International Journal of Soft Computing 10 (6): 462-467, 2015
ISSN: 1816-9503

Design of Software and Experimental Setup for Reconstruction and Visualization of Internal Structures of Conductive Bodies

[1]Grayr K. Aleksanyan, [1]Artem I. Kucher, [1]Alexander D. Tarasov,
[2]Nguyen Manh Cuong and [2]Chan Nam Phong
[1]Platov South-Russian State Polytechnic University (NPI),
Prosvescheniya Street 132, 346428 Novocherkassk,
Russian Federation
[2]Le Quy Don Technical University, 236 Hoang Quoc Viet, Ha Noi, Viet nam

Abstract: This study presents the system for identification of Foreign particles on conductive bodies using the electrical impedance tomography method. The system includes the device for measuring impedance between different points at the surface of the tested object and the program of reconstruction of the internal structure of conductive objects. The program allows identifying presence of inhomogeneity and visualizing impedance distribution across the tested object (volume). The experimental set-up for research performance has been designed and assembled. The research has been conducted using the physical model with 16 electrodes and two kinds of inhomogeneities.

Key words: Electric impedance tomography, reconstruction, experimental set-up, research, program, impedance measurement, internal structure visualization, conductive object, non-conductive object, bio-object

INTRODUCTION

Nondestructive monitoring and control of biological and engineering systems is one of the essential and promising trends of the modern research-engineering development. Within this context the Electrical Impedance Tomography (EIT) features significant potential (Pekker, 2004; Korzhenevsky, 2009; Pekker and Brazovsky, 2004; Holder, 2005; Rozhkova *et al*., 2009; Polydorides, 2002) the method of reconstruction and visualization of internal structure imperfections consisting in high-frequency current exposure upon simultaneous recording of potential using the electrodes placed on the object surface. In order to implement this method, the hardware-an-software tools of research performance featuring the option of further reconstruction and visualization of conductivities of the object internal structures are required (bio-object). In (Aleksanyan *et al*., 2014a, b, 2015a, b; Shaykhutdinov *et al*., 2015), the researches on design and analysis of the principles of design and algorithms of functioning of the new EIT methods and devices are performed as well as improvement of the approaches existing in this area. Within this study the device of EIT and the computer program that would allow reconstructing and visualizing the conductivity field inside of the tested object based on the measurement results are designed.

MATERIALS AND METHODS

As the object of research, a cylindrical vessel with open upper edge with electrodes placed along the perimeter at the equal pitch was used. As electrodes the medical re-usable electrodes from the nickel silver alloy with the diameter of d1 = 19 mm were used. The number of electrodes N = 16 placed within the same plane. As the conductive medium the 0.9% NaCl solution was used. The volume of the conductive medium V = 50 cm^3. As imperfections an aluminium ring with the diameter 52 mm (Ω1) and cylinder from the non-conductive material with the diameter of 42 mm (Ω2) were used. Vessel with the fixed electrodes and introduced imperfections Ω1 and 2 is presented in Fig. 1.

Fig. 1: Appearance of the vessel with electrodes and imperfections Ω1 and 2

Corresponding Author: Grayr K. Aleksanyan, Platov South-Russian State Polytechnic University (NPI), Prosvescheniya Street 132, 346428 Novocherkassk, Russian Federation

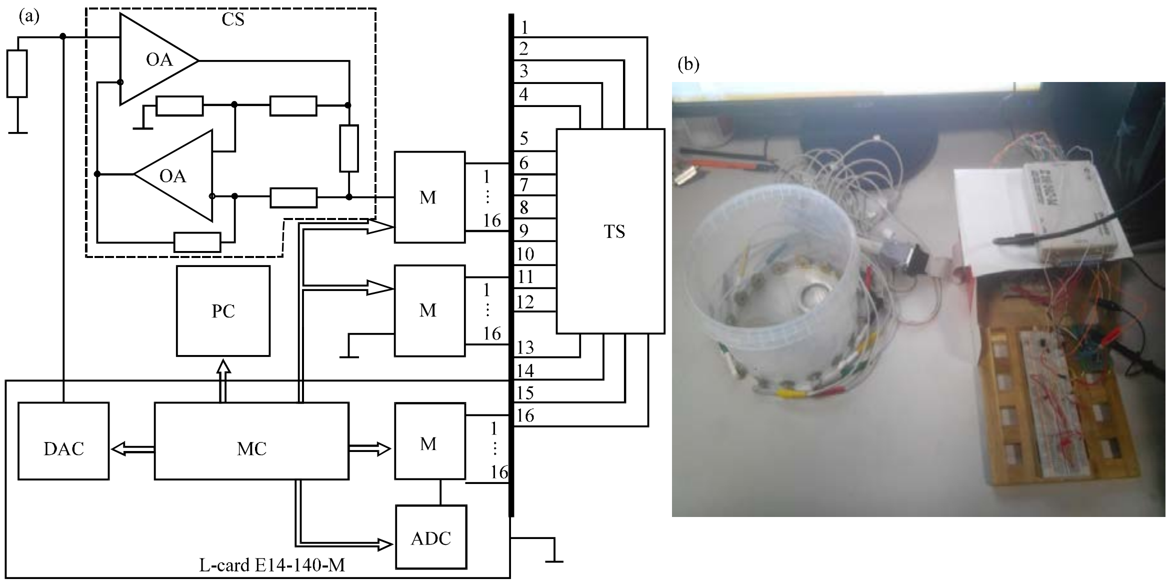

Fig. 2: Schematic diagram of the designed ES: a) Appearance of the designed ES; b) CS = Current Source; M = Multiplexor; TS = Test Sample (phantom); ADC = Analog-to-Digital Converter; DAC = Digital-to-Analog Converter; MC = Microcontroller; PC = Personal Computer; OA = Perational Amplifier

The Experimental Set-up (ES) was designed on the basis of the IOCS, L-CARD E14-140 MD and LabVIEW (National instruments) software (Gorbatenko *et al*., 2014). The schematic diagram of the designed ES is presented in Fig. 2a. The ES appearance is presented in Fig. 2b.

The experimental device operates as follows. On the PC in the control program the measurement parameters are set frequency, waveform and amplitude of injecting current, the file path for recording the measurement results and the ADC and DAC parameters are specified. After start of measurement the DAC is started. Then, MC outputs to the control inputs the M code corresponding to connection of the first electrode to the common point and of the second electrode to the power supply unit. Then MADC connects the second electrode to ADC, five voltage periods are measured (for averaging), the amplitude is calculated and written in the measurement values array. Then, MC outputs to the control inputs the M code corresponding to connection of the third electrode to the power supply unit. The amplitude is measured. The process described above is repeated until the drop in voltage is measured for all TS electrodes with respect to 1. Then, the second electrode is connected to the common point. The measurement process is repeated until all electrodes are connected to the common point one by one. Thus, the device allows obtaining the impedance values between all possible combinations of electrodes placed on TS. Upon this approach the number of possible measurements makes 240.

The software for reconstruction of internal structure of conductive objects has been designed for the ES. The program is deployed in the Octave environment. In the program, the EIDORS libraries are used for model design and visualization of impedance distribution across the object. The EIDORS software has approved itself among the EIT-devices designers (Adler and Lionheart, 2006; Polydorides and Lionheart, 2002). The program designs the two-dimensional model of the object of research a circle divided into finite elements (Fig. 3).

Thereafter, the model is split into equal sectors S. The number S corresponds to the number of measurements. Each S is assigned the impedance values obtained between the electrodes constituting a particular sector. Thus, intermediate (coarse) image of the conductivity field distribution are formed. The number of intermediate images equals to the number of electrodes N. The resulting image is obtained by means of element-by-element summing of all images with further division by the number of images. Upon this approach increase in the number of sectors S shall result in improvement of the resulting image quality. In order to increase the S number the method of linear interpolation of impedance values was used (Polovko and Butusov, 2004). In Fig. 3, the experimental results of voltage measurements for N = 16 electrodes according to the above-specified algorithm for a vessel without imperfections (Fig. 4a) and in the presence of a single conductive imperfection Ω1 (Fig. 4b) within the first electrode domain are presented. Thus, it is difficult to state absence of imperfections by the shape of the diagram.

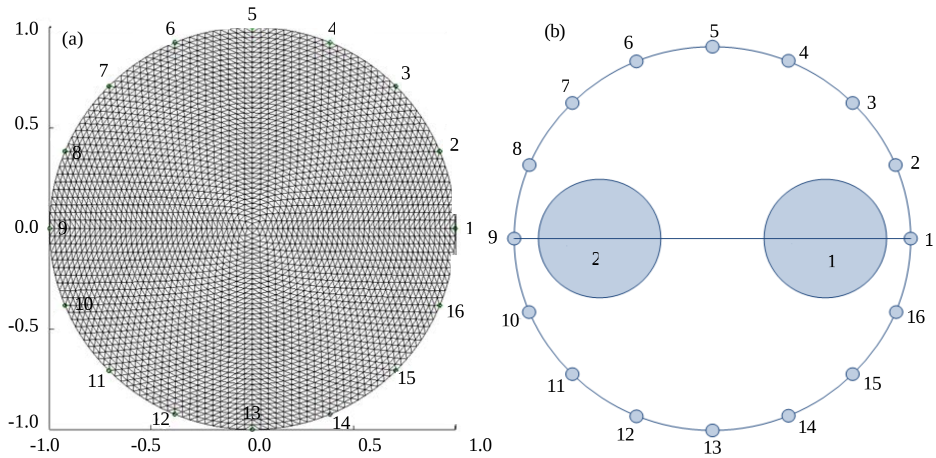

Fig. 3: Finite-element model of the tested object: a) Schematic representation of imperfections location: b) First electrode domain; 2-9th electrode domain) and 1-16 electrodes

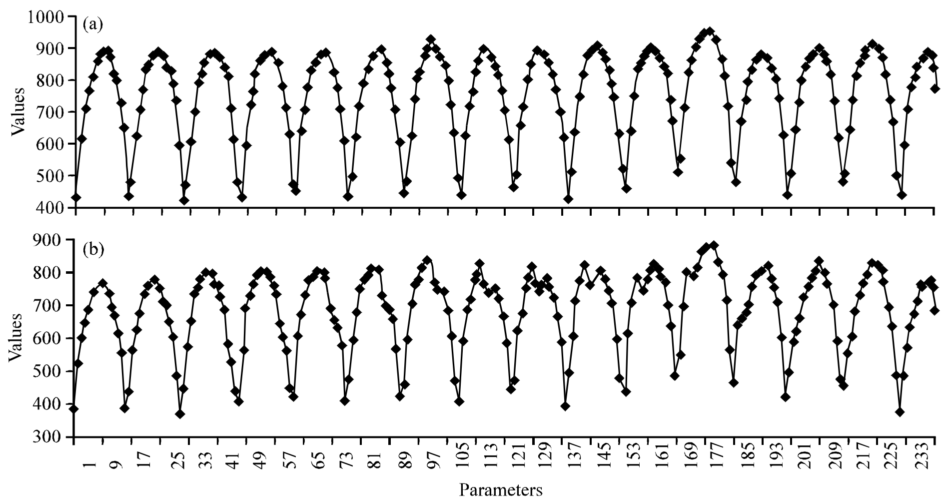

Fig. 4: Results of experimental studies: without imperfections; a) In presence of a single conductive imperfection; b) measurement

RESULTS AND DISCUSSION

Experimental data sets were processes using the program in the Octave environment. The possibility of determination of the inhomogeneity domain was investigated by means of implementation of the differential algorithm of electrical impedance tomography consisting in calculation of difference between the results of reconstruction of a homogenous and heterogeneous object. In Fig. 5, the results of operation of the designed program of reconstruction of internal structure of conductive objects for data obtained by measuring impedance of an object without imperfections Ω1 and 2 (homogenous object) are presented.

In Fig. 6, the results of operation of the designed program of reconstruction of internal structure of conductive objects for data obtained by measuring impedance of an imperfection from a non-conductive material Ω2 within the first electrode domain are presented.

In Fig. 7, the results of operation of the designed program of reconstruction of internal structure of conductive objects for data obtained by measuring impedance of an object with an imperfection from a conductive material Ω1 within the first electrode domain as well as by measuring impedance of an object with two imperfections a conductive one Ω1 within the first electrode domain and non-conductive one Ω2 within the second electrode domain.

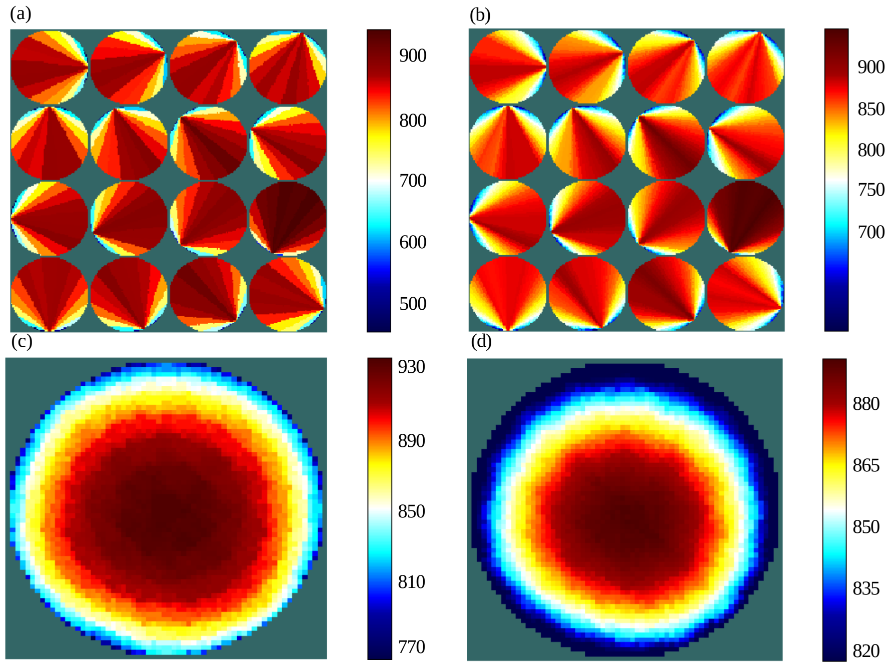

Fig. 5: Visualization of results of reconstruction intermediate images: a) resulting image; b) resulting image; c) without interpolation; intermediate images; d) with 3 additional points obtained as the result of linear interplation for a homogenous object

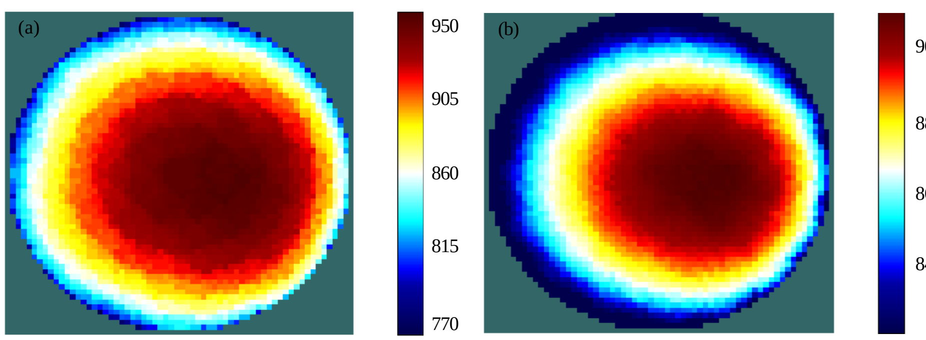

Fig. 6: a) Visualization of results of reconstruction resulting image without interpolation; b) Resulting ımage with 5 additional points obtained as the result of interpolation for a heterogenous object (non-conductive object Ω2 within the first electrode domain

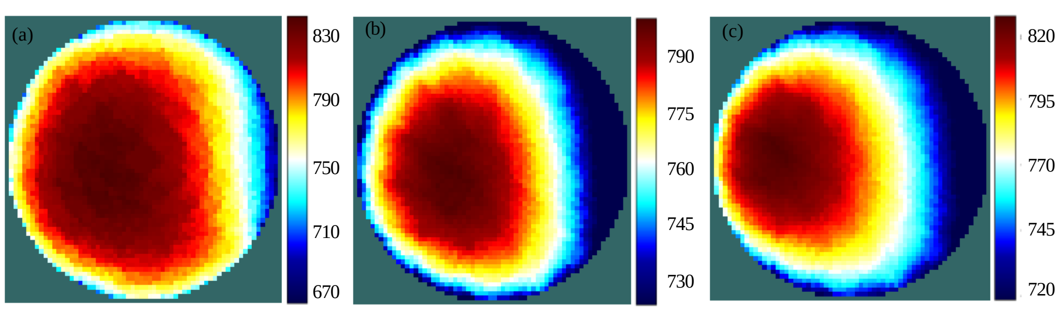

Fig. 7: Visualization of results of reconstruction resulting image: a) without interpolation, resulting image; b) with 5 additional points obtained as the result of interpolation for a heterogenous object (conductive object Ω1 within the first electrode domain as well as resulting image for an object with two imperfections; c) (conductive object Ω1 within the first electrode domain and non-conductive object Ω2 within the domain 2

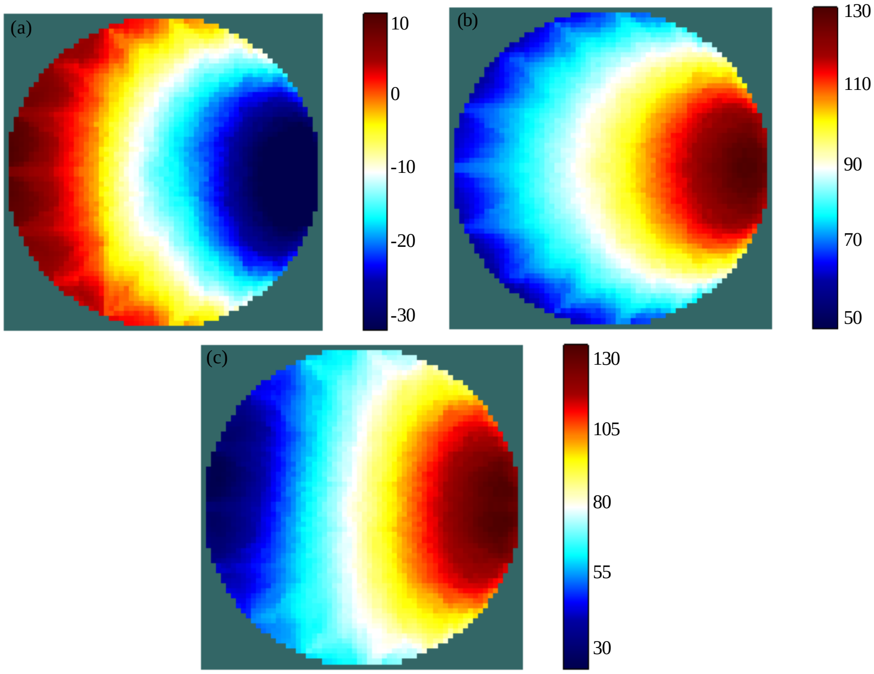

Fig. 8: a) Visualization of results of calculation of impedance variation visualization of impedeance distribution for a non-conductive imperfection within the 1 electrode domain; b) Conductive imperfection within the 1 electrode domain; c) Two imperfections within the area 1 (conductive) and 9 (non-conductive) electrodes)

In Fig. 8, the results of calculation of impeance with respect to a relatively homogenous object are presented. The variation was calculated by means of calculating difference between the relevant elements of reconstruction of a homo-and heterogenous objects.

Thus, having split the image into equal sectors S and comparing the total impedances of the sector S elements one may state presence or absence of imperfections within the object (bio-object) structure. At that comparing, the results of reconstruction with a homogenous object, it is possible to identify the location of imperfection and its kind.

CONCLUSION

During performance of research the ES for impedance measurement and program of reconstruction and visualization of internal structure of a conductive object for N = 16 electrodes were designed and assembled that allow improving the reconstruction quality using the algorithm of impedance values interpolation. The experimental set-up is implemented with the use of the modern precision technical means of collection and processing of measurement information. This hardware-and-software complex has been validated with the use of the physical model of the tested object. The results of measurements, reconstruction and visualization demonstrated the possibility of identifying the presence of imperfection within the object structure, its location as well as imperfection type (imperfection conductivity higher or lower than conductivity of the object of research). In future, the method sensitivity to geometrical dimensions and imperfection impedance shall be investigated; the impact of a few imperfections on the result of measurement and reconstruction shall be studied.

ACKNOWLEDGEMENT

The researches are performed within the frameworks of grant by the President of Russian Federation for government support of young Russian scholars MK.4856.2015.8.

REFERENCES

Aleksanyan, G.K., N.I. Gorbatenko and A.D. Tarasov, 2014a. Modern trends in development of electrical impedance tomography in medicine. Biosciences Biotechnology Research Asia, 11: 85-91.

Aleksanyan, G.K., N.I. Gorbatenko and A.D. Tarasov, 2014b. Development of hardware-software complex for electrical impedance tomography of biological objects. Res. J. Applied Sci., 9 (12): 1030-1033.

Aleksanyan, G.K., N.I. Gorbatenko, A.I. Kucher, K.M. Shirokov and C.N. Phong, 2015a. Developing principles and functioning algorithms of the hardware-software complex for electrical impedance tomography of biological objects. Biosciences Biotechnol. Res. Asia, 12: 709-718.

Aleksanyan, G.K., M.V. Lankin, A.M. Lankin and N.D. Narakidze, 2015b. Development of principles of computer appliance functioning, determination of characteristics of the biological object. Int. J. Appl. Eng. Res., 10 (3): 6489-6498.

Adler A. and W.R. Lionheart, 2006. Uses and abuses of eidors: an extensible software base for eit. Physiol. Meas, 27 (5): S25-S42.

Gorbatenko, N.I., D.V. Shaykhutdinov, G.K. Aleksanyan, V.V. Grechikhin and I.A. Stetsenko, 2014. Engineering and research applications on the basis of National Instruments NI Days technologies: collection of papers of the 13th International research-and-practice conference, November 19-20, 2014, Moscow. People's Friendship University of Russia; Representative office of the company "National Instruments" in Russia, CIS and the Baltic. M.: DMK Press, pp: 268-269.

Holder, D., 2005. Electrical Impedance Tomography. Methods, History and Applications Edited by David S. Holder. IOP Publishing, pp: 456.

Korzhenevsky, A.V., 2009. Quasi-static electrical impedance tomography for medicine. Abstract of thesis of Doctor of Physico-Mathematical Sci. Moscow, pp: 32.

Pekker, Y.S., 2004. Electrical impedance tomography. Tomsk: Publishing House NTL, pp: 298.

Pekker, Y.S. and K.S. Brazovsky, 2004. Modeling of biological objects in the electrical impedance tomography. Bulletin of the Tomsk Polytechnic University, 307 (2): 148-153.

Polydorides, N., 2002. Image Reconstruction Algorithms for Soft-Field Tomography: Ph.D. thesis , Polydorides Manchester, United Kingdom: N. UMIST, pp: 250.

Polydorides, N. and W.R.B. Lionheart, 2002. A Matlab based toolkit for three-dimensional electrical impedance tomography: a contribution to the EIDORS project. Meas. Sci. Technol., 13:1871-1883.

Polovko, A.M. and P.N. Butusov, 2004. Interpolation. Methods and computer techniques of implementation. SPb.: BHV Petersburg, pp: 320.

Rozhkova, N.I., D.K. Fomin, A.A. Nazarov, O.E. Jackobs, and O.A. Borisova, 2009. Capabilities of electrical impedance tomography in recognition of structural changes in biological tissues: experimental data (Digital resource). J. RNZRR MZ RF.

Shaykhutdinov, D., N. Gorbatenko, G. Aleksanyan, V. Grechikhin, K. Shirokov, V. Dubrov and M. Lankin, 2015. Development of a computer-based stand for testing algorithms of electrical impedance tomography. Res. J. Appl. Sci., 10: 173-175.