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INTELLIGENT SYSTEM OF DIAGNOSTICS OF THYROID GLAND PATHOLOGY

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Abstract*—It is considered a principle of thyroid pathology diagnostics intelligent system structure. It is determined basic ultrasound images features for patients with thyroid cancers. The block diagram of intellectual diagnostics is proposed. It includes two basic subsystems: making decision support and image processing. As a classifier it is used fuzzy neural networks (NEFCLASS) due to its synergy capabilities: rule-based representation and generalization possibilities. As a activation function of rule neuron (to calculate of activation of rules on the basis of membership functions) the T-norm is used. It is used convolution neural networks for ultrasound images processing.*

Index Terms—Thyroid pathology diagnostics intelligent system; fuzzy neural networks; convolution neural networks.

I. INTRODUCTION

Thyroid nodules are common in adults and may be detected by palpation in 10% of women and 2% of men. The prevalence may be as high as 50% or more if sensitive imaging such as ultrasonography is used. The vast majority of thyroid nodules are benign and do not require urgent referral. Furthermore, thyroid cancer is uncommon in patients who are not euthyroid, and assessment of biochemical thyroid status is useful in deciding on the referral pathway by the general practitioner (GP).

Diagnosis of malignant tumors is performed on the basis of the following types of research: doctor's consultation, X-ray methods, ultrasound and computed tomography, endoscopic method, magnetic resonance imaging, radioisotope diagnosis, radioimmunoscintigraphy, thermography.

II. PROBLEM STATEMENT

Currently, for the diagnosis of thyroid and liver disease, physicians conduct a survey on a specific scheme, which consists of a mandatory diagnostic minimum (MDM) and a set of additional surveys.

Signs that determine the type of thyroid gland pathology by ultrasound diagnostic are shown in Fig. 1.

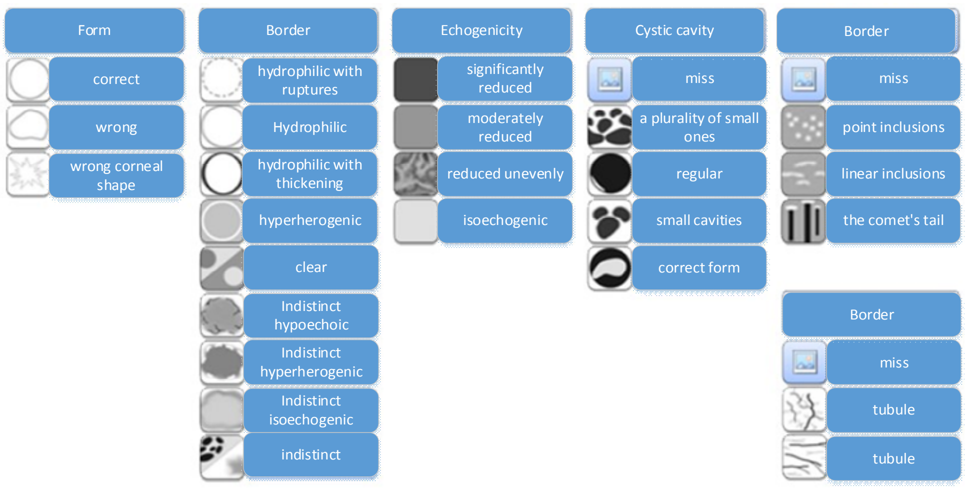

Fig. 1. Signs that determine the type of thyroid gland pathology

The values of the factors, which are determined by the results of ultrasound and used as inputs of neural network (NN) intelligent diagnostic system, are: type of ridge of tumors, structure of tumors, echogenicity of tumors, size of tumors.

Additional factors used as NN`s inputs are: general blood test, cancer-embryonic antigen (CEA), thyroid hormone level, thyrocalcitonin level, TTG level, T4 level, T3 level, cervical lymphadenopathy, solid consistency of the site, crampiness and stinging of the voice, history of neck and head irradiation, age, gender.

The general structure of the diagnostic system is shown in Fig. 2 by results of ultrasound diagnostic.

III. Problem Solution

Methods of MDM surveys differ varying degrees of importance. For their analysis, the degree of significance is proposed to be evaluated using the rank factor of importance (FI), obtained expertly. Under RN is the line number in the ranked (sorted) list of methods in order of decreasing their importance. For the main methods of MDM values of FI are presented in Table I.

On the basis of FI, and according to the relative number of received diagnostic parameters n_1 and their quantity N, we can determine the index of diagnostic significance for these research methods using the following expression:

$$\text{IDS}_s = \frac{\text{FI}_{\max} - \text{FI}_i + 1}{\text{FI}_{\max}} \cdot \frac{n_i}{N} 100\%, \quad (1)$$

where i is the number of the diagnostic minimum method; $i \in \overline{1, M}$; FI_i is the rank of importance of the ith method; $\text{FI}_{\max}$ is the maximum rank of importance; n_i is the number of diagnostic parameters, which are obtained with I method; M are total number of diagnostic minimum methods; N are total number of parameters obtained in the diagnostic minimum parametr: $N = \sum_{i=1}^{M} n_i$.

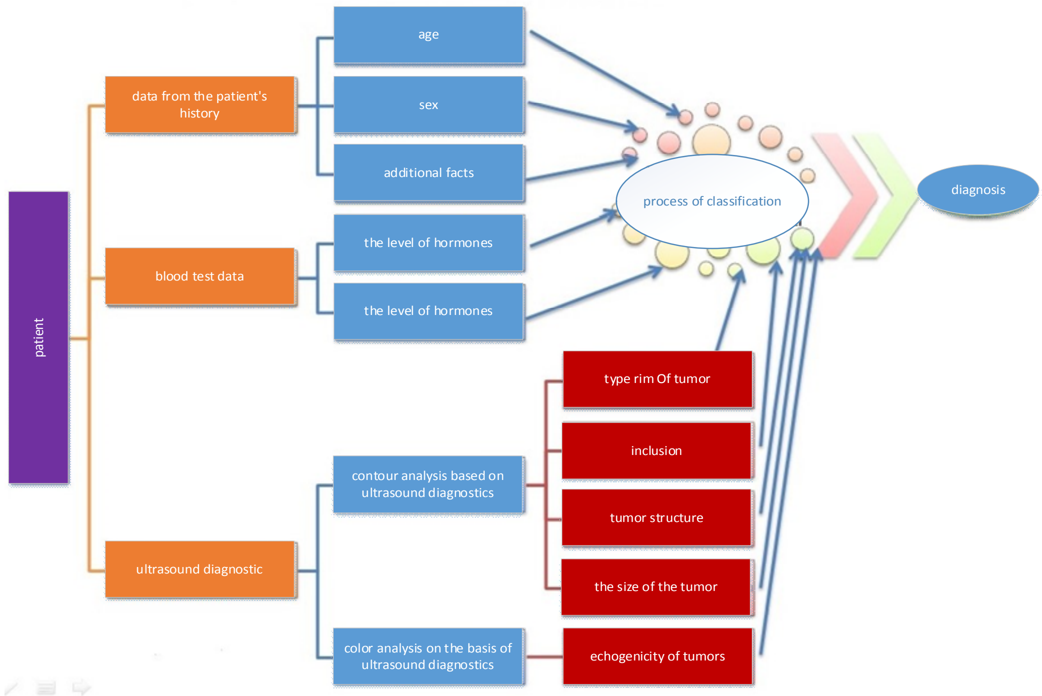

Fig. 2. General structure of the diagnostic system

Table I Methods of Examination from the Diagnostic Minimum

Number (i)	The name of the method	Description	RN	IDS
1	Poll and review	Recording of the main parameters of the body, complaints, description of the visible parts of organs and systems (belliness and auspiciousness of the voice)	2	13%
2	Palpation	Thickening of the thyroid gland to determine lymphadenopathy	4	3,4
3	General blood test	Definition of ESR (erythrocyte sedimentation rate), hemoglobin content, blood cells	3	9
4	Biochemical blood test	Determination of the content of a number of chemicals	3	9
5	Oncomarkers	Determination of Cancer-Embryonic Antigen (CEA)	2	11
6	Blood test for hormones	Determination of the level of TSH, T4, T3, tireocalcitonin	1	14
7	Ultrasound diagnostic	Thyroid gland studies	1	18
8	ECG	Detection of a violation of the cardiovascular system (CVS)	4	1,7

An ideal diagnostic test based on the expression (1) will have IDS = 100%, if FI = 1, and $n=N$, which corresponds to the lack of results of surveys by other methods (M = 1). Indeed, such an IDS can not be reached. In this case, the larger total number of IDS of the aggregate types of surveys, the more accurate diagnosis which are based on it. The values of IDS and RN for the basic methods of diagnostic minimum are shown in Table I.

All inspections should be devided in three groups:

1) strong significance (types 6 and 7, for which IDS ≥ 14%);

2) middle significance (types 1, 3, 4 and 5, for which 9% < IDS ≤ 13%);

3) weak significance (types 2 and 8 for which IDS < 3,5%).

In this case, we can conclude that the need for surveys of the 3rd group is only possible in case of the impossibility of conducting surveys of the 1st and 2nd groups.

In modern medicine, the effectiveness of the work of the staff and the provision of medical care to the depends on the medical appointments and recommendations of the doctor, who makes the decision. Therefore, in order to ensure the quality of medical services, special attention is paid to the problem of rational statement of the clinical diagnosis of the disease.

This problem is complicated by the lack of experience in doctors, the rapid development of medicine and the lack of time resources for advanced training and staff experience, resulting in the use of duplicative research and the waste of expensive and unnecessary treatment.

At present, systems of information providing of health care are actively developing. One of the promising directions of the modern stage of health informatization is the development of computerized decision-making support systems for doctors. Increasing the methods and technologies of the diagnosis of diseases put forward the requirements for the creation of DMSSFD, which increases the efficiency of medical services to practitioners when taking medical and diagnostic decisions. The process of making these decisions when diagnosing a disease in modern conditions is impossible without the involvement of expert systems. Using of such an information support system to assist doctors in the diagnosis process with the use of new knowledge and technologies helps to increase the effectiveness of treatment, reduce the number of medical errors and optimize the cost of treatment, which will ultimately lead to a reduction in morbidity and mortality. Main technologies for providing DMSSFD:

– production models;
– semantic networks;
– decision trees.

The structural scheme of the intelligent diagnostic system is presented in Fig. 3.

Information from the patient enters the system through the interface and includes data according to the Table I. Digital video images are fed into filtration units and eliminated geometric distortions to eliminate the effects of noise. After this, the video enters the block of allocation of an abnormal area, which is realized on the basis of the convolutional neural network. Evaluation of the signs that determine the type of thyroid gland pathology by ultrasound scan is performed in the anomalous area evaluation block.

Then comparison of the parameters of the signs obtained from the analysis of images, with the normal state of the body, which is studied and with pathological changes, located in the database. It stores the survey data and typical, pre-formed with the help of a block of statistical processing, signs of diseases. This unit interacts with the decision support unit and the creation of medical documents. On the basis of data obtained from the block of information on a set of pathogenetic factors (SPF), the block of multivariate analysis allows us to make a regression equation for them. Next, with the help of decisive rules from the same block, the recommended solution is formed.

Block of decision-making and creation of medical documents forms and displays on the monitor special data in a physically convenient form, as well as assesses their informational reliability and gives recommendations to the doctor for the diagnosis, taking into account the factors influencing the disease.

III. Algorithms for Determining Diagnostic-Significant Signs of Disease on the Basis of Ultrasound Image Processing

General statement of the problem of pattern recognition to detect unformalized elements.

Formulation of the classification problem. X is the set of object descriptions, Y is a set of class names. There is an unknown target addiction – reflection $y^*: X \rightarrow Y$, the meaning of which is known only in the objects of the final training sample:

$$X^m = \{(x_1, y_1),\dots,(x_m, y_m)\},$$

where X^m set of elements of the training sample by dimension m.

It is necessary to construct an algorithm capable of determining the affiliation of an arbitrary object $x \in X$ to class $y \in Y$.

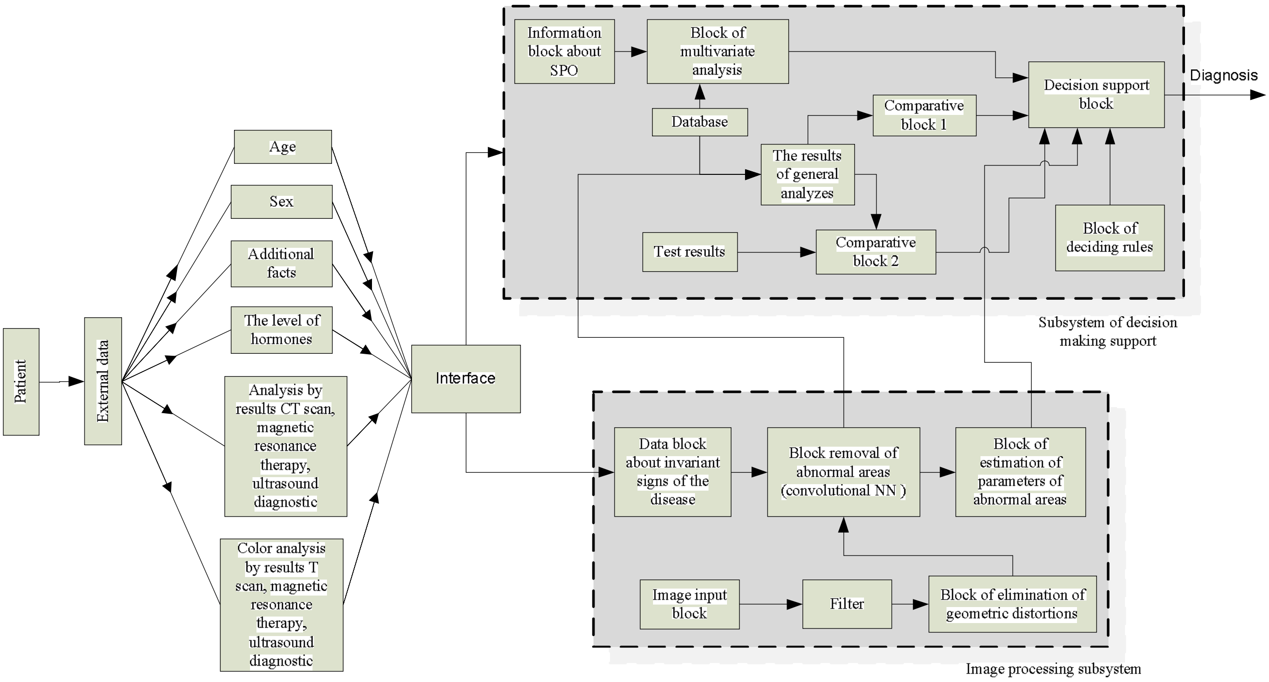

Fig. 3. The block diagram of intellectual diagnostics

Video image processing in DMSSFD. Convolutional Neural Network (CNN) – This is a special architecture of an artificial neural network that imitates features of the visual area of the cerebral cortex.

1) In contrast to the multi-layer perceptron, CNN has the following distinctive features: Local full connectivity: in accordance with the concept of receptive fields, CNN use spatial localization by applying a scheme of local coherence between neurons of adjacent layers. Thus, this architecture provides an opportunity for educated "filters" to produce the strongest response to the spatially-localized input image. The structure of many such layers is equivalent to using a nonlinear filter and is sensitive to a larger area of the pixel space. Thus, the network initially creates a representation of small details of the input, and then it collects the representation of larger areas.

2) Joint scales: in CNN each filter is repeated throughout the visual field. These repetitive nodes use a common parameterization (vector of weights and thresholds) and form a map of signs. This means that all neurons in a given convective layer respond to the same sign within its receptive field. The repetition of the nodes thus allows the signs to be detected, regardless of their position in the visual field, providing the property of the invariance with respect to the displacement.

Together, these properties allow CNN to achieve a better generalization of image recognition tasks. Sharing scales dramatically reduces the number of free parameters through which the network learns, reducing memory requirements for network operation and enabling training of larger, more powerful networks.

A composite network consisting of a convolutional neural network, a classifier and a deconvolutional neural network is shown in Fig. 4. Such architecture allows not only to recognize the elements of the image, but also to determine their location on the image. The deconvolutional neural network is a mirror image of a convolutional neural network.

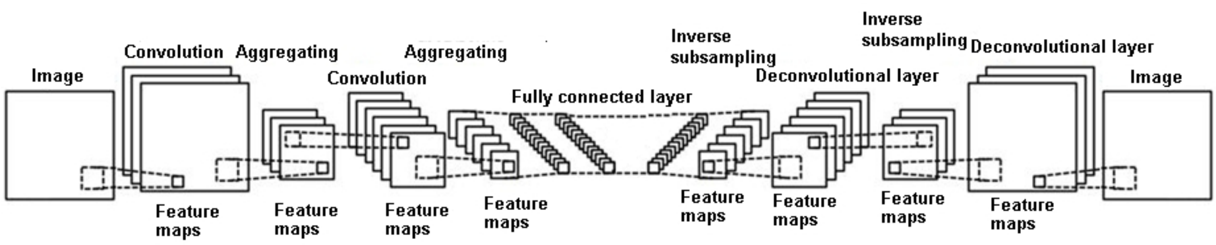

Fig. 4. Combined convolutional neural network

The results of the patient's ultrasound diagnosis are shown in Fig. 5. After image processing, it is received three contours. One of them managed to classify.

The neoplasm is hypoechoic since the middle tone is in the appropriate place on the echogenicity scale. Echostructure is heterogeneous. There are hyperechoic calcifications.

On the basis of the corresponding template, a conclusion was made about the "wrong" form of neoplasm.

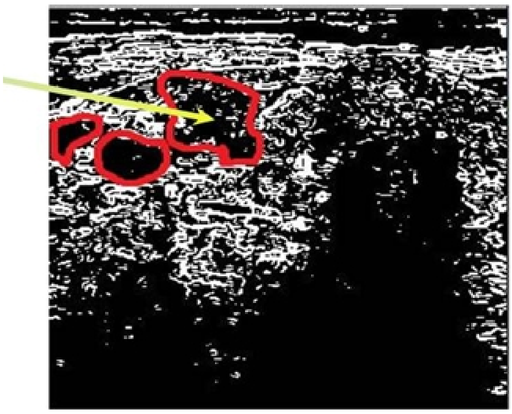

Fig. 5. Contours of the patient ultrasound examinations results

IV. CONCLUSIONS

It is proposed a new approach for the thyroid pathology diagnostics intelligent system creation. The intelligent system is based on fuzzy neural networks. It is executed the testing of this system.

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О. І. Чумаченко, А. Т. Кот, О. О. Войтюк. Інтелектуальна система діагностики патології щитовидної залози
Розглянуто принцип побудови інтелектуальної системи діагностики патологій щитовидної залози. Визначено основні особливості ультразвукових зображень для пацієнтів з раком щитовидної залози. Запропоновано структурну схему інтелектуальної діагностики, яка включає дві основні підсистеми: підтримки прийняття рішень і обробки зображень. В якості класифікатора використовується нечітка нейронна мережа (NEFCLLASS) через її синергетичні можливості: представлення результату на основі правил і можливості узагальнення. Як функції

активації нейрона (для розрахунку активації правил на основі функцій приналежності) використовується Т-норма. Для обробки ультразвукових зображень використовується згорткова нейронна мережа.
Ключові слова: інтелектуальна система діагностики патології щитовидної залози; нечіткі нейронні мережі; згорткові нейронні мережі.

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Е. И. Чумаченко, А. Т. Кот, О. О. Войтюк. Интеллектуальная система диагностики патологии щитовидной железы

Рассмотрен принцип построения интеллектуальной системы диагностики патологий щитовидной железы. Определены основные особенности ультразвуковых изображений для пациентов с раком щитовидной железы. Предложена структурная схема интеллектуальной диагностики, которая включает две основные подсистемы: поддержки принятия решений и обработки изображений. В качестве классификатора используется нечеткая нейронная сеть (NEFCLLASS) из-за её синергетических возможностей: представление результата на основе правил и возможности обобщения. В качестве функции активации нейрона (для расчета активации правил на основе функций принадлежности) используется Т-норма. Для обработки ультразвуковых изображений используется сверточная нейронная сеть.
Ключевые слова: интеллектуальная система диагностики патологии щитовидной железы; нечеткие нейронные сети; сверточные нейронные сети.

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