Building a model for recognition of morphostructure pathologies in animal tissues

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Abstract. Microscopic images of histological analysis have a complex flat structure. The result of the analysis and interpretation of the diagnosis strongly depends on the qualification of the veterinarian; therefore, the development of methods and models for automated histological diagnosis of diseases is an urgent task. The article considers the known approaches for building expert systems of histological diagnostics. Expert systems of histological analysis can be used in clinical veterinary medicine for advanced training of veterinary pathologists. The possibility of using the theory of finite automata for construction of the device - histological analyzer is shown. As an example of histological analysis the task of recognition of images of morphofunctional changes in rodent tissues on the example of the soft brain of a rat damaged by chlamydia infection is considered. Pathological indicators of morphostructural changes in tissues in case of chlamydia infection have been revealed and explained: erythrocyte slide with clot formation, nuclei hyperchrome, tissue edema, hemorrhage and desquamation of endotheliocytes. For image recognition it is suggested to use computer neural network technologies based on multilayer perceptron. The number of synoptic scales for perceptron design has been calculated. Examples are given and construction of training sets on the basis of which the table of truth for neural network training constructed is shown. Computer experiments have shown the possibility of using neural network technologies for recognition of pathology indicators during histological analysis of morphostructural changes in animal tissues.

1. Introduction

The work is devoted to automating the recognition of histological analysis images, widely used in veterinary medicine, to detect pathologies at the cellular level. Pattern recognition requires preliminary processing of the examined tissue, obtaining samples and their analysis. Histological diagnostics is a complex of labor-intensive operations, including analysis of clinical data, analysis of micro- and macro-preparation, and setting up histological analysis. Development of an automated workplace of a histologist veterinarian will help to solve the problem of rapid diagnosis of the disease and take timely measures for treatment [1].
2. Equipment and devices used in studies
Theoretical studies in the field of pathology recognition have been performed using approaches of
general systems theory, system analysis and intelligent mathematical models. The following equipment
was used for laboratory histological studies: technical and analytical scales, pH-meter, microtomes
(sledge, rotary, freezing), cryostat, water bath, table for melting wax slices, set of automatic pipettes,
thermostat, refrigerator and microscope.

3. The results of the study and their discussion
3.1. General scheme for finding pathology indicators
To automate the process of determining the diagnosis of the disease it is necessary to classify the
histological analysis images. The task is to define the resulting image, represented by a set of features,
to one or more predefined classes. Currently, for these purposes, wavelet transformation, which converts
analogue image into digital frequency domain [2,3], micro and macro diagnostics of histological
analysis, realized in diagnostic complex "Atlant" [4,5], computer neural network technologies, end
machines [6] and others are widely used.

Let us consider the task of recognizing images of morphofunctional changes in rodent tissues on the
example of the soft brain of a rat damaged by chlamydia infection (figure 1).

![Figure 1. Pathology of the pia mater of a rat damaged by chlamydia infection. x 400.](image)

Let us introduce a set of indicators \(Y(y_1, y_2, \ldots, y_n)\) diagnosing the disease \(D(d_1, d_2, \ldots, d_m)\). A
simplified set of indicators specific to the pathology of the rat pia mater damaged by chlamydia infection
is presented as an array described in table 1.

| Indicator | Name                                      | Image | Indicator Properties |
|-----------|-------------------------------------------|-------|----------------------|
| \(y_1\)  | Sludge of erythrocytes with formation of blood clots | ![Image](image) | Colour Structure of the tumour |

Table 1. Pathology indicators.
Hyperchrome of the nuclei

Intensified color Structure of the tumor

Tissue edema

Color Structure of the tumor

Hemorrhage

Color Blurriness of the tumor

Endotheliocytodesquamation

Color Edge velvety of the tumor

Functional connection of $Y$ indicators and preliminary diagnoses $D$ can be connected with the table of truth with the construction of logical functions and relay-contact circuits, as, for example, was described in the construction of the histological analyzer in the work [6]. The task of pattern recognition of pathological changes in tissues finds its application in oncology [7], histology [8] and other fields of medicine and veterinary medicine.

To detect indicators and the possibility of machine search it is necessary to form a topological map, for example, in the form of a mesh area. An important element in solving the problem is to determine the mesh topology. To form the mesh topology, we will take orthonormalized vectors, through which the input signals retina will be formed. Optimization of the retina size is also important for finding the required indicators. The general algorithm of setting and solving the task of recognizing indicators of pathological changes and making a diagnosis can be presented in the following diagram (figure 2).

![Figure 2](image-url)

**Figure 2.** Scheme of solving the problem of recognition of pathology indicators and formation of diagnosis.

### 3.2 Neural network construction and training

The use of neural network technologies can be offered for pathology indicators recognition. We will use the technique of drawing a neural network based on perceptron. We will determine the required number of synoptic weights $A$ using the formula for elements with sigmoid nonlinearity:

$$
\frac{Y_N P_M}{1 + \log_2 P_M} \leq A \leq Y_N \left( \frac{P_M}{X_K} + 1 \right) \left( X_K + Y_N + 1 \right) + Y_N,
$$
where $Y_N$ – output signal dimension (number of indicators),
$P_M$ – the dimensionality of the training sample,
$X_K$ – the size of the input signal (number of retinal parameters).
Let's consider Figure 3 as a training set to search for pathology indicators.

Input signal in case of $5 \times 5$ field will be a vector of 25 elements. Thus, the first layer of the retina will consist of 25 elements - neurons. The last $Y_N$ layer will consist of five elements – pathology indicators. We'll take a training $P_M$ set of 50 samples.

Then the number of synoptic weights $A$ must satisfy the condition:
\[
\frac{5 \cdot 50}{1 + \log_2 50} \leq A \leq 5 \left( \frac{50}{25} + 1 \right) (25 + 5 + 1) + 5,
\]
\[
37.65 \leq A \leq 469.
\]

Let's take the number of neuro-like elements in the hidden layer equal to two, then the number of synoptic links between the first and the second layers will be: $25 \cdot 2 = 50$,
and the number of links between the second and the third layers will be equal: $2 \cdot 5 = 10$.
The total number of synoptic links will be $A=60$, which satisfies the calculated condition. The constructed structure of a neural network with calculated synoptic links on the perceptron is shown in figure 4.

Table 2 shows a fragment of a training sample compiled in accordance with figure 3. The addresses of the cells are compiled in a row, by passing from left to right and from the top to the bottom.
Table 2. Training set truth table.

| Set | Input signal, $X_K$ | Output signal, $Y_N$ |
|-----|---------------------|---------------------|
|     | $y_1$   | $y_2$   | $y_3$   | $y_4$   | $y_5$   |
| a   | 00011 00001 01000 10000 00000 | 1 | 0 | 0 | 0 | 0 |
|     | 01000 00000 01000 00000 00001 | 0 | 1 | 0 | 0 | 0 |
|     | 00010 01000 01000 01000 10000 | 0 | 0 | 1 | 0 | 0 |
|     | 00000 00001 00111 00000 11100 | 0 | 0 | 0 | 1 | 0 |
|     | 01000 00000 00000 00000 00110 | 0 | 0 | 0 | 0 | 1 |
|     | 11000 00010 00000 00000 00010 | 1 | 0 | 0 | 0 | 0 |
| b   | 00010 00000 00000 00000 01011 | 0 | 1 | 0 | 0 | 0 |
|     | 00010 0001 00000 01111 00000 | 0 | 0 | 1 | 0 | 0 |
|     | 01000 00000 11000 00000 00000 | 0 | 0 | 0 | 1 | 0 |
|     | 00000 00000 00000 00000 01110 | 0 | 0 | 0 | 0 | 1 |
|     | 00011 00011 00010 10000 00000 | 1 | 0 | 0 | 0 | 0 |
| c   | 00011 00000 10001 01001 00001 | 0 | 1 | 0 | 0 | 0 |
|     | 11000 00000 00110 00010 00110 | 0 | 0 | 1 | 0 | 0 |
|     | 00010 00100 00000 00000 00000 | 0 | 0 | 0 | 1 | 0 |
|     | 00011 00110 10000 10000 00001 | 0 | 0 | 0 | 0 | 1 |
|     | 00000 00010 01101 10001 00000 | 1 | 0 | 0 | 0 | 0 |
| d   | 00000 11100 00011 00000 00000 | 0 | 1 | 0 | 0 | 0 |
|     | 11110 00000 00000 00000 00000 | 0 | 0 | 1 | 0 | 0 |
|     | 11000 00000 00100 00000 00011 | 0 | 0 | 0 | 1 | 0 |
|     | 00000 00000 01110 01100 00100 | 0 | 0 | 0 | 0 | 1 |

Once the network has been trained, it can be used to recognize the pathology indicator. For a running network, it is possible to calculate the correlation coefficient and the mean square error of diagnosis recognition. As a result of the search the most probable indicator of the investigated pathology sample is determined by the coefficient of reliability of the obtained result.

3.3. Pathology recognition

Identification of pathology images was carried out on the developed computer program that implements the construction and training of the perceptron. Let us consider the recognition of indicator $y_1$ (Sludge of erythrocytes with the formation of blood clots). To simplify the solution of the problem we will take a white background, and the indicators will be marked by dark areas. An example of a training set according to table 2 is shown in figure 5.

![Figure 5. Perceptron training on $y_1$ indicator recognition](Sludge of red blood cells with clot formation).

The image shown in figure 6 has been created to check the program operation. The result of the image recognition was recognized as set $a$. 


Figure 6. The result of image recognition of the pathology.

The conducted experiments showed the possibility of using neural networks for recognition of pathology indicators in histological analysis.

4. Conclusion
The use of a neural network for the development of a module for automated recognition of indicators of morphological and structural changes in animal tissues is proposed. The module of automated recognition of pathology indicators is supposed to be introduced into the designed histological analyzer of disease diagnosis. For image recognition it is proposed to use neural networks on perceptron. The conducted experiments have shown the possibility of using neural network technologies for recognition of pathologies in histological analysis of morphological changes in animal tissues.

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