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USE OF NEURON IMAGE ANALYSIS TO BUILD CLASSIFICATION MODEL OF CORPORA LUTEA OF DOMESTIC CATTLE

Summary

The paper presents the results of studies on the usefulness of the texture images USG (ultrasonography) analysis by GLCM (Gray Level Co-Occurrence Matrix) in neural modeling. Tests pertained to the efficacy of the classification of the corpora lutea located in ultrasound images of the domestic cattle ovaries performed by artificial neural networks. The tests were performed using three different methods: the first one used unprocessed images - raw, the second method used image processing - unsharp mask. In the third method the raw images were processed by filter reducing the noise - despeckle filter. For each of the presented methods, the best generated neural network model had the structure of the MLP (Multi Layers Perceptron). The best results, in terms of artificial neural network were obtained in the case of ultrasound images that were not processed prior to texture analysis. As a result, it generated MLP neural model of structure 5:5-8-1:1.
Key words: *neural modeling, computer image analysis, corpus luteum, ovaries, domestic cattle*

WYKORZYSTANIE NEURONOWEJ ANALIZY OBRAZU W BUDOWIE MODELU KLASYFIKACYJNEGO CIAŁEK ŻÓŁTYCH U BYDŁA DOMOWEGO

Streszczenie

W pracy zaprezentowano wyniki przeprowadzonych badań nad przydatnością analizy tekstury obrazów USG (UltraSonoGraphy) metodą GLCM (Gray Level Co-Occurrence Matrix) w modelowaniu neuronowym. Sprawdzano skuteczność klasyfikacji przez sztuczne sieci neuronowe ciałek żółtych znajdujących się na obrazach USG jajników bydła domowego. Badania wykonano za pomocą trzech różnych metod: w pierwszej wykorzystano obrazy nieprzetworzone – surowe, w drugiej posłużono się metodą przetwarzania obrazu – filtrem wyostrzającym. Natomiast w trzecim sposobie obrazy surowe zostały przetworzone filtrem redukującym zaszumienia. Dla każdej z zaprezentowanych metod, najlepszy wygenerowany model sieci neuronowej miał strukturę MLP (Multi Layer Perceptron). Najlepsze wyniki, pod względem jakości sztucznej sieci neuronowej uzyskano w przypadku obrazów USG, które nie były przetwarzane przed analizą tekstur. W efekcie wygenerowano model neuronowy MLP o strukturze 5:5-8-1:1.
Słowa kluczowe: *modelowanie neuronowe, komputerowa analiza obrazu, ciałko żółte, jajniki, bydło domowe*

1. Introduction

Ultrasound is one of the most widely used techniques in medical imaging. It is usually used to examine muscles, tendons and internal organs. This method has gained its popularity because it is relatively inexpensive, and safe, and because it provides images in so-called 'Real-time'. Also, what is important from the point of view of medicine, there is no need to open the body to observe irregularities and do the diagnosis [3]. Diagnosis based on ultrasound imaging is a common method for the study of the physiology of both human and animals ovaries [2, 6]. This technique permits development assessment of a single follicle without touching a structure. Before ultrasound was introduced an ovary fragment was cut out and on the basis of its slice analysis, condition of this gland was evaluated. Conventional histological tests provide information only about the current state of the organ and do not allow the assessment of the functioning of the ovary and the formations in the period of estrus cycle [7]. Currently, ultrasound imaging allows a non-invasive visualization of all ovarian functional creations including corpora lutea (*CL - Corpus luteum*) [4].

The corpus luteum is a transient endocrine gland (Fig. 1), which is formed after ovulation from follicular secretory cells. The main function of the *CL* is the production of progesterone, which regulates the reproductive function. For cattle and other domestic livestock species, ovulation is normally confirmed a few days after its occurrence, by detecting the corpus luteum (Fig. 1b) during ultrasound examination [16]. *CL* is a gland whose identification and diagnosis may cause some difficulties. This is due to the fact that it is a very individual gland, which means that it can take different shapes: oval, round, oblong, and it can have different locations: you can find it on the surface of the ovary or in the flesh [11].

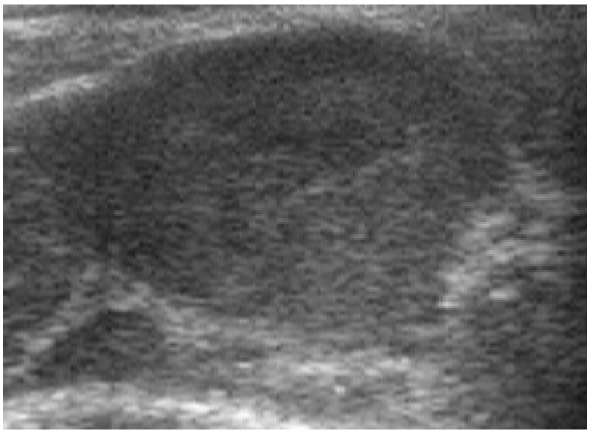
Digital ultrasound images are two-dimensional arrays of individual elements (pixels), whose values are in the range of gray levels. Each pixel can be described by a value of 0 (black) to 255 (white) and a discrete representation of the tissue. The image of the ovary with functional creations located on it, acquired during the ultrasound, is called echostructure [13]. Ultrasound, despite the fact that it has many advantages like: low costs of research or device mobility also has its drawbacks, which include: large image graininess and noisiness. The noise is characteristic for ultrasound images and is caused by the presence of structures smaller than the wavelength of the device in the analyzed tissue.

In addition, the effect of noise is enhanced by a different acoustic impedance due to the close location of the structures.

In addition, obtaining high-quality images requires the presence of a skilled operator of ultrasound device [12].

a)

b)



Source: own work / Źródło: opracowanie własne

Fig. 1. The corpus luteum in the middle - luteal phase - a), *CL* image captured during ultrasound examination - b)
Rys. 1. Ciałko żółte w środkowej fazie lutealnej - a), obraz CL uzyskany w czasie badania USG - b)

Computer image analysis and neural modeling is a tool commonly used to solve problems in agricultural engineering [1, 14, 15]. It helps, for example with identification and classification of selected orchard and cereal pests of, which allows to precisely select the appropriate insecticides. In addition, it is possible to a forecast nitrogen loss from fields fertilized with slurry, which is without a doubt the environmental aspect because it allows selection of the appropriate time, dose and method of nitrogen spreading [9]. In ecological farms breeding should be conducted using natural methods. But it is allowed to use artificial insemination of female cattle. Control and diagnosis phases of development of corpora lutea through ultrasound imaging allows a precise determination of the time of conception. Based on ultrasound of the ovaries of bovine animals and determining the condition of the *CL* also confirmed the occurrence of pregnancy after fertilization. Therefore, in cases where pregnancy is not established you can fertilize the cow at the next estrus [8].

The aim was to build a classification model *CL* specifying the location of the corpus luteum: on the surface or in the parenchyma of the ovary domestic cattle. To achieve this goal methods of computer image processing and analysis, as well as methods of neural modeling were used.

2. Material and research methods

Research material consisted of ultrasound images of domestic cattle ovaries gained during the study period from January 2013 to April 2016. The cattle came from three experimental farms belonging to the University of Life Sciences in Poznan. Ultrasound examination was conducted by a qualified device operator - veterinarian. During the tests mobile device Dramiński Ultrasound Scanner model iScan (Fig .2) was used, working with a frequency of 7.5 MHz. Animal examination was carried out using a linear rectal probe.

a)

b)

Source: own work / Źródło: opracowanie własne

Fig. 2. Ultrasound Scanner Dramiński model iScan - a), image of domestic cattle ovary acquired using this device - b)
Rys. 2. Aparat do ultrasonografii Scanner Ultrasound Dramiński, model iScan - a), obraz uzyskany tym urządzeniem - b)

Methods of computer image processing and analysis used during the study were: sharpen filter, filter removing the speckle-noise and GLCM texture analysis method. 216 ultrasound images of domestic cattle ovaries were analyzed in total. Analyses were conducted in threefold independent ways. The first approach included a *GLCM* texture analysis method performed on the raw images, ie. those which were not processed by any of the above filters. Texture analysis method *GLCM* is a way to determine texture parameters, which are second-order statistical variables. In the second approach, the images were treated by a sharpening filter - unsharp mask (radius = 1, mask = 0.60) in order to increase the visibility of *CL* on the surface of the ovaries (Fig. 3).

a)

b)

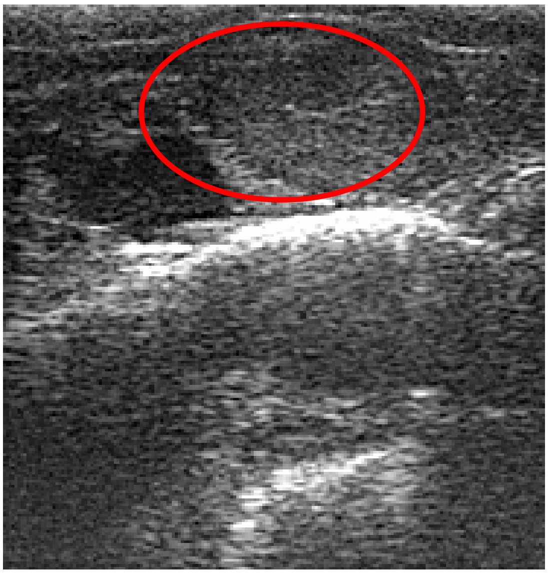


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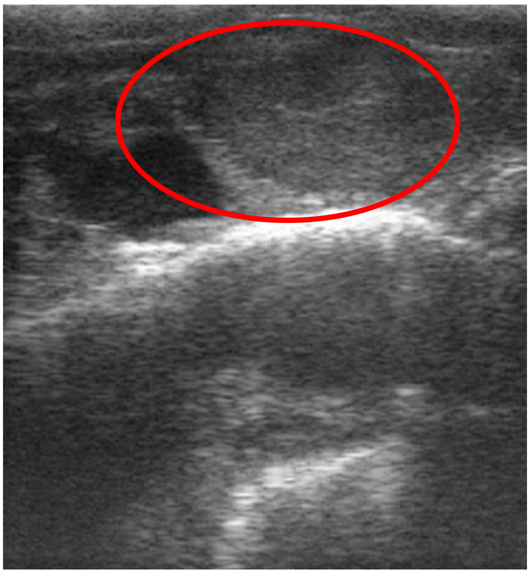
Fig. 3. Ultrasonographic image of ovarian domestic cattle. *CL* marked a red ellipse: unprocessed image - a), the sharp filter processed image - b)

Rys. 3. Obraz USG bydła domowego. CL zaznaczono czerwoną elipsą: zdjęcie nieprzetworzone - a), przetworzone filtrem wyostrzającym - b)

In the third approach, each of the images were processed by a filter that reduces the noise – despeckle mask, which is a variation of the median filter (Fig. 4). Processing and analysis of images was conducted using ImageJ - an Open Source software generated for the analysis of biomedical multidimensional images [5].

Using this application the images were converted into a form acceptable for the simulation of artificial neural networks - a training set was prepared (Table 1). During the research three learning files were generated, for each of the presented approaches. These learning files were a base to study the usefulness of artificial neural networks for the classification of *CL* in terms of its location: on the surface of the ovary and in the interior. In addition, it tested and compared the effects of selected filters on the results obtained during neural modeling.

a)



b)

Source: own work / Źródło: opracowanie własne

Fig. 4. Ultrasonographic image of domestic cattle ovaries. CL marked with a red ellipse: unprocessed image - a), the sharp filter processed image - b)

Rys. 4. Obrazy ultrasonograficzne jajników bydła domowego. CL zaznaczone czerwoną elipsą: zdjęcie bez działania żadnego filtra - a), obraz przetworzony filtrem wyostrzającym - b)

Each learning file included statistical variables that describe the texture: Angular Second Moment - *AMS*, homogeneity - *IDM* (Inverse Difference Moment), similarity (correlation), difference (contrast), entropy.

It also specifies two-state output variables *S* or *M*, where as *M* is a position of a *CL* in the parenchyma, and *S* is a position on the surface of the ovary. Each of the learning files consists of 216 cases, divided in standard ratio of 2: 1: 1, respectively, for the training file, validation and test. Neural analysis was performed in the STATISTICA environment using Neural Networks module. Moreover, an *'Automatic Network Designer'* tool was used. A series of simulations in order to produce an optimal neural network model for each of the three approaches is presented in the study.

Table 1. Fragment of training file used to generate neural model, the output column marked with blue colour
Tab. 1. Fragment zbioru uczącego wykorzystanego do wytworzenia modelu neuronowego, zmienna wyjściowa zaznaczona niebieskim kolorem

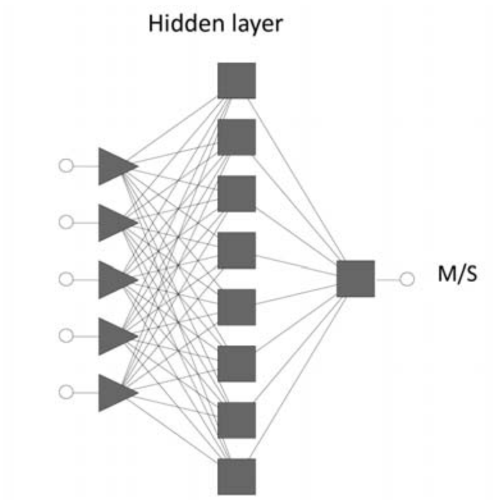
ASM	IDM	Correlation	Contrast	Entropy	*M/S*
1.049E2	0,5425	4.516E1	2.248E7	7.587E-1	*S*
8.604E1	0,5331	4.209E1	1.843E7	5.897E-1	*S*
8.231E1	0,5632	3.878E1	1.763E7	1.152E0	*S*
9.901E1	0,5703	6.218E1	2.121E7	8.035E-1	*M*

Source: own work / Źródło: opracowanie własne

3. Results and conclusions

Using the method presented above three independent learning files were generated, and subjected to a series of simulation. The output variable was of binary *M / S* informing about *CL* position.

The best neural model generated for the raw image subjected to texture analysis using only *GLCM*, characterized by the structure of the *MLP* 5:5-8-1:1 (Fig. 5). The learning process of the neural network technique was carried out with 'teacher', using the back-propagation algorithm - *BP* (*Back Propagation*). The results obtained with the training set concerning its quality and error *RMS (Root Mean Square)* are shown in Table 2. The Quality is understood as the ratio of correctly classified cases to all cases. Presented neural model has 5 input neurons, 8 neurons in the hidden layer and one neuron in the output of the artificial neural network.



Source: own work / Źródło: opracowanie własne

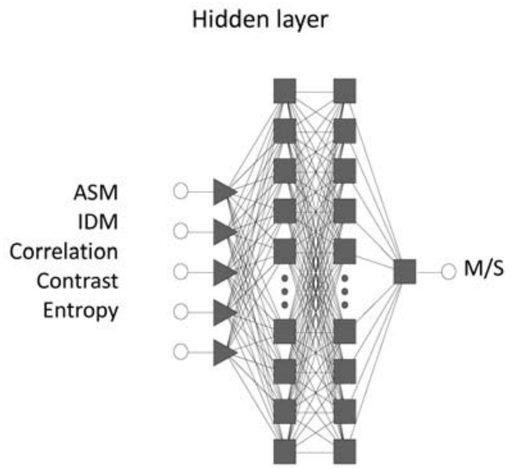
Fig. 5. MLP Artificial Neural Network with structure 5:5-8-1:1. Best model generated for raw images
Rys. 5. Model neuronowy MLP o strukturze 5:5-8-1:1. Najlepsza sieć wygenerowana dla zbioru obrazów nieprzetworzonych - surowych

Table 2. The results of quality and *RMS* error of individual files – raw images
Tabela 2. Wyniki jakości oraz *RMS* dla poszczególnych zbiorów – obrazy nieprzetworzone

Quality of:		*RMS* error of:
learning file	0. 745614	0. 3983616
validation file	0. 7719298	0. 4276413
test file	0. 4736842	0. 577738

Source: own work / Źródło: opracowanie własne

Second approach presented in this paper is a use of the image processing filter - unsharp mask. The best model generated has the structure of MLP 5: 5-28-31-1: 1 (Fig. 6). The learning process of the neural network technique was carried out with 'teacher' using the Delta-Bar-Delta - DD algorithm. The results obtained with the training set concerning its quality and RMS error are shown in Table 3. The present neural model has 5 input neurons, 28 neurons in the first hidden layer, 31 neurons in the second hidden layer, and one neuron in the output.



Source: own work / Źródło: opracowanie własne

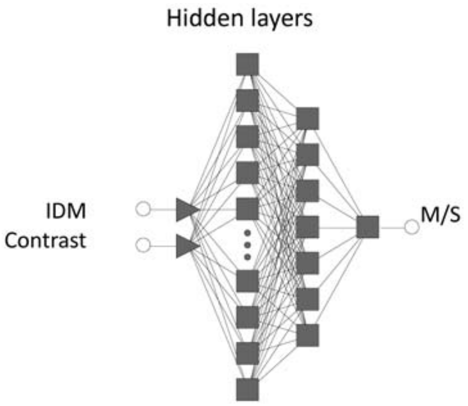
Fig. 6. MLP Artificial Neural Network with structure 5:5-28-31-1:1. Best model generated for images treated with sharpening filter – unsharp mask
Rys. 6. Model neuronowy MLP o strukturze 5:5-28-31-1:1. Najlepsza sieć wygenerowana dla zbioru obrazów przetworzonych filtrem wyostrzającym

Table 3. The results of quality and *RMS* error of individual files –images processed by unsharp mask
Tab.3. Wyniki jakości oraz RMS dla poszczególnych zbiorów – obrazy traktowane filtrem wyostrzającym

	Quality of:	*RMS* error of:
learning file	0.6694915	0.5080106
validation file	0.7796610	0.4549553
test file	0.4915254	0.6738777

Source: own work / Źródło: opracowanie własne

The last approach, which was used in the *GLCM* texture analysis of images previously processed by filter reducing noise - despeckle mask. Best neural model generated for images processed by this mask has the structure of *MLP* 2:2-13-7-1:1 (Fig. 7). The learning process of the neural network technique was carried out with 'teacher' and in addition *BP* algorithm was used. The results obtained in the case of the training file, concerning its quality and error *RMS* are shown in Table 4. It is worth mentioning that in the case of this approach the network in the best generated model used only two input variables: the contrast and *IDM*. This model therefore has two neural neurons in the input, 13 neurons in the first hidden layer 7 through the second and one neuron in the output.



Source: own work / Źródło: opracowanie własne

Fig. 7. *MLP* Artificial Neural Network with structure of 2:2-13-7-1:1. Best model generated for images treated with despeckle filter
Rys. 7. Model neuronowy MLP o strukturze 2:2-13-7-1:1. Najlepsza sieć wygenerowana dla zbioru obrazów przetworzonych filtrem usuwającym zaszumenia

Table 4. The results of quality and *RMS* error of individual files –images processed by despeckle filter
Tab. 4. Wyniki jakości oraz RMS dla poszczególnych zbiorów – obrazy traktowane filtrem usuwającym zaszumienia

Quality of:		*RMS* error of:
learning file	0.6052632	0.4714598
validation file	0.6491228	0.4717694
test file	0.5263158	0.5429605

Source: own work / Źródło: opracowanie własne

Best neural model was generated from images that have not been processed in any way. It can therefore be concluded that raw images are the most appropriate for the *GLCM* texture analysis method, more than those that were previously processed by unsharp mask or despeckle-noise filter.

All the best neural models for different approaches generated by auto designer are of *MLP* structure. The results suggest that neural networks are a useful tool for the classification of ultrasound images of the ovaries of domestic cattle. *CL* is a gland whose identification during a conventional examination makes a lot of difficulties, that is why neural modeling can help during the tests on the location of the corpus luteum. Current knowledge indicates that similar studies have not yet been carried out. The presented results are an introduction to the further use of artificial neural networks in the analysis of ultrasound images of the ovaries of domestic cattle. The use of neural modeling in ultrasonography may allow for limiting the use of hormonal preparations in cattle, which is a promising step towards ecology farming.

4. References

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