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SPIE.

Event: Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2017, 2017, Wilga, Poland

Neural expert decision support system for stroke diagnosis

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ABSTRACT

In the work the hybrid expert system for stroke diagnosis was presented. The base of expert system consists of neural network and production rules. This program can quickly and accurately set to the patient preliminary and final diagnoses, get examination and treatment plans, print data of patient, analyze statistics data and perform parameterized search for patients.

Keywords: expert system, neural network, production rule, stoke, medical diagnosis

1. INTRODUCTION

Cerebrovascular diseases is one of the most important and complex problems of modern clinical medicine, because of their large prevalence, high disability and mortality[1-3]. A special place is occupied by brain strokes which annually hit 10mln. people and kill about 6-7 mln. people. Stroke is one of the main reasons of premature mortality, ranking in the list of the World Health Organization the second place after coronary heart disease and ahead of cancer diseases[3]. There is a clear age correlation of stroke incidence – after 55 years stroke risk increases significantly, and for every ten years it doubles. Although nowadays there is a tendency to a decreasing in the age of patients who suffered a stroke[4, 5]. Much of the surviving patients become disabled[6]. The most common of all cerebrovascular diseases is ischemic stroke, its share is about 80% of all strokes. Due to ischemic stroke about 10-12% of patients die, 20% of patients require permanent third-party supervision and only 20-25% of people who have suffered an ischemic stroke, may return to work[7]. At the same time 31% of stroke survivors require assistance for personal care, and 20% cannot walk alone[5]. Only on the medical care of patients with acute ischemic stroke in developed countries is spent annually from 4 to 6% of the funds allocated to health[4, 5]. Long-term results of ischemic stroke treatment are directly dependent on the adequacy of the organizational and preventive measures[8, 9].

The incidence of stroke in the world is 200 cases per 100 thousand of population. For the USA, stroke is the third cause of death rate, for the European countries - the second. Among patients older than 25 years, the incidence and mortality are increased approximately 2-3 times with each next decade. In some countries a year after suffering a stroke kills up to 50% of patients, among 80% of surviving patients remain heavily disabled and require assistance[4, 5].

Ukraine is among the countries where the rate of stroke incidence is higher than the average in Europe. Every year from 100 to 120 thousand country inhabitants are suffering from stroke for the first time. Thus, according to official statistics of Ministry of Healthcare in Ukraine in 2015 more than 111 thousand people had a stroke and more than 40 thousand of them died. Incidence rate of stroke in 2015 was more than 300 per 100 thousand of population, and stroke mortality – 86,6 per 100 thousand population. More than a third of all brain strokes occurred in people of working age[10]. Stroke is a major cause of disability in the population. This disease is a burden to the family of the patient, and significantly reduces

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Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments 2017, edited by Ryszard S. Romaniuk, Maciej Linczuk, Proc. of SPIE Vol. 10445, 104453I
 · doi: 10.1117/12.2280956

the quality of life and able-bodied potential of others. Only 10% of patients return to work, 20% require assistance, 30% have a memory and attention impaired[4, 5].

Hemorrhagic stroke is the most devastating type of stroke that is likely to lead to more deaths and severe disability. Ischemic to hemorrhagic stroke value in Ukraine is from 4: 1 to 3:1, while in developed countries - from 7:1 to 4:1. Death rate within first 30 days after hemorrhagic stroke is 30% to 55% [11]. The main reasons for high rates of disability and mortality due to cerebral stroke in Ukraine are patients' ignorance about stroke and consequently delayed medical care seeking, lack of quick patient delivery to a specialized stroke department, the lack of a sufficient number of specialized stroke departments, which have all-day ability to perform neuroimaging methods of disease diagnostics, lack of awareness of physicians who provide care to stroke patients with international standards its diagnostic and treatment [1, 5, 7, 11]. In order to improve early stroke diagnosis and its timely treatment the many scientists considered the possibility of using intelligent information technologies[12-17]. Basically, it is the medical expert systems, which are based on the knowledge of experts and which can accurately diagnose the disease, as well as accelerate the process due to automation. Namely the developing a system of this type formed the basis of this research.

2. THE STRUCTURE OF EXPERT SYSTEM

To solve the problems of diagnosis, including medical, in expert systems (ES) many technologies are used. Namely, neural networks, fuzzy logic, production rules, Bayesian networks, evolutionary algorithms, discriminate functions[18-26]. The most effective implementation technology of ES is the hybrid technology, which means integration of multiple technologies into one system. For stroke diagnosis it is proposed to use such approach, which consists in applying neural network to establish a preliminary diagnosis and production rules for establishing the final diagnosis.

It is known that preliminary diagnosing is based on the initial data, complaints of the patient, life anamnesis, results of the explore and neurological status of the patient. In terms of the clinical signs of brain insult, an extended neurological sickness diagnosing is conducted by the doctor, which allows defining its localization and its severity. Preliminary diagnosis is formed as follows[24]:

- Acute cerebrovascular accident (CVA) in left hemisphere;
- CVA in right hemisphere;
- CVA within brainstem (vertebrobasilar system - VBS));
- not CVA.

The next step is the differential diagnosis of acute cerebrovascular accident with other diseases, which are similar by symptoms. While the preliminary acute cerebrovascular accident diagnosis establishment doctor excludes diseases such as brain tumors, hypo- and hyperglycemic coma, liver failure, drug overdose, and others. Correctness of preliminary diagnosis depends on his knowledge, experience and professional skills. In a final diagnosis doctor determines the type of stroke, its location and severity. The final diagnosis are confirmed by computed tomography (CT) or magnetic resonance imaging (MRI) [7, 22]. With a view to earlier stroke diagnosing, its precise topical localization, a possibility to develop the hybrid expert system for stroke diagnosing, which is the complex using of neural networks technology and production rules, is being considered. The basis of the knowledge base of expert system was formed by the results of patients with acute cerebrovascular accident final diagnosis. As the final diagnosis were considered:

- CVA for the hemorrhagic type cerebellum, parietal and temporal lobe, thalamus and brain hemispheres;
- CVA ischemic type in the basins of the left middle cerebral artery (MCA), right MCA, right back cerebral artery, in the brain stem (vertebral-basilar pool), the right frontal lobe;
- TIA in left MCA, right MCA, brainstem (VBS);
- Lacunar infarction in left MCA, right MCA, left anterior cerebral artery (ACA), the left posterior cerebral artery, right ACA, brainstem (VBP) and its hemispheres.

The typical structure of hybrid expert system that combines neural networks and expert production system, shown in Figure 1.

Architecture of neural expert system (NES) for strokes diagnosing (Fig. 2) consists of the modules: user interface, symptoms input module, database, neural network, knowledge base, CT data input module, inspection and treatment plan issuance module, search module, statistical data processing module, printing module.

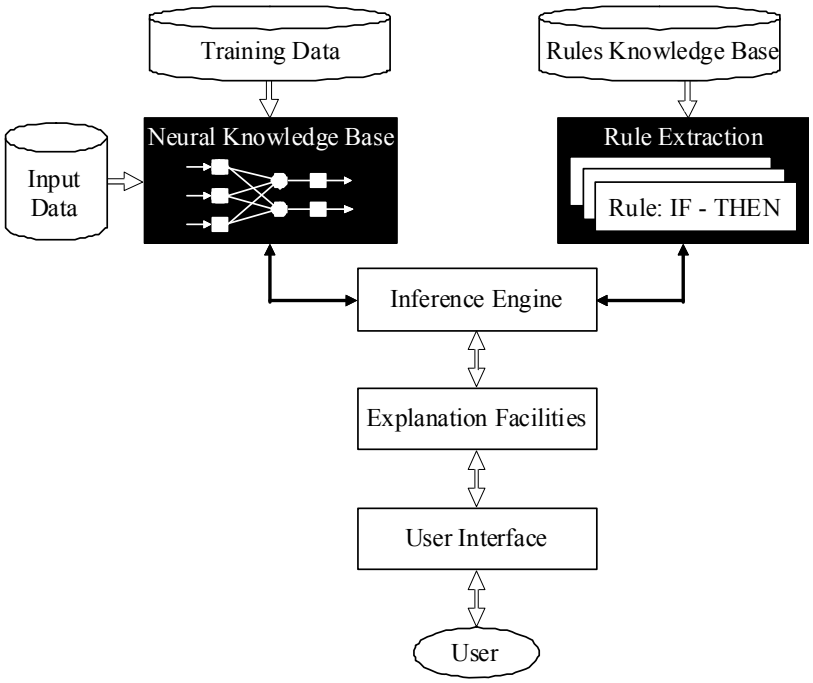

Fig. 1. Basic structure of a hybrid expert system.

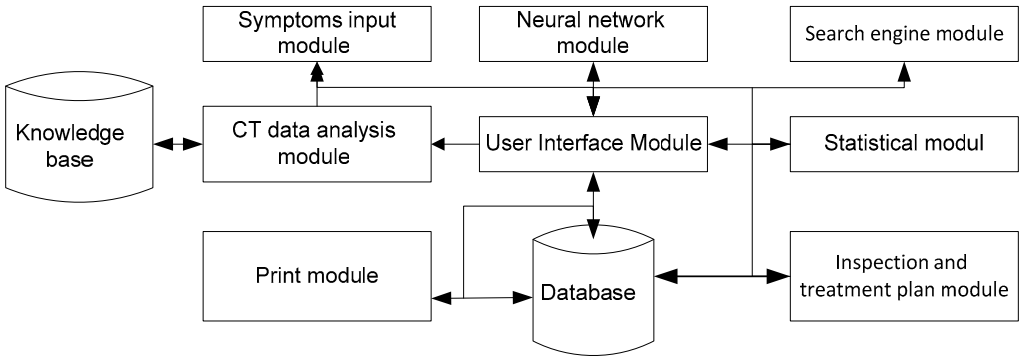

Fig. 2. Architecture of the neural expert system

The input of the expert system receives patient data, such as name, date, age, address, and complaints and symptoms of the patient. Based on expert assessments there were selected 17 most informative symptoms to establish the preliminary diagnosis:

- presence of language disorders;
- breach of movements in the extremities;
- blood pressure;
- headache;
- blurred vision;
- reduce sensitivity.
- changes in the face;
- position in bed;
- eye slits;
- tendon and periosteal reflexes of hands;

- tendon and periosteal reflexes of legs;
- stiff neck ;
- disturbances in Romberg posture;
- hemiparesis;
- hemiplegia;
- consciousness;
- unsteadiness of walking;

After determining complaints and symptoms of the patient data is entered into the database, which contains personal data of the patient. The neural network module functions on the basis of these data that establishes a preliminary diagnosis and records it to the database. After a CT scan is becomes possible to establish a final diagnosis. For this, radiological examination conclusion data introduced into the CT analysis module. Based on the production knowledge base the final diagnosis is established and inputted to the database.

Monitoring of the progress of ongoing medical appointments to the patient performed in inspection and treatment plan module. If needed there is possible to form statistical reports for further strokes analysis using statistics module and search engine module. These patient or other statistical reports can be printed using the appropriate module.

3. IMPLEMENTATION OF EXPERT SYSTEM

Next we present the results of service availability modeling in To implement the functions of the ES for a preliminary diagnosis establishing a neural network module was developed. It is based on multilayer perceptron with structure {17, 4, 4} and hyperbolic tangent neurons activation function [25]. The input layer of the neural network - 17 neurons, because of number of analyzed symptoms and complaints. In output layer - 4 neurons defined by four preliminary diagnoses: 3 CVA types and 1 - no stroke. NN learning algorithm - modified Levenberg-Marquardt back propagation algorithm. The criterion of assessing the quality of learning - standard deviation is 0.01. The simulation was conducted in the Matlab 2014 environment with Neural Network Toolbox. The environment was chosen because of its rich functionality and rapid implementation of flexible neural network algorithms[26]. 142 case histories of patient were used to construct the neural network module. Input (output) data for the learning was realized by reading (writing) from (to) xls-file. Diagnostic accuracy of the developed neural network module in the testing set is 96% in the diagnosis of CVA in the left hemisphere, 91% - CVA in the right hemisphere, 100% - CVA in the trunk, 100% - not CVA.

By using the MATLAB 2014 tools the m-function of the trained NN was obtained and then through the means of Deployment Toolbox it was compiled into the autonomous software module, which can be used as a standalone program without MATLAB software environment, but using the Matlab Compiler Runtime libraries. This neural network module is integrated into the NES, but it can be used as a standalone application. NES development was performed with C++ programming language in Borland C++ Builder environment. MS Access was used as the database creation environment. The main interface module of the system is the main window (Fig. 3). It provides the access to all NES functional modules.

As can be seen from Figure 3, the preliminary diagnosis of CVA localization is determined by the highest value that returns one of the neurons in the output layer. To establish a final diagnosis of the type of stroke the production knowledge base with 41 "if-then"-rules was implemented based on selected case histories of data. If according to results of CT white stain was found - this means that the type of stroke is hemorrhagic. If black stain with diameter greater than 1 cm was found – the stroke is ischemic, but if black stain with less 1 cm diameter was detected, this means that the patient has lacunar infarct. Otherwise, if the scan did not reveal any changes, the patient had transient ischemic attack. Some "if-then" - rules can be represented as follows:

Rule 3: IF (stain - black and bigger than 1 cm) AND (location - the left side of the frontal, parietal and temporal lobe), THEN (diagnosis = ischemic type CVA in the basin of the left middle cerebral artery).

Rule 11: IF (stain - less than 1cm and black) AND (location - leftward to the front of frontal lobe), THEN (diagnosis = lacunar infarct in pool of left anterior cerebral artery.

Rule 12: IF (stain - white) AND (location - in the right parietal lobe), THEN (diagnosis = hemorrhagic type CVA in the right parietal lobe).

The final diagnosis is established with 100% accuracy based on this knowledge base, given the radiologist's correct conclusion.

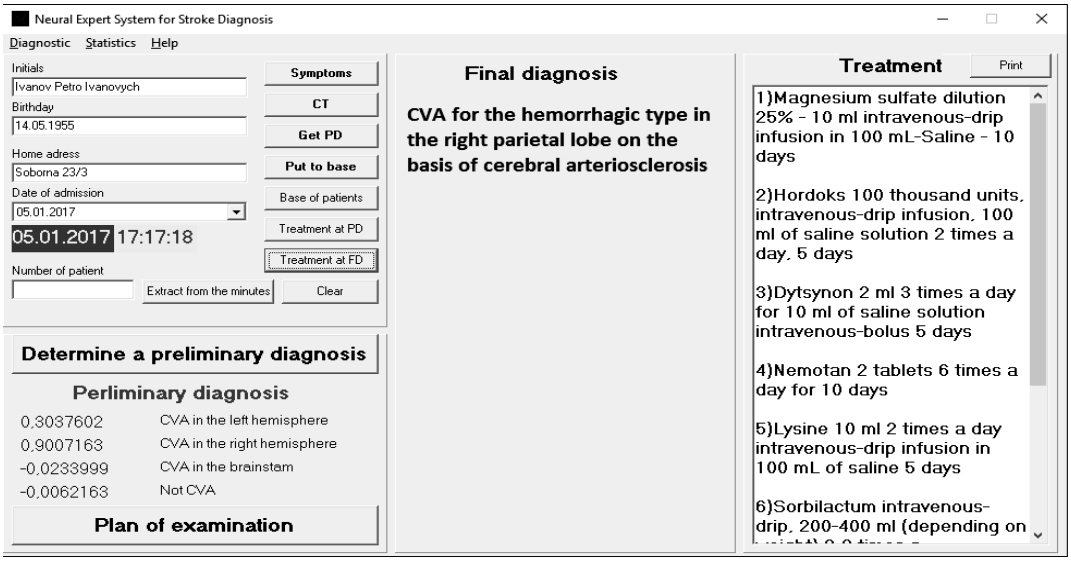

Fig. 3. Main window of NES

4. CONCLUSIONS

An approach for building a hybrid expert system for strokes diagnosing was offered, which is the complex usage of the neural networks to establish multi-parameter preliminary diagnosis of the disease for the stroke localization and production rules to establish a final diagnosis depending on stroke type. Designed expert system reduces the duration of stroke diagnosing and increase the accuracy of diagnosis. Developed neural expert system allows to register and monitor the treatment of patients in hospital and, if necessary, to adjust the treatment. Using the developed neural expert system is an effective way of intellectual support for doctor at neurological or stroke units of general hospital and it allows educating young low-skilled specialists during the daily medical activity.

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