part of the S_i area of the object in the i scan line is $S_i = l_i \ \delta = v_x \ \delta \ \tau_i$, where δ is the width of the strip (the distance between adjacent rows). The area of the whole object can be defined as

$$S = v_x \ \delta \sum_{i=1}^{n} \tau_i \ , \qquad (1)$$

where $i = 1$ is the strip, corresponding to the first intersection of the object under study with the scanning element, n is the total number of raster rows overlapping this object.

Therefore, the measurement of the coordinates and length of straight segments in the direction of scanning, as well as the areas of objects, is reduced to measuring the duration of the image signals in the direction of scanning [3]. The measurement of the coordinates and length of rectilinear segments in the direction of the vertical scan (the y axis) is reduced to determining the number of raster lines overlapping the corresponding linear segment.

The estimation of the sphericity of the object in the case of its shape close to the sphere (Fig. 1) is determined by finding the sphericity coefficient $K_{c\phi}$, which is calculated by the formula

$$K_{c\phi} = K_{\phi} / K'_{\phi} \ , \qquad (2)$$

where K_{ϕ} is the shape factor of the circle, K'_{ϕ} - the shape factor of the object image.

The value of the shape factor of a circle is defined as

$$K_{\phi} = P_p^2 / S_p \ , \qquad (3)$$

where P_{ρ} and S_{ρ} are the perimeter and the area of a circle close to ideal.

If the shape of the embryo is close to a circle, the shape factor is equal $K_{\phi} = 12{,}56$.

In the variant, when the shape of the object differs from the circle, the shape factor is found in the following way: from the parameters of the two-dimensional image of the object [3], the ratio K'_{ϕ} between the maximum distance $|r_{\max}|$ between two points of the image contour G and the sum of the distances $|r_{\min}|_k$ between the points of the image contour in the direction, perpendicular to the line joining the points of the contour G, maximally distant from each other, multiplied by the number of the discrete partition $N(l)$.

$$K'_{\phi} = \frac{|r_{\max}| \ N(l)}{\sum_{k=1}^{N(l)} |r_{\min}|_k} \ . \qquad (4)$$

With a step discretization l tending to zero, we get

$$K'_{\phi} = \frac{|r_{\max}| \ N(l)}{\sum_{k=1}^{N(l)} |r_{\min}|_k} = \frac{|r_{\max}|^2}{\int_0^{|r_{\max}|} |r_{\min}|_k \ dl} \ . \qquad (5)$$

Taking into account the fact that $\int_0^{|r_{\max}|} |r_{\min}|_k \ dl = S$, we have

$$K'_{\phi} = |r_{\max}|^2 / S \ . \qquad (6)$$

Thus, physically the coefficient of sphericity characterizes the degree of deviation of the shape of the object from the circular one. Hence the perimeter of an object having a shape different from a circle is defined as

$$P = \sqrt{K'_{\phi} \cdot S} \ . \qquad (7)$$

In the digital processing of video images, the generated video signal is quantized and further extracted in semitone images using a gradient method based on the procedure of spatial differentiation.

4. The Use of Computer Graphics Techniques

To evaluate the parameters of the object we use the image processing methods, with their subsequent recognition [4]. To calculate the measured parameters $d_{\rho}, S_{\rho}, P\rho$ and $P\rho / S\rho$, we choose 2 images of objects of different shapes (Fig. 1). The dimensions of each of these images are pixels.

To solve this problem, it is necessary to allocate the contours of objects on the images. Data filtration is divided into linear filtration (using the convolution matrix) and non-linear one. The operation of linear filters can be represented in the form of a convolution of a processed image with a filter whose core is represented in the form of a matrix or mask, the coefficients of which have a different value (weight):

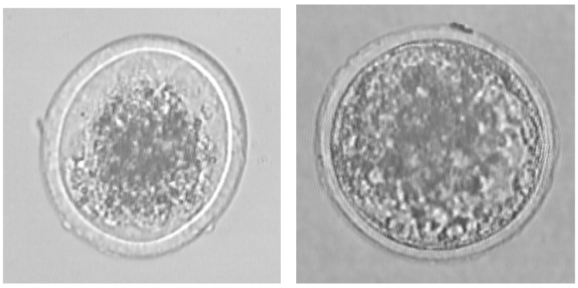

Fig. 3. Basic images for processing

$$z'(x,y) = \sum_{(s,t)\in S_{xy}} h(s,t)\, z(s,t)\,, \qquad (8)$$

where $z(s,t)$, $z'(x,y)$ are the brightness of the pixels with coordinates s, t and x, y of the distorted and restored images respectively; $h(s,t)$ - weight coefficients of the matrix of the filter core; S_{xy} - the area of the filter core or its aperture (the centre of the aperture coincides with the pixel $z(x,y)$ of the distorted image).

To eliminate random noise, it is advisable to use an averaging filter, for example, a Gaussian filter, the advantage of which is the absence of artefacts after its application. The Gaussian filter matrix of size 5×5 and $\sigma = 1$ is represented as:

$$h_G = \begin{vmatrix} 0{,}003 & 0{,}013 & 0{,}022 & 0{,}013 & 0{,}003 \\ 0{,}013 & 0{,}059 & 0{,}097 & 0{,}059 & 0{,}013 \\ 0{,}022 & 0{,}097 & 0{,}159 & 0{,}097 & 0{,}022 \\ 0{,}013 & 0{,}059 & 0{,}097 & 0{,}059 & 0{,}013 \\ 0{,}003 & 0{,}013 & 0{,}022 & 0{,}013 & 0{,}003 \end{vmatrix}$$

To isolate the contour lines, we use the Sobel filters. A feature is the transformation of the image separately along each of the axes. To do this, we use matrices

$$h_X = \begin{vmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{vmatrix}, \quad h_Y = \begin{vmatrix} -1 & 2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{vmatrix},$$

which gives two separate images:

$$G_X = \sum_{(s,t)\in S_{xy}} h_X(s,t)\, z(s,t)$$

and

$$G_Y = \sum_{(s,t)\in S_{xy}} h_Y(s,t)\, z(s,t).$$

These images can be combined using expression $z'(x,y) = \sqrt{G_X^2 + G_Y^2}$.

The result of smoothing and extracting contours is shown in Fig. 4. For convenience, it is also possible to obtain images in inverse colour.

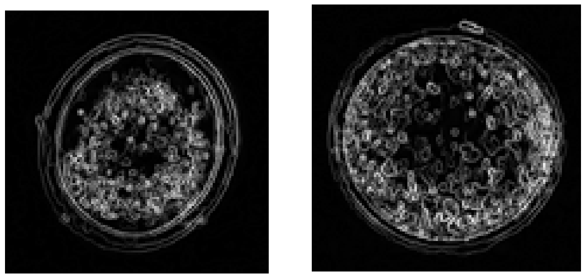

Fig. 4. Result of smoothing and extraction of contours

The next step is to separate the same colours inside the object and outside it. Filling the area around the embryo is not difficult - we use the fill to the specified colour. In this case, the algorithm of wave filling (colour correction) will perfectly cope with the problem posed. Its essence lies in the successive (wavy) spreading of the fill colour from the initial coordinate to some boundaries (see Figure 5).

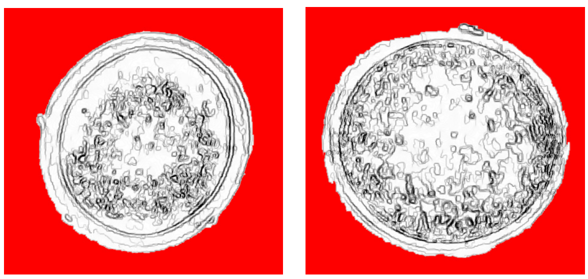

Fig. 5. The result of filling around the biological object

In our case, the starting point is located in the upper left corner of the image - in all the examples presented, it is located outside the embryo. The algorithm of filling can be realized both with the help of recursion, and without it.

Based on the small size of the image, we chose a recursive version.

The filling of the area inside the embryo may differ. For acceleration it is preferable to paint an entire line of the image at once (see Fig. 6).

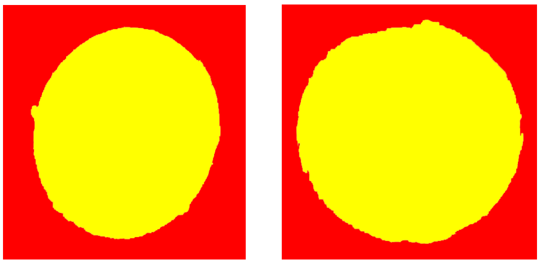

Fig. 6. The result of filling inside the bioobject

As a result of the performed operations, the procedure of segmentation of objects was implemented, which allows us to operate with images consisting of only two colours (we will designate the colour inside the embryo $Coulor_1$ and outside - the $Coulor_2$). Calculation of the number of these colours makes it possible to obtain the measured parameters of the researched images of the bioobjects.

To obtain an area S_ρ, it is necessary to count the number of pixels with the colour $Colour_1$. For the first image, this value is 102092 pixels.

With a total number of pixels 206116 (corresponding to a size of 454×454 pixels) and a resolution of 72 pixels per inch for this image, we have an area of 127.18 cm^2 (taking into account the optical magnification of the microscope).

Getting the value of the perimeter P_ρ suggests counting the number of pixels located on the border of two colours. The counting is performed using a 3×3 matrix, which slides around the image and fixes the differences of neighbouring colours $Colour_1$ and $Colour_2$. Because transitions are possible from both $Colour_1$ to $Colour_2$ and from $Colour_2$ to $Colour_1$, such transitions will be 2 times greater than their actual number.

Table 1. Calculation of the final characteristics of bioobjects

Total s=206116 pixels		
$min\ d_\rho$ / $max\ d_\rho$	$\frac{345}{378}$ pixels	$\frac{397}{400}$ pixels
S_ρ	102082 pixels	120072 pixels
P_ρ	$\frac{2270}{2} = 1135$ pixels	2456/2=1228 pixels
P_ρ/S_ρ	$\frac{1135}{102082} = 0{,}011$	$\frac{1228^{2}}{122639} = 0{,}01$
$K_\phi = \frac{P_\rho^2}{S_\rho}$	$\frac{1135^{2}}{102082} = 12{,}6195$	$\frac{1228^{2}}{120072} = 12{,}5589$

5. Conclusion

To determine the geometric characteristics of a microbiological object, a structural diagram of an automated system with uniformly distributed hardware and software in the case of multi-graded representation of the image is proposed, which makes it possible to increase the information capabilities of the system. The proposed method of two sequential differential operators (masks) allows providing a higher accuracy of measurement and increasing the objectivity of making a decision about the viability of the microbiological object and, thus, complements the morphological evaluation.

6. References

[1] **Yu. E. Megel', V. A. Shigimaga, A. I. Rybalka, I. I. Kalimanova, A. A. Torba.** Apparatnaya realizaciya impul'snogo metoda izmereniya provodimosti kletki. *Sbornik dokladov 24-th National Scientific Symposium with international participation "METROLOGY and METROLOGY ASSURANCE 2014"* September 7–11, 2014, Sozopol, Bulgaria, ISBN 1313-9126, C. 290–294.

[2] **S. L. Gorelik, B. M. Kac, V. I. Kivrin.** *Televizionnye izmeritel'nye sistemy.* M.: Svyaz', 1981, p. 168.

[3] **A. I. Rybalka, I. I. Kalimanova.** Matematicheskaya model' izmereniya parametrov geometricheskix ob"ektov. *Sbornik dokladov 19-th*

National Scientific Symposium with international participation "METROLOGY and METROLOGY ASSURANCE 2009" September 10–14, 2009, Sozopol, Bulgaria, ISBN 1313-9126, p. 99–102.

[4] **L. Shapiro, Dzh. Stokman.** *Komp'yuternoe zrenie:* Per. s angl. M.: Binom. Laboratoriya znanij, 2006, p. 752.

[5] **V. A. Gorxovatskij.** *Strukturnyj analiz i intellektual'naya obrabotka dannyx v komp'yuternom zrenii.* Khar'kov: Kompaniya SMIT, 2014, p. 316.

Authors:

Yury Evgenevich Megel. MSc in radio-electronics, Kharkov Institute of Radio¬electronics (1972). DSc. (2004), Professor (2005) in KhNTUA "P. Vasilenko".

Scientific field and interests: Digital automation of biotechnological processes.

Workplace: Kharkiv Petro Vasylenko National Technical University of Agriculture, Department of Cybernetics.

Mailing address: 44, Alchevskikh st., Kharkiv, Ukraine, 61002;

Web address: *http://www.khntusg.com.ua;*

e-mail: megel_ye@mail.ru

Ivanka Ivanova Kalimanova. MSc in Physics/Physical optics, Kharkov State University, Ukraine (1969). Ph.D – Technical University of Sofia (1986), Associate Professor in the Department of Precision Engineering and Measuring Devices, Faculty of Mechanical Engineering, TU-Sofia, (1991).

Scientific field and interests: optical, electro-optical and laser devices, optical measurements.

Workplace: Technical University of Sofia, Mechanical Engineering Faculty, Laboratory "CMM".

Mailing address: 8 "Kl. Ohridski" Blvd, 1756 Sofia, Bulgaria;

Web address: *http://www.tu-sofia.bg;*

e-mail: ikaliman@tu-sofia.bg

Antonina Ivanovna Rybalka. MSc in physics, Kharkov State University, Ukraine (1969). Ph.D. (1978), Associate Professor, (1989) in the Department of Physics, Faculty of Automation and Computerized Technology, Kharkiv National University of Radio Electronics.

Scientific field and interests: Optical systems, modeling of optical systems.

Workplace: Kharkiv National University of Radio Electronics, Faculty of Automation and Computerized Technology, Department of Physics.

Mailing address:14, Nauki ave., Kharkiv, Ukraine, 61166;

Web address: *http://nure.ua;*

e-mail: airybalka@mail.ru

Sergey Vladimirovich Kovalenko. MSc in information technologies, Kharkov State Polytechnic University (1996); Ph.D. (2015); NTU «KhPI», Department of Systems Analysis and Information-Analytical Technologies. Scientific field and interests: digital image processing.

Workplace: National Technical University "Kharkiv Polytechnic Institute", Faculty of Computer Science and Program Engineering, Department of Systems Analysis and Information and Analytical Technologies.

Mailing address: 2, Kyrpychova str., Kharkiv, Ukraine, 61002,

Web address: *http://www.kpi.kharkov.ua*

e-mail: adbc@ukr.net

Svetlana Nikolavna Kovalenko. Kharkov State Polytechnic University (1996). Ph.D.. (2009), Associate Professor (2011); Kharkiv Petro Vasylenko National Technical University of Agriculture, Department of Cybernetics. Scientific field and interests: pattern recognition.

Workplace: KhNTUA "P. Vasilenko", Educati-onal and scientific institute of business and management,

Mailing address: Alchevskikh st., 44,
Kharkiv, Ukraine, 61002;

Web address: *http://www.khntusg.com.ua,*

e-mail: adbc@ukr.net