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INVERSE PROBLEM SOLUTION WITH THE AID OF NEURAL NETWORK

ABSTRACT *The paper presents practical application of neural network to solution inverse problem in tomography. Presented are method to detect changes in shape and position of an object inside another object by using tomography. Computed tomography allows direct, non-invasive diagnosis of brain and other intracranial structures. With this method it is possible to detect anomalies.*

Keywords: *Neural Network, inverse problem, computer tomography, Boundary element method.*

1. INTRODUCTION

This paper aims to develop methods to resolve the inverse problem in two-dimensional impedance tomography-based on neural approach. For this purpose, a model was created. From this model obtained data that were used for neural network learning. The network is designed to detect changes the size of the inner area, and its location.

Detection of the size and position of one area inner another is very important. The identification of this type is used to detect cases of various types of tumors, a stroke in infants. Identifying whether a tumor or a stroke does not increase, or not move.

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PROCEEDINGS OF ELECTROTECHNICAL INSTITUTE, Issue 251, 2011

Solutions has been developed for the child's head model, with the additional area modeling stroke. Based on the model data are calculated, which were used for neural network learning.

In electrical tomography image reconstruction algorithm uses the knowledge about the distribution of current within the test object and information about the measured values of voltage between the electrodes on its surface. On this basis, the inverse problem is solved, which leads to determine the distribution of conductivity or dielectric permittivity. Nonlinearity of the inverse of impedance Tomography stems from the fact that the current flow is determined by an unknown conductivity distribution inside the test object – the current flows on the road of least electrical resistance. This problem is defined as ill-conditioned, since large changes in internal conductivity give small changes in the values of the measured voltages on the surface of the object [7].

Current trends in research on tomography are designed to improve accuracy, efficiency and time identification of internal parameters of the test facility, which amounts to solving the inverse problem in real time. For this purpose you can use neural networks, which have been successfully applied to solve real technical problems. The main advantage of the neural networks in tomography is the parallel processing of information and the fact that they allow the creation of nonlinear models, as well as control of complex multi--dimensional problem. An important feature of neural networks is the ability to deliver real-time size of the identified parameters, and thus the solution of the inverse problem on-line. Impedance computed tomography is used to detect various types of tumors, brain hemorrhage in infants. Identifying whether a tumor or a stroke does not increase, or does not move. Sample tomography with visible bleeding is shown in Figure 1.

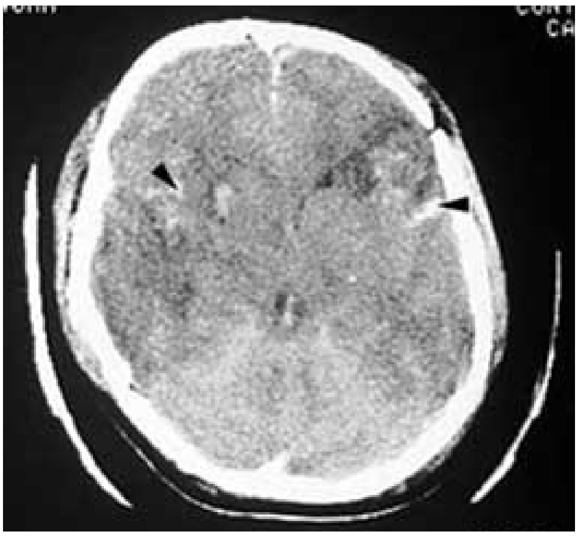

Fig. 1. CT scan of the skull with Small haemorrhages (arrowheads)

The main advantages of tomography are non-destructive, non-invasive, radiation-free examination of the object, low-cost measuring equipment and its operation, the possibility of imaging of small changes in conductivity. The article also presented a method for monitoring and parameterization of hemorrhage in the brain.

2. PROBLEM DESCRIPTION AND BEM EQUATIONS

Using the Boundary Element Method [1, 2, 4], has been calculated for the tomography example, the area in the shape of "beans" inside the circle. The inner region models the stroke, or various types of tumors. While the outer area of the infant head shapes. The entire circle was divided into 48 pieces, from which were read the third element potentials.

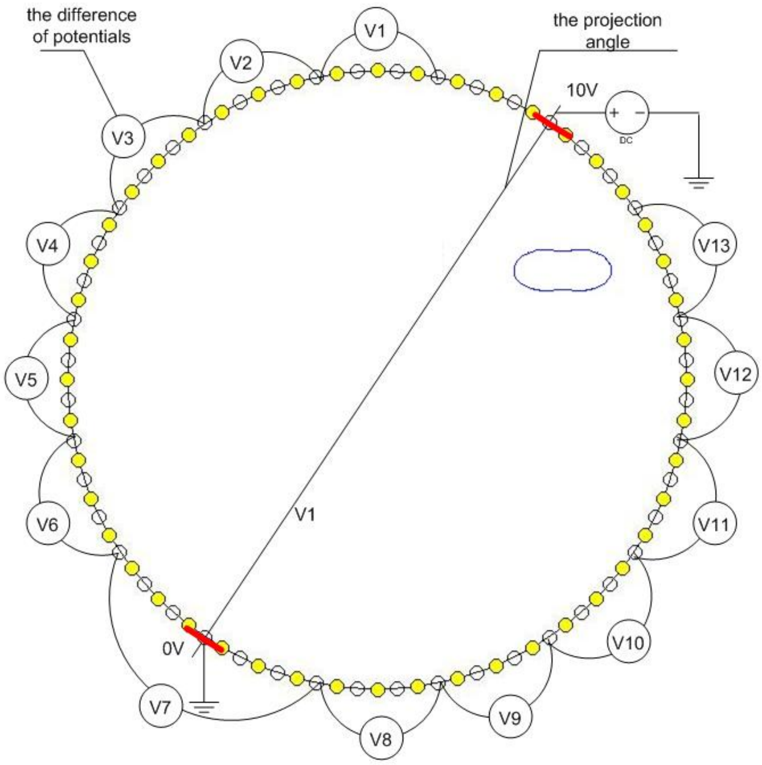

Fig. 2. The system for measuring voltages

BEM solves equations in integral form, in contrast to FEM, which solves the partial differential equations. Regardless of the type solved the differential equation, boundary integral form the equation (called *Boundary Integral Equation* – BIE) is as follows (1). Type of problem solving depends on the choice of the so-called fundamental solution. Green's function G. In the case of

BEM discretization are only the edges of areas. This greatly reduces the complexity and time needed for generate a mesh adapted to the test object. Dimension elements boundary is one less than the defined problem. This results in a significant acceleration of solving the task compared to the methods area.

$$c_i\Phi_i + \int_\Gamma \Phi \frac{\partial G}{\partial n} d\Gamma = \int_\Gamma \frac{\partial \Phi}{\partial n} G d\Gamma + \int_\Omega f G d\Omega \tag{1}$$

where:

G – Green's function;

f – the function of force / sources in the area;

c_i – a factor that removes the singularity of the equation resulting from non--continuity of the original function, ie as a result of integration;

$\partial /\partial n$ – derivative in the direction normal to the shore.

Formulate of equations for the example above we obtain equation (2):

$$c_i\Phi_{I,i} + \int_{S_1} \Phi_I \frac{\partial G_I}{\partial n_I} dS + \int_{S_{1-II}} \Phi_I \frac{\partial G_I}{\partial n_I} dS = \int_{S_I} \frac{\partial \Phi_I}{\partial n_I} G_I d\Gamma + \int_{S_{I-II}} \frac{\partial \Phi_I}{\partial n_I} G_I d\Gamma \tag{2}$$

$$\int_{S_{1-II}} \Phi_{II} \frac{\partial G_{II}}{\partial n_{II}} dS = \int_{S_{I-II}} \frac{\partial \Phi_{II}}{\partial n_{II}} G_{II} d\Gamma \tag{3}$$

where:

index I is the outer edge of the object;

index II is an internal edge of the object.

Introducing new signs

$$H_{i,j} = \int_{S_j} \frac{\partial G}{\partial n} dS \tag{4}$$

$$G_{i,j} = \int_{S_j} G dS \tag{5}$$

The Edge areas of the first and the second was divided into 48 pieces so equations 1 and 2 take the form:

$$c_i \Phi_{I,i} + \sum_{j=1}^{48} H^I_{I,ij} \Phi^I_{I,j} + \sum_{j=1}^{48} H^I_{I-II,ij} \Phi^I_{I-II,j} = \sum_{j=1}^{48} G^I_{I,ij} \frac{\partial \Phi^I_{I,j}}{\partial n_{I,j}} + \sum_{j=1}^{48} G^I_{I-II,ij} \frac{\partial \Phi^I_{I-II,j}}{\partial n_{I-II,j}} \tag{6}$$

$$\sum_{j=1}^{48} H^{II}_{I-II,ij} \Phi^{II}_{I-II,j} = \sum_{j=1}^{48} G^{II}_{I-I,ij} \frac{\partial \Phi^{II}_{I-II,j}}{\partial n_{I-II,j}} \tag{7}$$

The BEM procedure applied to the considered problem leads to the following system of equations:

$$H^I_I \Phi^I_I + H^I_{I-II} \Phi^I_{I-II} = G^I_I \frac{\partial \Phi^I_I}{\partial n_I} + G^I_{I-II} \frac{\partial \Phi^I_{I-II}}{\partial n_{I-II}} \tag{8}$$

$$H^{II}_{I-II,ij} \Phi^{II}_{I-II} = G^{II}_{I-I,ij} \frac{\partial \Phi^{II}_{I-II}}{\partial n_{I-II}} \tag{9}$$

while there:

$$\Phi^{II}_{I-II} = \Phi^I_{I-II} \tag{10}$$

$$\frac{\partial \Phi^{II}_{I-II}}{\partial n_{I-II}} = -\gamma \frac{\partial \Phi^I_{I-II}}{\partial n_{I-II}} \tag{11}$$

Writing matrix obtain:

$$\begin{bmatrix} -G^I_I & -G^I_{I-II} \\ 0 & -\gamma G^{II}_{I-II} \end{bmatrix} \begin{bmatrix} \dfrac{\partial \Phi^I_I}{\partial n_I} \\ \dfrac{\partial \Phi^I_{I-II}}{\partial n_{I-II}} \end{bmatrix} = \begin{bmatrix} -H^I_I & -H^I_{I-II} \\ 0 & -H^{II}_{I-II} \end{bmatrix} \begin{bmatrix} \Phi^I_I \\ \Phi^I_{I-II} \end{bmatrix} \tag{12}$$

Then the calculated values of the potentials on the outer edge.

We thus obtained 16 different potentials. Measurements of the potentials consisted of an examination of their values on successive elements, for different projection angles (Fig. 2). For one projection angle is obtained 13 independent voltages and angles using another projection in this example is the 8, were obtained 104 independent measurements. These are data for only one position and only one dimension of the internal element. For the network training data were prepared for different sizes of the internal element, and a variety of positions. Prepared 3 different sizes of the internal element.

3. CONSTRUCTION OF NEURAL NETWORK

Neural network [3,5] was built using the graphical tools in Matlab nntool. Choosing the network structure – the number of neurons in input layer had a relationship with a number of tensions generated by pole for one layer of electrodes (Fig. 2). Neural networks were trained to samples containing the simulation. To minimize the differences between the sizes of the network output and expected output values, the learning process was carried out for different numbers of neurons in the hidden layer. Selected network for which the results obtained were the most accurate results. Designed network is unidirectional neural network learned by backpropagation. The network consisted of three layers of neurons (input, hidden, output). The first layer had 10 neurons, 5 hidden neurons and output third.

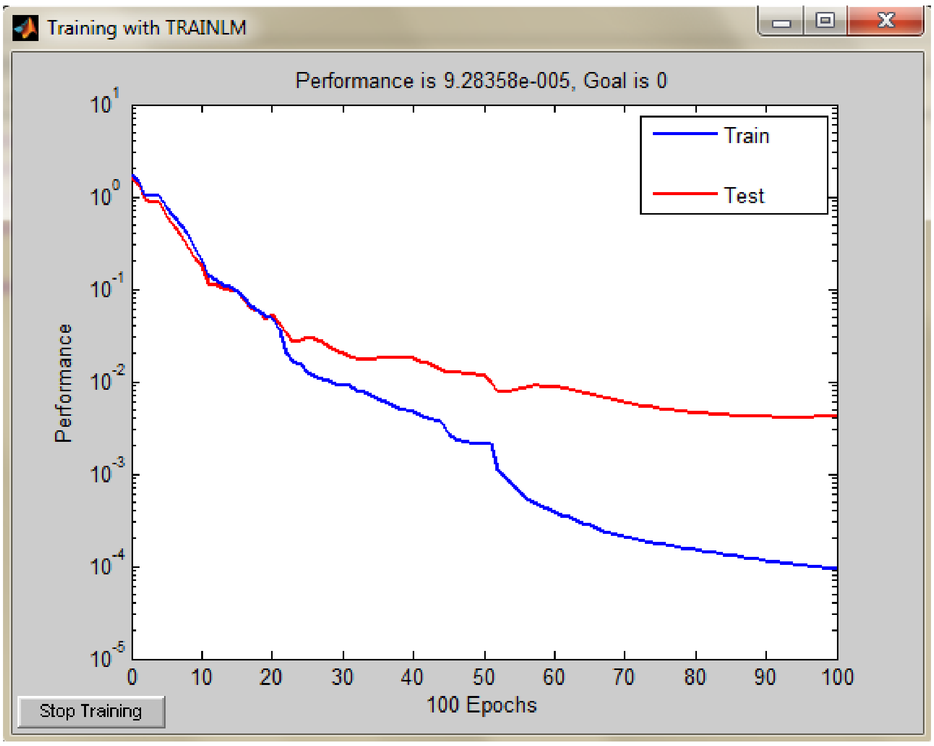

Fig. 4. Network learning process

Activation functions of neurons in each layer were respectively tansig, tansig and purelin [8]. For the network training was selected Levenberg--Marquardt method (trainlm), correction weights was carried out using a simple gradient (learngd). As an indicator of the quality of training the network mean square error was selected. Restriction placed on the number of epochs the network was equal to one hundredth Network learning process is illustrated in Figure 4. After the learning process was carried out simulation of neural networks, the results are presented in Figures 5. In this figure on the x-axis are shown the position of another sample of the internal object, while the y-axis values. Continuous line was presented normalized internal dimension of the object, are successively the values 1, 0.5, 0.75. Circles are shown the value of the distance between the centers of the objects inside the neural network response and the real object.

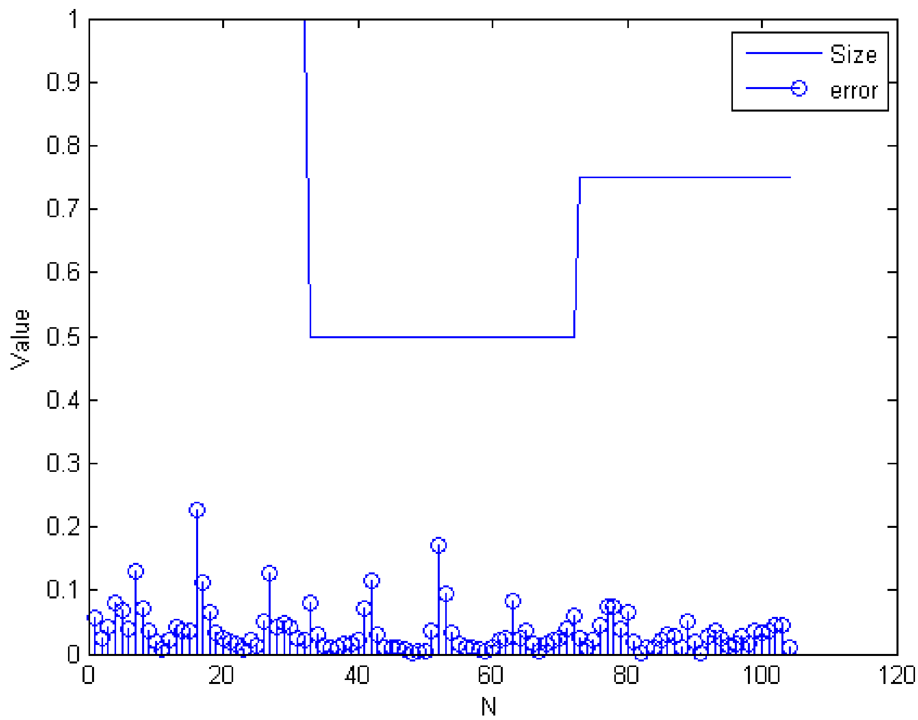

Fig. 4. The distance between the detected and the actual object

4. SUMMARY

The task of the neural network was the best locate the internal object. Neural network is built very well locates the object. The paper was presented to the use of multilayer networks percepton which are considered to be one of the most effective tools in optimization theory [6], to identify the parameters of the interior of two-dimensional objects. In practice, to solve real technical problems, it becomes necessary to use a neural network with increased size in order to improve the accuracy of identified parameters. Network size, and thus a large number of weights entails the preparation of an adequate number of samples of learners.

LITERATURE

1. Aliabadi M.H.: The Boundary Element Method: Vol. 2 Applications in Solids and Structures, WileyBlackwell 2002.
2. Brebbia C.A., Walker S.: Boundary element techniques in engineering, London-Boston, Newnes-Butterworth 1980.
3. Duch W., Korbicz J., Rutkowski L., Tadeusiewicz R.: Sieci Neuronowe, Biocybernetyka i Inży-nieria Biomedyczna 2000, T. 6, Akademicka Oficyna Wydawnicza Exit, 2000.
4. Jabłoński P.: Metoda elementów brzegowych w analizie pola elektromagnetycznego, Wydaw-nictwo Politechniki Częstochowskiej, 2003.
5. Osowski S.: Sieci neuronowe w ujęciu algorytmicznym, WNT, Warszawa, 1996.
6. Osowski S.: Sieci neuronowe do przetwarzania informacji, Oficyna Wydawnicza Politechniki Warszawskiej, 2000.
7. Sikora J.: Boundary Element Method for Impedance and Optical Tomography, Wydawnictwa Politechniki Warszawskiej, 2007.
8. http://www.mathworks.com/products/neuralnet/.

Manuscript submitted 21.07.2011

ROZWIĄZANIE PROBLEMU ODWROTNEGO PRZY POMOCY SIECI NEURONOWYCH

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STRESZCZENIE *W pracy przedstawiono praktyczne zastosowanie sieci neuronowych do rozwiązania problemu odwrotnego w tomografii komputerowej. Przedstawiono metody do wykrywania zmian w kształcie i położeniu obiektu wewnątrz innego obiektu. Tomografia komputerowa pozwala na bezpośrednią, nieinwazyjną diagnostykę mózgu i innych struktur wewnątrzczaszkowych. Dzięki tej metodzie możliwe jest wykrywanie zmian.*

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