Information System for Automating Processes of Biological Objects Detection, Recognition, and Measurement

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***Abstract*—The article briefly describes the existing and proposes novel approaches to the detection, estimation of the number and measurement of physical parameters of biological objects in the frames of computer vision systems. The object detection method is based on a two-stage algorithm: at the first stage, the approximate position of the object is determined using edge detection algorithms; at the second stage, graphic models of the object are built by creating graphical primitives. An algorithm for constructing graphical primitives is developed using the color of a biological object as a parameter. The presence of the second stage can significantly reduce both false positive and false negative results. To implement the presented model theoretical studies and practical experiments are carried out. During experiments, it was revealed that the proposed approach allows increasing the accuracy of determining biological objects, since it works with a color image and, accordingly, uses the ranges of digital color channels. In addition, the construction of graphical primitives, taking into account color ranges, makes it possible to estimate the physical characteristics of a biological object. The proposed two-stage technique for the automatic determination of biological objects makes it possible to solve the problems of positioning ultraviolet and low-frequency laser devices for point irradiation. The presence in the algorithm of the stage of constructing graphical primitives on biological objects makes it possible to estimate the degree of fatness of the animal, which is one of the components of determining its state of health, and can be part of an automatic system for contactless determination of the animal's weight.**

Keywords—raster image processing, object measurement, computer vision system, pattern recognition, data filtering, edge detectors

I. INTRODUCTION

The problem of food security is always acute and urgent for any country. One of the components of food security is the autonomy and economic independence of the national food system (food independence), which in turn depends on the level of development of crop production and animal husbandry in the country. In modern conditions the systems of intensive livestock farming are an important part of ensuring food security [1]. These systems are the most typical for the production of pork - one of the main types of meat consumed in many European countries, including Ukraine. Meat consumption is directly related to the standard of living in the country, it is characterized by high production costs and, consequently, high prices for products. According to the Organization for Economic Cooperation and Development (OECD) [2], meat production is constantly growing, while pork production in the period from 1990 to 2020 (except for a short period of time) occupies a leading position in world meat production (Fig. 1)

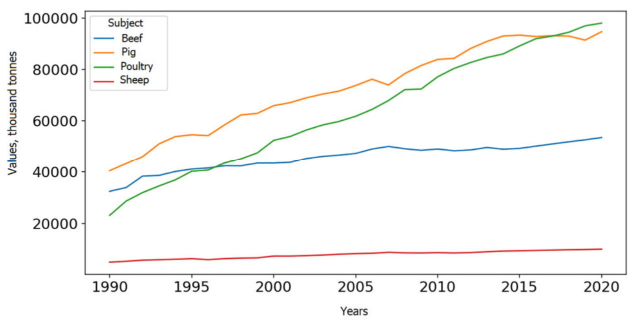

Fig. 1. Production of meat between 1990 and 2020

Fig. 2 reflects the total amount of meat produced by type of finished product in the period from 1990 to 2020. The presented diagram reflects that pork is the most produced type of meat in the world, despite the fact that in some countries it is prohibited for consumption for religious reasons.

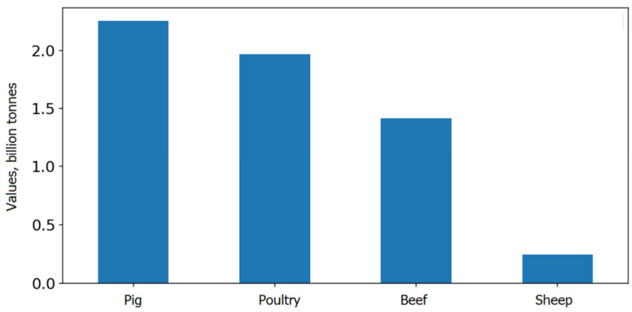

Fig. 2. The total production of meat between 1990 and 2020

A component of intensive livestock production is increasing the efficiency in the use of resources and the application of high-tech methods to achieve maximum productivity. Intensive livestock systems are characterized by the desire to increase the density of animals per unit area. In such an environment, animal disease detection systems are essential. One of the components of such systems is computer vision subsystems.

Computer (technical) vision in general and pattern recognition in particular are some of the applications of the artificial intelligence system. There are several promising applications for the use of image recognition systems in animal husbandry:

1. Non-contact weight estimation of the animal. This does not lead to stressful situations, which negatively affects the fattening process of the pig. At the same time, it makes it possible to draw up an individual diet and composition of food additives for each animal, which will make it possible to improve the yield. Based on non-contact weighing, it is also possible to determine the presence of animal diseases - weight loss is often an indicator of illness.

2. Artificial ultraviolet irradiation of an animal is essential for the production of vitamin D [3]. This vitamin is necessary to prevent anemia, improve feed digestibility, improve the resistance of the animal's body and, consequently, increase the rate of production growth. It is a well-known fact that irradiation of piglets with ultraviolet rays increases metabolism, the content of hemoglobin and erythrocytes in the blood, increases the amount of vitamin D, and also increases live weight by 10-12% and has a beneficial effect on feed digestibility.

3. Strictly dosed low-frequency laser irradiation of sows [4], which is also an insolation replacement, reduces gestation period, as well as the number of stillborn piglets, improves lactation and reduces time of postpartum recovery.

Since energy costs are one of the essential components of the meat production cost in general and pork production in particular, the use of energy-saving technologies is a key factor in reducing costs, which in turn leads to a decrease in product prices and an increase in consumption of this product. In this study, a reduction in energy consumption is proposed due to the point irradiation of animals, which requires the determination of the number of animals and their coordinates in a relative and absolute coordinate system.

To solve the problem of image recognition in modern information systems the convolutional neural networks (CNN) [5, 6, 7] or methods of edge detection in the class of binary images [8, 9] are used. Both of these approaches have their drawbacks. The first one requires a large amount of data for training and high computing power of a computer system. Moreover, it is prone to overfitting [5]. In addition, at present, neural networks have been built and trained for the detection and identification of objects of different nature, the open source code of which is in the public domain, for example, on GitHub, and therefore are not the subject of this study. The disadvantage of edge detection methods is a decrease in the signal-to-noise ratio as a result of the use of linear high-pass filters and, as a result, an increase not only in the edges of objects, but also in the noise created by small objects in the image [10].

II. Research Problem Statement

The purpose of this study is to justify an approach based on processing and decision-making based on color images. The following situations are possible in the field of view of technical vision systems:

1. Empty field of view of the system: there are no objects;
2. Single object: there is one object in the field of view;
3. Two or more separate objects are in the system's field of view;
4. There are several touched objects;
5. There are several overlapped objects.

The proposed approach can be used with equal reliability for all these cases, but, in our opinion, it allows more likely to identify objects in the case when the objects are touched or overlapped.

To effectively solve problems in all 5 cases, the task is to develop an algorithm for determining the number of objects in the field of view of the technical vision system after receiving them from the image capture unit.

For the proposed system to be a universal decision-making tool for finding biological objects in the field of view, it must include the following elements (Fig. 3):

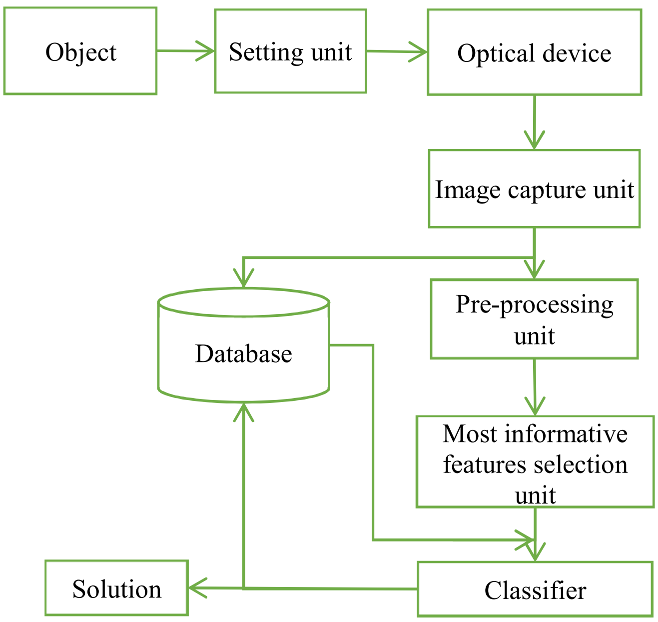

Fig. 3. The scheme of searching for a biological object in the image

1. The system setting unit, which includes such parameters as the size of the field of view, the distance from the fixing device to the objects, the types of objects, etc.;

2. Image capture unit can be represented by an optical device with wired or wireless communication;

3. Data pre-processing unit performs noise smoothing, lighting adjustment, etc.;

4. The unit of most informative features selection. In our case, such information is provided by the color of the biological object, that should be found;

5. A classification unit where an object is assigned to one of the possible classes;

6. Decision making unit.

The structures and algorithms of blocks number 1, 2, 3 are not the subject of this study, so we will focus on the algorithm of units of most informative features selection, classification and decision making, which are the essence of the algorithm for finding biological objects.

III. LOCATION OF BIOLOGICAL OBJECTS IN IMAGES

We will search for objects using a modified segmentation algorithm. The general task of segmentation is to divide an image into multiple regions that include pixels that are similar to each other within a given region [10, 11]. One of the functions of segmentation is the decomposition of the image into parts, with their further processing. The areas of the segmented image must be holistic and homogeneous. For example, to detect an object in an image, you can detect areas of images that are similar in colour and texture to areas of the desired object.

The application of filters for edge detection to the image can significantly reduce the amount of processed data due to the fact that the filtered part of the image is considered less significant, but the most important structural properties of the image are preserved. On the other hand, the object edge detection may precede the task of image segmentation. In our case, it is necessary to select the body of the pig, while indicating its "center of gravity". The operation of such filters is based on detecting brightness differences, while using discrete analogs of the derivatives of the first and second order.

Contour filtering is implemented by a number of algorithms [10-14], such as the Canny operator, the Sobel operator, the Laplace operator, the Pruitt operator, and the Roberts operator. Formulas (1) are matrices for extracting the boundaries of the Sobel operator for determining the contours in four directions:

$$H(x) = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}, \; H(y) = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix},$$

$$H(xy) = \begin{pmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{pmatrix}, \; H(yx) = \begin{pmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{pmatrix}. \quad (1)$$

The H matrices are applied to the original image as convolution matrices.

Now let's apply the described actions to a raster image (Fig. 4), which pictures several pigs. The camera is located at a slight "elevation" in relation to the objects in question. This makes it possible to obtain images with partially overlapped recognition objects.

Fig. 4. The original raster image for processing

The use of edge detection filters assumes channel-by-channel (separately by R, G, B color channels) filtering using convolution matrices (1). After performed transformations, the image should be converted to the Grayscale mode, and then, if necessary, to binary one. The result of the Sobel operator application is shown in Fig. 5.

Fig. 5. Result of image processing using the Sobel operator

The use of the Canny detector allows us to achieve the similar result (Fig. 6). This algorithm consists of 5 quite resource-intensive steps.

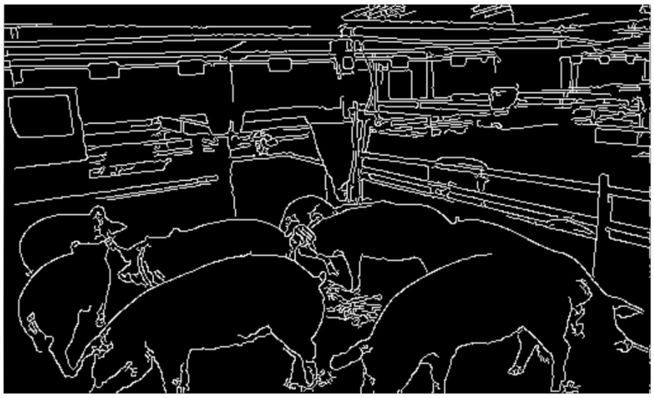

Fig. 6. The result of using the Kenny detector

Next, let's return to calculations with a color image in local areas. The pig detection filter works at the pixel level.

The original RGB image is converted to a logarithmic color space using following transformations:

$$\begin{aligned} I &= L(G) \\ R_g &= L(R) - L(G) \\ B_y &= L(B) - \frac{L(G)+L(R)}{2} \end{aligned} , \quad (2)$$

where $L(x)$ is calculated by the formula:

$$L(x) = 105\log_{10}(x+1+n) . \quad (3)$$

The value n represents random noise and is taken from the interval [0, 1]. The value I , found from (1), is used to determine the texture amplitude map:

$$T = med_2(|I - med_1(I)|) , \quad (4)$$

where med_1 and med_2 are nonlinear median filters. The raster aperture med_2 is larger than the corresponding value for med_1 . The value T is used to detect areas for which the texture is not very pronounced.

The values of hue (H) and saturation (S) are used to select areas that are similar in color to the pig's skin color. The R_g and B_y values are also median filtered before use. Conversion from logarithmic color space to hue and saturation values is described by the expressions:

$$\begin{aligned} H &= \arctan(R_g, B_y) \\ S &= \sqrt{R_g^2 + B_y^2} \end{aligned} . \quad (5)$$

To accept a positive answer about the color matching to the pig on an image, it is enough to fulfill one of the conditions (6) or (7):

$$T < 5;\ \ 110 < H < 150;\ \ 20 < S < 60 , \quad (6)$$

$$T < 5;\ \ 130 < H < 170;\ \ 30 < S < 130 . \quad (7)$$

The base color q_b is determined using the database according to the selected object type specified in the system setting unit. The database stores pre-assembled color instances that are specified in decimal RGB color representation $c_b = (R_b, G_b, B_b)$. As a system tuning parameter, a tolerance Δ is set up, within which the color distance r between the current color and the base one q_b is later compared. The color distance r is defined as the geometric distance between red, green, and blue color components, corrected by coefficients,

$$r_i = \sqrt{k_1\left(R_b - R_i\right)^2 + k_2\left(G_b - G_i\right)^2 + k_3\left(B_b - B_i\right)^2} , \quad (8)$$

where R_b, G_b, B_b are respectively red, green and blue components of the base color q_b ; R_i, G_i, B_i are red, green and blue of the current color q_i , respectively; k_1, k_2, k_3 are components of the K vector of correction coefficients.

The vector K of correction coefficients is introduced due to the different display by optical components of color components in the RGB palette. To calculate the color intensity, as well as to compare colors, we will use a vector of values [10]:

$$K = \begin{bmatrix} 0.299 \\ 0.587 \\ 0.114 \end{bmatrix} . \quad (9)$$

Information about object is concentrated not only in the color representation, but also in its boundaries. Object contour determination allows us to calculate, with some error, the volume of the object. And in our case, the weight of the animal also can be calculated.

The essence of the proposed approach for detecting biological objects in the field of view of the system is to build quadrangles $ABCD$ on the obtained image and to calculate their area S_{ABCD} .

If $S_{ABCD} \geq S'$, then a positive decision about determining the object of this class in the image is made. Here, S' is a predefined value that depends on previous system settings, such as frame size, biological object size, distance of the optical device from the biological object, and so on.

In addition, the proposed method calculates the coordinates of the center of the object relative to the beginning of the frame. With the help of simple transformations, knowing the absolute coordinates of the location of the optical device, the absolute coordinates of the object can be calculated.

Let's represent the algorithm as a sequence of steps:

1. Find the point A of a quadrangle $ABCD$ by rule: the point A lies on the boundary of feasible area and this point is the highest among all possible. That is, if $Q = \{q \mid \lim(r \leq \Delta)\}$ is the set of all boundary points for which the color distance $r \leq \Delta$, then

$$A(x_a, y_a) : A \in Q \wedge y_a = y_{min} . \quad (10)$$

2. Find the point B of quadrangle $ABCD$ by rule:

$$B(x_b, y_b) : B \in Q \wedge y_b = y_{max} , \quad (11)$$

that is, the color distance for the point B is also within the tolerance and it (the point) is the lowest of all possible.

3. Find the middle O of the segment AB :

$$O\left(x_o, y_o\right) = O\left(\frac{x_a + x_b}{2}; \frac{y_a + y_b}{2}\right) . \quad (12)$$

4. Find points C and D by rules:

$$C(x_c, y_c): C \in Q \wedge y_c = y_o \wedge x_d \leq x_o \quad (13)$$
$$D(x_d, y_d): D \in Q \wedge y_d = y_o \wedge x_d \geq x_o \quad .$$

5. Construct a quadrangle $ABCD$ and find its area using the Gaussian formula:

$$S = \frac{1}{2}\left| x_a y_d + x_d y_b + x_b y_c + x_c y_a - x_d y_a - x_b y_d - x_c y_a - x_a y_d \right| \quad (14)$$

6. A positive decision about presence of a biological object in the image should be made in accordance with its area, i.e. in the case when $S \geq S'$.

IV. Measurements and Comparisons

Building quadrangles based on color representations of objects and outlines allows us to replace an object of complex shape with its model in the form of a graphical primitive (Fig. 7). The counting of the number of objects in the image is carried out simultaneously with the construction (filling) of quadrangles.

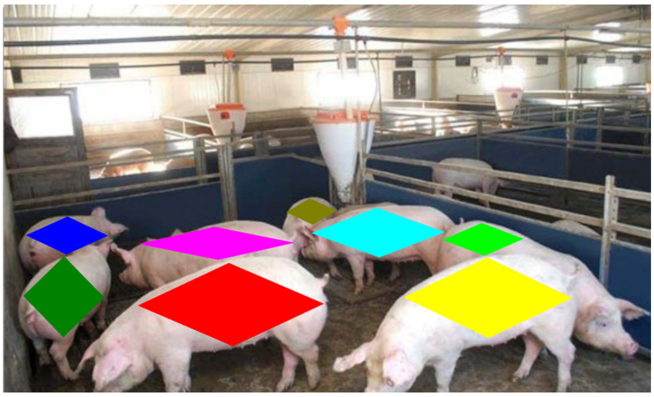

Fig. 7. Construction of primitives

The resulting primitives are used to find the center of the object. Further, the area of the quadrangle built on the image can be used to make a decision about the presence of a biological object in the image and to measure the physical parameters of it. This, in turn, makes it possible to estimate the live weight of the pig.

To estimate the weight of a pig, the following sequence of steps [16] can be used:

1. Measure body length and heart girth. Usually these data are given in centimeters. The found values should be multiplied.

2. Determine the degree of fatness of the pig (Fig. 8) [16].

Usually objects are divided into three groups and for them the fatness coefficients are taken: a fairly thin pig $k = 162$, an average fatness $k = 156$, normal and good fat content $k = 142$. The disadvantage is the rather rough rounding of the coefficient. In our case, such rounding can be eliminated by finding the ratio of the diagonals of the constructed polygon in the image. For example, for “good fatness”, the ratio of the larger diagonal of the quadrangle to the smaller one is in the range from 1.16 to 1.24. This allows us to more accurately calculate the body condition coefficient of the pig.

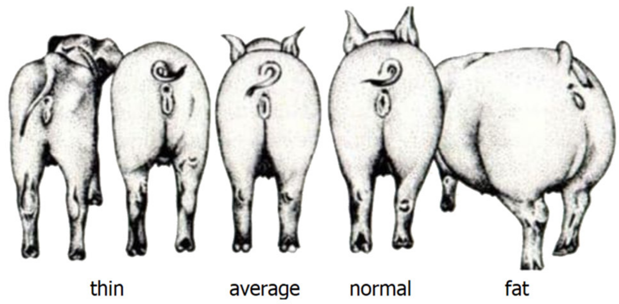

Fig. 8. Determination of pig’s fatness

3. The obtained result from step 1 should be divided by the coefficient k from step 2, thereby obtaining the weight of the pig in kilograms.

V. Conclusions

The problem of providing the country's population with high-quality and affordable food products is always acute and relevant for any country in the world and constitutes the problem of ensuring the country's food security. One of the components of food security is food independence of the state, which is ensured by developed agriculture. At present, biotechnology is an integral part of agricultural production and cannot exist without information and computer technologies. This study proposes a two-stage method for detecting and assessing the physical dimensions of biological objects in the field of vision of technical vision systems. At the first stage, a rough estimation of the location of the object is carried out using the method of edge detection (segmentation). At the second stage, based on relative coordinates (relative to the beginning of the frame), a graphic primitive is built according to the developed algorithm. The input parameters for the primitive construction algorithm are the coordinates of the biological object obtained at the first stage, as well as the color of the object. The application of the described two-step approach allows to reduce false positives (detecting an object where it is not present) and false negative (not detecting an object in a place where it is). In addition, this approach makes it possible to assess the body condition of the animal. This, in turn, is a component of the non-contact determination of the animal's weight, which is planned to be implemented in further studies.

References

[1] Food and Agriculture Organiztion of the Inited Nations, “Sustainable agricultural development for food security and nutrition: what roles for livestock?” , FAO, 2016, 140p.

[2] J. Brooks, C. Delpeuch, A. Matthews, and G. Solano,“Global Food Security: Challenges for the Food and Agriculture System”. OECD, 2013, 10.1787/9789264195363-en.

[3] S.V. Skolozdra, B.P. Tchaikovsky, and O.S. Lecik, “Calculation, selection and control of ultraviolet radiation of animals and poultry”, Scientific Bulletin of Lviv National University of Veterinary Medicine and Biotechnology. Gžický, 2010 (12, № 3 (4)), pp. 60-65.

[4] T. Strizhak, A. Belykov, A. Korobov, and A. Strizhak, “The use of low-intensive laser radiation as a modern biotechnological method of pigs reproductive quality increasing”, Scientific and Technical Bulletin of the Institute of Animal Science of the National Academy of Agrarian Science of Ukraine, 2018, vol. 119, pp. 142-149

[5] Y. LeCun, Y. Bengio, and G.Hilton, “Deep learning”, Nature, 521, 436-444, 2015. doi: 10.1038/nature14539

[6] S. Albawi, T. A. Mohammed and S. Al-Zawi, "Understanding of a convolutional neural network," 2017 International Conference on Engineering and Technology (ICET), 2017, pp. 1-6, doi: 10.1109/ICEngTechnol.2017.8308186.

[7] C. Wang, and Y. Xi, “Convolutional neural network for image classification”, Johns Hopkins University Baltimore, MD, 1997. T. 21218.

[8] A. S. Kutsenko, Y. Y. Megel, S. V. Kovalenko, S. M. Kovalenko, Z. Omiotek, and U. Zhunissova "An approach to quality evaluation of embryos based on their geometrical parameters", Proc. SPIE 11176, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2019, 111762G (6 November 2019). doi: 10.1117/12.2536420

[9] Y. Megel, I. Kalimanova, A. Rybalka, S. Kovalenko, and S. Kovalenko, “Automation of measurement of objects geometrical parameters”, Proceedings of International Scientific Symposium "Metrology and Metrology Assurance", 2017, pp. 225-259.

[10] L.B. Kashcheev, and S.V. Kovalenko, “Graphic editor Inkscape. Construction of fractals and filters ”, Kharkiv: NTU “KhPI”, Ltd “Planeta-Print ”, 2019, 173 p.

[11] W. Rong, Z. Li, W. Zhang and L. Sun, "An improved Canny edge detection algorithm," 2014 IEEE International Conference on Mechatronics and Automation, 2014, pp. 577-582, doi: 10.1109/ICMA.2014.6885761.

[12] W. Gao, X. Zhang, L.Yang and H. Liu, "An improved Sobel edge detection", 2010 3rd International Conference on Computer Science and Information Technology, 2010, pp. 67-71, doi: 10.1109/ICCSIT.2010.5563693.

[13] W. Burger, and M. J. Burge, “ Digital image processing: an algorithmic introduction using Java”, Springer, 2016, 811p.

[14] S. van der Walt, J. L. Schönberger, J. Nunez-Iglesias, F. Boulogne, J.D. Warner, N. Yager, E. Gouillart, T. Yu, and the scikit-image contributors. 2014. “scikit-image: image processing in Python”, PeerJ 2, :e453, 2014, doi:10.7717/peerj.453

[15] L. Eastwood, and J. Smith. "Determining the Size of Finisher Pigs, Replacement Gilts and Sows", Ontario Ministry of Agriculture, Food and Rural Affairs, 2020, 7p.