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# A neural network algorithm for automation of cytological diagnostics of a thyroid gland follicular tumors

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**Abstract.** A neural network algorithm is proposed for automation of cytological diagnostics of follicular tumors of a thyroid gland by images of an intraoperative material. Experimental results show the algorithm efficiency for constructing a medical expert system.

**1. Introduction.** The problem of the use of new computer technologies for the refinement of diagnostics and treatment of diseases gains in importance in modern medicine. Of great interest for practical public health services are the systems for differential diagnostics of diseases.

The artificial neural networks [1], representing nonlinear systems concern such technologies, which allow one to classify data much better, than with conventional linear methods, thus considerably raising the efficiency of a method of diagnostics, not reducing its sensitivity. The neural networks are able to make decision, which are based on hidden regularities detected in multi-dimensional data and are capable of learning on examples, generalizing the former experience and applying it to the new diagnostic cases.

As a rule, the cytological diagnostics defines the choice of a conservative or a surgical method for medical treatment of thyroid gland diseases. Follicular tumors of the thyroid gland make the greatest difficulties for differential diagnostics because of the absence of explicit symptoms permitting one to

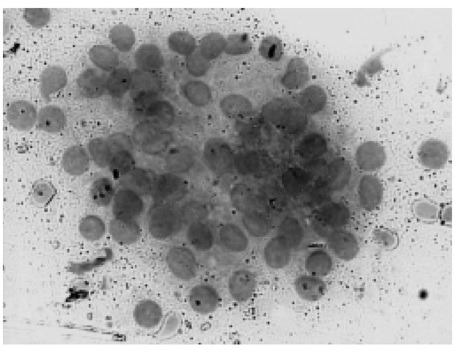

**Figure 1.** Follicular adenoma

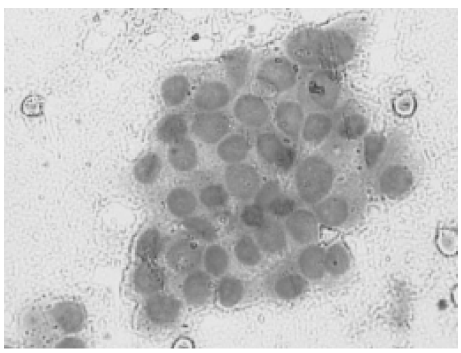

**Figure 2.** Follicular carcinoma

distinguish the follicular adenoma from the high-differentiated follicular carcinoma [2] (Figures 1 and 2).

**2. Statement of the problem.** Usually, the medical diagnostics uses the neural networks with a binary vector of input data [2, 3]. Every vector component defines availability or absence of some classification feature. To generate the feature vector on the basis of image analysis of an intraoperative cytological material of the thyroid gland, it is necessary to consult with a highly qualified specialist. Another way is the creation of intellectual program systems which are capable of realizing automatic diagnostics of new patients by images of the thyroid gland cytological material on the basis of images set already classified by specialists. The solution of this problem is the objective of this paper.

**3. Evaluation of image essential features.** One of the most important issues of image recognition is distinguishing essential features which permit one to increase separability of classes and to effectively recognize images. In this paper, we use the following effective approach [4].

Let $X$ be an image of the $i$-th class, $i = 1, \ldots, c$, $A_i$ denote a mean value of the $i$-th class, and $A$ denote the total mean value. The between-class scatter matrix $G_b$ and the within-class scatter matrix $G_w$ are the following:

$$G_b = \sum_{i=1}^{c} (A_i - A)(A_i - A)^T, \qquad G_w = \sum_{i=1}^{c} E[(X - A_i)(X - A_i)^T],$$

where $E(x)$ is expectation of $x$. As separability, we use the value $J = \frac{\mathrm{tr}(G_b)}{\mathrm{tr}(G_w)}$.

For increasing the separability of the image classes, we select appropriate Fourier frequency bands with maximum value of $J$ (in [4], the frequency bands with $J > 1$ are selected). By this technique we transform all images of the training set $X$ (i.e., the images with a known classification). For the set $Y$ of transformed images, we evaluate the matrix $G_w^{-1} G_b$, its eigenvectors $\phi_i$, $i = 1, \ldots, M$, and for each vector $\phi_i$ evaluate the Fisher discrimination vector $F(\phi_i) = \frac{\phi_i^T G_b \phi_i}{\phi_i^T G_w \phi_i}$.

Then we select the eigenvectors $\phi_i$ with a maximum value $F(\phi_i)$ (in [4], the eigenvectors with $F(\phi_i) > 1$ are selected), obtain the discrimination matrix $W$ composed of the selected $\phi_i$, and transform all images from $Y$ by the expression $Z = YW$.

The same transforms $X \to Y \to Z$ are realized for tested images.

**4. The recognition system architecture.** For partitioning a set of tested images into two classes, "follicular adenoma" (FA) and "follicular carcinoma" (FC), we use a two-layered neural network. A number of neurons in the first layer is equal to the number of images in the training set.

Every first-layer neuron corresponds to one ("own") image of the set and computes the Euclidian distance $D(Z, Z_t)$ between the own image $Z$ and the tested image $Z_t$. Then $k$ "winners" are detected in the first layer by a minimum distance to the image under testing. Output of the $i$-th winner, $i = 1, \dots, k$, is equal to $e_i = 1/D(Z_i, Z_t)$ if $Z_i$ belongs to the class "follicular adenoma", or $e_i = -1/D(Z_i, Z_t)$ if $Z_i$ belongs to the class "follicular carcinoma". Outputs of other first-layer neurons are equal to zero.

The second-layer neuron calculates the sum $S = \sum_{i=1}^{k} e_i$ of the first-layer outputs and compares the sum with the thresholds $T > 0$ and $-T$. For $S > T$, the system detects FA, for $F < -T$, the system detects FC; and for $-T \leq S \leq T$ the system does not make any classification.

**5. Experiments.** In the experiments conducted, the images are compressed to $256 \times 256$ size (the range of Fourier frequencies is $1 \div 128$). For both classes (FA and FC), 30 training images are used (three images for each of ten patients with a stated histological diagnosis). For this training set, the dependence of separability on frequency is presented in Figure 3.

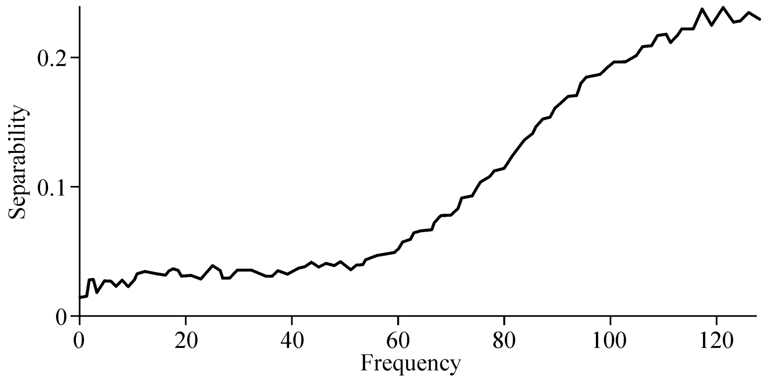


**Figure 3.** Separability as a function of frequency

From Figure 3 it follows that for low-frequency bands, the separability is essentially lower than for high-frequency bands. Therefore the low-frequency bands are excluded from the image spectrum. In the experiments in question, we distinguish a band with frequencies from 96 up to 128 showing the best recognition results (see the table).

In the experiments, the set under testing included data about 45 patients with FA and 39 patients with FC (with a stated histological diagnosis). For constructing the matrix $W$, three eigenvectors are used, the number of winners being $k = 5$. The value $N^+$ is equal to the number of patterns classified as FA, $N^-$ is the number of patterns classified as FC, $N^0$ being the number of non-classified patterns. The recognition confidence is evaluated as ratio of the number of correctly recognized images to the total number of images classified as images of the type $N^+$ or $N^-$. For example, for FC with

| Parameter | $T = 0$ | | $T = 10$ | | $T = 20$ | |
|---|---|---|---|---|---|---|
| | FA | FC | FA | FC | FA | FC |
| $N^+$ | 37 | 16 | 36 | 15 | 33 | 14 |
| $N^0$ | 0 | 0 | 3 | 5 | 7 | 8 |
| $N^-$ | 8 | 23 | 6 | 19 | 5 | 17 |
| Confidence | 0.70 | 0.74 | 0.71 | 0.76 | 0.70 | 0.77 |
| Recognized portion | 0.82 | 0.59 | 0.80 | 0.49 | 0.73 | 0.44 |

the threshold $T = 0$, we have the recognition confidence $23/(23+8) = 0.74$. From the table we see that setting the threshold $T > 0$ allows one to increase the recognition confidence (because of decreasing the number of correctly recognized images).

**6. Conclusion.** Follicular tumors of the thyroid gland make great difficulties for differential diagnostics because of the absence of explicit symptoms permitting one to distinguish the follicular adenoma from the high-differentiated follicular carcinoma. To generate the feature vector on the basis of the image analysis of an intraoperative cytological material of the thyroid gland it is necessary to consult with a highly qualified specialist. Another way is the creation of intellectual program systems which are capable of realizing automatic diagnostics of new patients by images of a cytological material of the thyroid gland on the basis of another set already classified by specialists. The neural network algorithm is suggested for the cytological diagnostics automation of follicular tumors of the thyroid gland by images of an intraoperative material. For distinguishing essential image of features, we selected the Fourier high-frequency bands with a maximum separability. The results of the experiments show the algorithm efficiency for constructing medical expert system.

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