

Development of Hardware-Software Complex for Electrical Impedance Tomography of Biological Objects

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Abstract: This study is devoted to the development of a hardware-software complex electrical impedance tomography for realizing the method of full-scale-model approach. The publication presents a structural diagram of the device and the algorithm of its operation as well as the interface of the developed software system. It describes the proposed method applied to electrical impedance tomography.

Key words: Electrical impedance tomography, a hardware-software complex, full-scale-model approach, bioobjects, electrodes

INTRODUCTION

Now a days Electrical Impedance Tomography (EIT) is one of the promising methods of the human's functional status diagnostics. This method's apparent advantages are simplicity of hardware implementation, innocuity, non-invasiveness, possibility of researching of dynamic processes (Webster, 1990; Pecker *et al.*, 2004; Bohare *et al.*, 2011; Pahuja *et al.*, 2011; Brown *et al.*, 1998). However, notwithstanding the method's advantages, there are problems in the sphere of creation of technical equipment for researching, reconstruction (bidimensional and three-dimensional) and visualization of spatial structure of internals, diseases diagnostics (Bera and Nagaraju, 2011a, b; Sarode *et al.*, 2012; Korzenevsky, 2009). We need new theoretical basics, approaches, methods, data processing algorithms and technical equipment allowing to solve complex problems of finding disorders in human's tissues and organs, estimation of inhomogeneities and visualization of bioobject's spatial structure with accuracy and imaging speed which are enough for diagnostic purposes.

MATERIALS AND METHODS

It is known that biotissue's resistance depends on many factors. Generally, the biotissue's resistance can be described as follows:

$$R = f(\lambda, S, k, I, t_1, \nu)$$

Where:

λ = An electrodes application place

S = An electrodes area

k = A coefficient considering additional conditions (damages, physiology, state of environment and so on)

I = A current strength

t_1 = The current travel time

ν = The current frequency

Therefore, it is difficult to estimate bioobject's internal structures conductivity in the process of measurement only on the bioobject's surface.

To these effects Prototype Simulation Approach (PSA) was for the first time suggested to be used in EIT. PSA application allows to amplify the electrical impedance tomography theory and technical equipment functional capabilities to a substantial degree. Conjunctive use of experimental researches, modelling and computer technologies allows to develop new models, methods, algorithms and devices which are based on them to visualize and reconstruct tomographic images of bioobjects' internal organs. While applying PSA, measurements results are used both as initial data for solving an electric conductivity estimation inverse problem and as a calculation validation criterion. And it is necessary to develop models setting algorithms at the same time. The suggested approach advantage is the possibility to obtain reliable diagnostic information on the internal organs state via noninvasive registration of potentials on the human's body surface without object direct electrical measurements (for example, directly on the heart). This is achieved owing to estimation of electrical conductivity directly on the object and further adjustment of a mathematical model until model values of the whole object coincide with the experimental ones. When these

conditions are fulfilled, further estimation of internal structures of objects (organs) is performed with the help of modelling.

The structural diagram of the device implementing the suggested method in the EIT theory is shown in Fig. 1 (Korzenevsky, 2009).

A bioobject is influenced by drive signals vector S in the form of the low amplitude high-frequency current. Measuring unit receives vector F of physical characteristics, emerging as a result of influence and transforms them into measurement information vector U . Measurement information in a modeller is transformed into vector Φ of physical characteristics shown by a bioobject under simulated conditions. The controller arranges the measurement process via control signals (Q_{GCC} , Q_{IV} , Q_{YM}) after analyzing measurement information from EIT electrodes and results of modelling with the help of algorithms present in the controller (Gorbatenko, 2001).

The whole process of bioobject's conductivity estimation can be described by the following equations system (Gorbatenko, 2001):

$$\begin{aligned} F &= W_{OH}(S) \\ S &= W_{GCC}(Q_{GCC}) \\ Q_{GCC} &= W_1(U, \Phi) \\ Q_{YM} &= W_2(U, \Phi) \\ Q_{CV} &= W_3(U, \Phi) \\ U &= W_{IV}(Q_{IV}, F) \\ \Phi &= W_{YM}(Q_{YM}, U) \end{aligned}$$

Where:

$W_{OH}, W_{GCC}, W_{YM}, W_{IV}$ = Transfer functions of bioobjects of current source and modeller
 W_i = Controller's transfer functions

Thus, we develop a universal experimental computational method based on combining of measurement and mathematical modelling of bioobject's electrical conductivity into a unitary method.

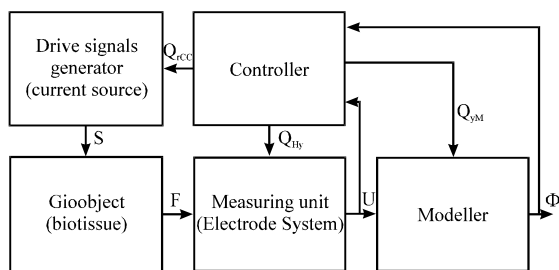


Fig. 1: Structural diagram of the device implementing the prototype simulation approach in EIT

To study biotissues and particular bioobjects using PSA we need technical equipment for registering, processing, analyzing and visualizing of electrical conductivity.

For solving the described problems and performing the research, we need to develop a hardware-software complex for electrical impedance tomography. This device structural diagram is shown in Fig. 2.

The biological objects electrical impedance tomography hardware-software complex is based on modularity (building block concept) which improves reparability and significantly reduces expenses for consumables and equipment operation. It consists of electrode system assemblage for collecting and registering of signals from electrodes (measurement system), high-frequency driving current generator, personal computer coupling unit, computer with specialized software for processing, analyzing, displaying and archiving of data, power supply unit. Figure 3 shows the general flow-chart of functioning of the developed electrical impedance tomography hardware-software complex.

Alternating high-frequency electrical current is injected into the body by means of connecting of high output resistance power supply source. In the process of measuring power supply source output is connected to one of the measuring electrodes with the help of a multichannel multiplexer. Then one should register potentials on the bioobject's surface from the rest of electrodes. The the source is connected to the next measuring electrode. This cycle is repeated until all electrodes are taken. Thus, the power supply source is successively connected to each measuring electrode and measurements are made. The measurement system general electrode and the power supply source general electrode are located on a human's body.

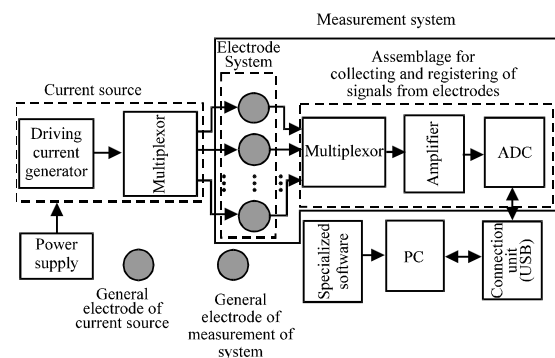


Fig. 2: Structural diagram of a hardware-software complex for electrical impedance tomography

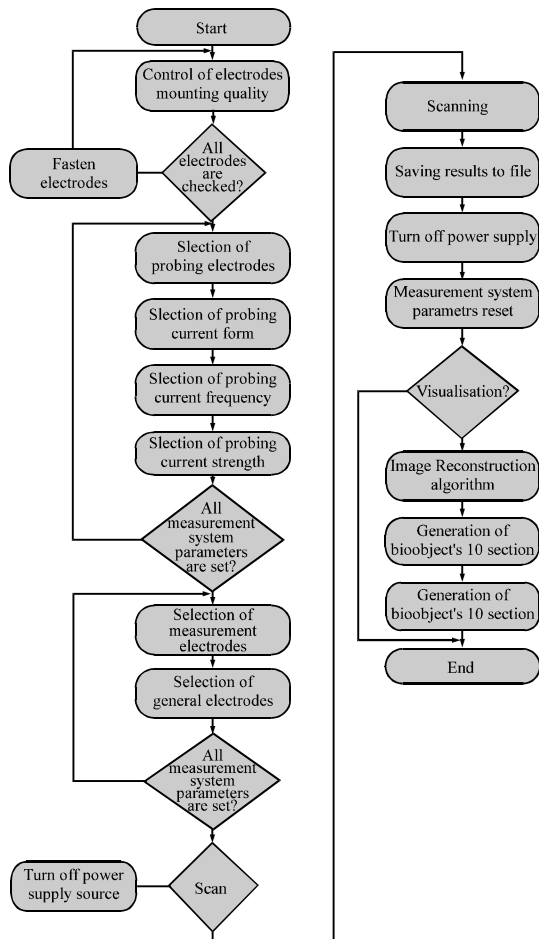


Fig. 3: General flow-chart of functioning of the developed electrical impedance tomography hardware-software complex

RESULTS

We have developed the useful software with a user sets main parameters of the power supply source: current form, current strength, current frequency. There is a possibility of the software selection of probing electrodes amount. For researches performing, there is a possibility of creation of different reference systems for pickup of potentials from a bioobject. For the sake of convenience and demonstrativeness, the monitor screen displays the map of electrodes location, showing injecting and measuring electrodes and also electrodes with poor contact with the bioobject's surface. The developed electrical impedance tomography hardware-software complex uses 5 belts with 16 electrodes in each for potentials pickup.

Nowadays, we have a possibility to obtain 10 sections of bioobjects with a spacing 5 mm. The software

estimates the time spent for image reconstruction. If necessary, a user can save obtained images of bioobject's sections.

CONCLUSION

Thus, we developed an electrical impedance tomography hardware-software complex allowing to study bioobjects (biotissues) with the help of PSA. Further, researches in this sphere are directed towards optimization of Electrode System, power supply source, creation of the bioobject probing scheme and selection of the most appropriate reference system. On the basis of obtained results we plan to develop an algorithm of reconstruction and visualization of bioobject's internal structures spatial distribution.

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