INFORMATION TECHNOLOGY

Розглянуто поняття електроімпедансної томографії. Вивчено сучасні програмні рішення, що реалізують методи і алгоритми електроімпедансної томографії. Зроблено висновок, що існуючі рішення для прикладних наукових досліджень і розробок в області електроімпедансної томографії або не реалізують диференціальні методи реконструкції, або не володіють можливістю багатокористувацького доступу. Дана обставина накладає ряд обмежень при проведенні науково-дослідних робіт в області електроімпедансної томографії. З огляду на сучасний стан розвитку науково-інженерних аспектів електроімпедансної томографії та проблеми і обмеження, які виникають при цьому, пропонується розробити спеціалізований веб-портал, який би систематизував і акумулював вже досягнуті результати в області електроімпедансної томографії, і пропонував дослідникам нові можливості проектування алгоритмічних і технічних засобів.

Ключовою особливістю пропонованого веб-порталу є можливість віддаленого рішення основного завдання електроімпедансної томографії (реконструкції та візуалізації поля провідності) на основі завантаженої вимірювальної інформації методом диференціальної реконструкції.

Наведено структуру розробленого веб-порталу, що включає в себе наступні модулі: модуль проведення диференціальної реконструкції, модуль зберігання медіаконтенту, база знань. Крім використання вже існуючих алгоритмів, на веб-порталі присутня можливість створення і тестування власного алгоритму, який додається користувачем. Пропонований алгоритм тестування дозволить змінювати параметри методу реконструкції зображень, одержуваних за допомогою томографічних вимірювань таким чином, щоб забезпечити найбільш гнучкий підхід до вирішення конкретного завдання. Особливістю алгоритму тестування є реалізація алгоритмів порівняння точності реконструкції поля провідності. Порівняння може проводитися на пропонованому порталом наборі даних або на даних, що завантажуються користувачем. Викладено результати експериментів за часом виконання завдання з різними моделями, що використовуються для реконструкції зображень

Ключові слова: електроімпедансна томографія, програмне забезпечення, реконструкція зображень, медична візуалізація, розподіл провідності

DEVELOPMENT OF THE WEB PORTAL FOR RESEARCH SUPPORT IN THE AREA OF ELECTRICAL IMPEDANCE TOMOGRAPHY

G. Aleksanyan
PhD, Associate Professor*
E-mail: graer@yandex.ru

A. Katsupeev
Senior Lecturer*
E-mail: andreykatsupeev@gmail.com

A. Sulyz*
E-mail: sulyzn2012@gmail.com

S. Pyatnitsin*
E-mail: pyatnicyn.stanislav@yandex.ru

D. Peregorodiev*
E-mail: peregorodiev2001@mail.ru
*Department of Information and Measurement Systems and Technology
Platov South-Russian State Polytechnic University (NPI)
Prosveshcheniya str., 132, Novocherkassk, Russian Federation, 346428

1. Introduction

Electrical impedance tomography (EIT) [1] is a medical imaging method [2] for the distribution of the resistivity of the human body (or internal organs). The main advantage of EIT over analogs (magnetic resonance imaging, computed tomography) is the ability to monitor changes in the patient's body in real time and, by monitoring these changes, take operational measures.

Since the field of EIT requires a large number of complex calculations, it is advisable to develop a web portal capable of reconstructing and visualizing user-provided data. These conditions require the design of a web portal capable of processing media content and providing it in a user-friendly way.

The relevance of work in this direction is confirmed by the presence of a large number of information systems for working in the area of EIT, which, however, for the most part, do not have multi-user online access, which could facilitate the conduct of research by scientists in this field.

2. Literature review and problem statement

The main software solutions that implement the methods and algorithms of EIT can be divided into two groups, shown in Fig. 1.

Group *D* packages have enhanced functionality for the design and development of software and technical solutions in the area of EIT. However, their main drawbacks are the need for additional software installation, the lack of multi-user access, especially online.

Group *W* solutions are open, highly informative software solutions that differ from Group *D* in less functionality (for example, a resource [3]) and do not provide the possibility of solving online reconstruction problems. The resource [4] implements only the algorithm of static reconstruction of EIT – differential algorithms are not presented.

One of the solutions to these problems is the creation of a specialized Web portal that includes the capabilities and functions of both special systems of group *D* and the

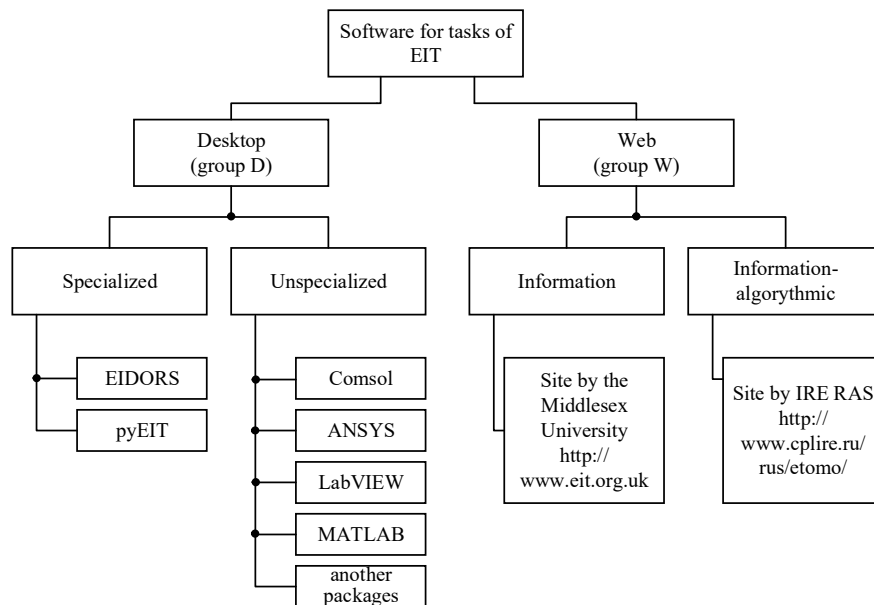advanced capabilities of group *W*, in particular the practical implementation of dynamic EIT algorithms.

Fig. 1. Software solutions in EIT area

In group D, the following solutions can be distinguished: the work [5] presents an information system designed for 2D visualization and processing of large data arrays, developed in the ComsolMultiphysics [6] environment. Other solutions include the solution developed in the LabVIEW environment [7]. These solutions allow the processing of EIT data, but do not solve the issue of providing online access to the information system. The reconstruction problem is also solved in [8], which also allows for the implementation of 3D reconstruction. This product was developed in the MATLAB environment, as well as the system described in [9]. The solution described in [10] is designed for single-user operation. A similar orientation is present in the work [11] based on Java.

Other technical solutions include the pyEIT framework, which is based on Python and is used to model and visualize EIT. The capabilities of pyEIT include finite element modeling, 2D and 3D visualization, solving the forward and inverse EIT problems, meshing and image formation for external applications. PyEIT supports both dynamic and static reconstruction [12].

Another solution for processing the results of electrical impedance tomography is MATLAB-based EIDORS package [13], which includes such reconstruction algorithms as the Gauss-Newton algorithm, back projection method, conjugate gradient method, internal point method, GREIT, etc. On the basis of EIDORS, another functional can be implemented, an example of which is the work [14], where stimulation models are formed using EIDORS.

The key disadvantage of all systems in this group is the inability to work in multi-user mode, the need to install additional software and the inability to remotely access the system. Based on this, it can be concluded that the development of an information system presented in the form of a web service will allow scientists to provide support for research in the area of EIT only through their work with the site.

The solutions presented in group W have the following disadvantages:

– do not support differential reconstruction of the conduction field;

– do not support user registration and access rights;

– do not support the creation and testing of algorithms added by users.

Thus, the developed web portal allows for the implementation of static and dynamic reconstruction within the framework of a web service, which simplifies access to the algorithmic base of the representatives of the scientific community involved in research on this topic.

3. The aim and objectives of the study

The aim of the work is to develop a multi-user portal for research support in the area of EIT, capable of dynamically reconstructing the conduction field of the object under study, provide the ability to create and test reconstruction algorithms added by portal users. In addition, the portal should contain a knowledge base on EIT.

To achieve this aim, the following objectives are accomplished:

– determine the structure and functioning principles of the web portal, develop a user guide for the web portal;

– develop web services: a reconstruction service using the EIT method, a service for storing media content and a knowledge base service for EIT, including an EIT database, determine the roles and rights of users;

– develop an algorithm for testing and comparing reconstruction algorithms added by users of the web portal with reference algorithms;

– perform experiments to evaluate the time of the web portal work with models of various dimensions.

4. Description of electrical impedance tomography methods and implementation of the web portal

In general, the EIT algorithm consists of four parts: the formation of a finite element grid, the solution of a forward problem, the solution of the inverse problem, and the results visualization.

The result of the finite element mesh formation is the studied area, divided into triangles in the case of 2D visualization and tetrahedrons in the case of 3D visualization. In the course of a forward problem, the distribution of potential is calculated after measurements carried out in the EIT process. As a result of the inverse problem, the conduction field of the object under study is reconstructed. The visualization result is to display the reconstructed conduction field to the user.

The web portal is a specialized web application designed for a specific audience, analyzing, processing and delivering information, and providing access to various web services based on the personalization of users using any device connected to the Internet [15–17]. In this web portal, all structural units of the system are separated from each other.

The structural units are web services, which are software components that are interacted over the Internet using open protocols [18]. Fig. 2 shows the classification of web portals by their purpose.

Thus, the web portal for research support in the area of EIT is a type of vertical web portals dedicated to a specific topic and aimed at a specific audience. The developed web portal is intended mainly for researchers involved in solving the problems of EIT in the area of biomedical research.

Within the framework of the developed web portal, the user is given the opportunity to carry out tomographic reconstruction using the standard reconstruction algorithms and algorithms developed by the portal users – algorithms added by user (AAU). The classification of the algorithms is shown in Fig. 3. To visualize the reconstructed measurements, the use of color maps of the conductivity distribution is provided.
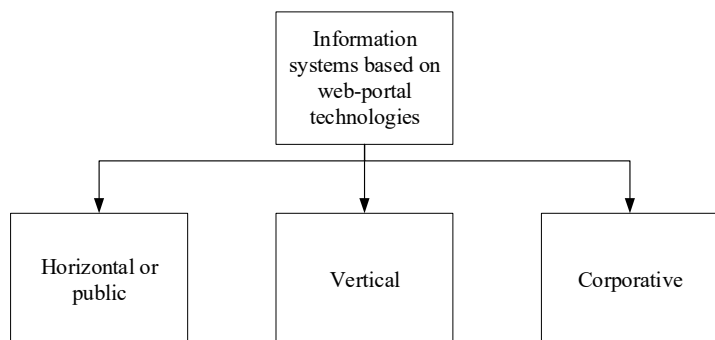

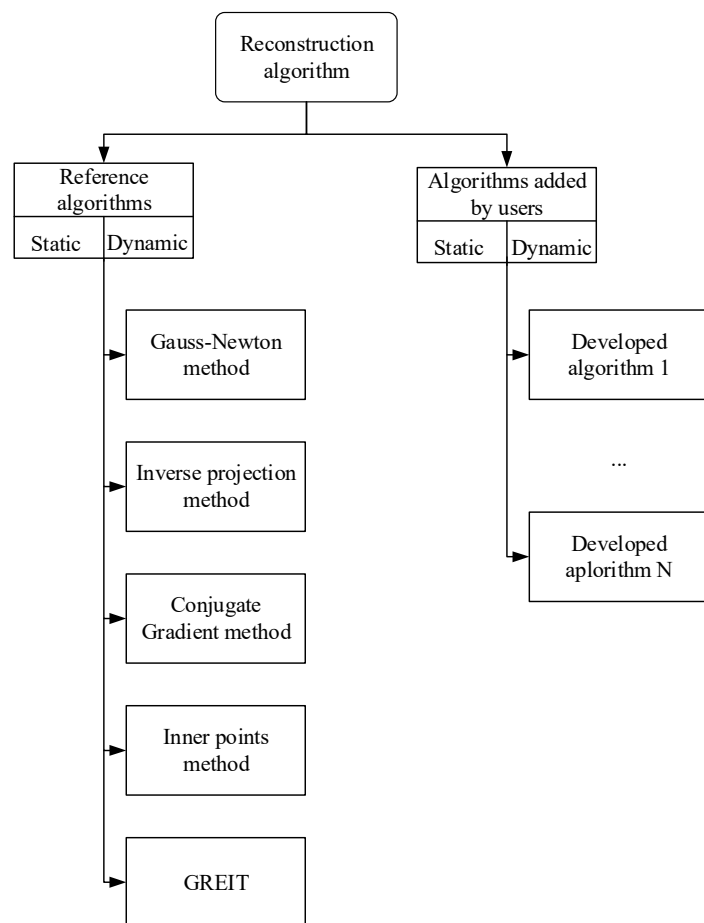Fig. 2. Classification of web portals based on web portal technologies

Fig. 3. Algorithms in the presented web portal

The reconstruction algorithm is a mathematical apparatus for reconstructing the distribution of electrical impedance inside a biological object [19].

The reference reconstruction algorithms, within the framework of the web portal being developed, are considered the reconstruction algorithms developed in the course of previous studies and tested in solving real biomedical problems of EIT. Such algorithms are: the Gauss-Newton algorithm [20], the double initial internal point algorithm [21], the full variation algorithm [22] using the double initial internal point method [21], the conjugate gradient algorithm [23], the truncated singular expansion algorithm [23].

In order to expand and promote the web portal, users can create their own algorithms, in accordance with the rules specified in the user's manual of the EIT web portal.

The user's manual applies to every web service of the portal and contains: web service description, rules of conduct (if necessary) and operating instructions.

In the EIT web portal, all reconstruction algorithms are divided into two groups in accordance with the type of reconstruction used [24]:

1) static reconstruction. One data set is used, and the conductivity distribution in the object at the time of measurement is reconstructed from it;

2) dynamic reconstruction. Two data sets are used for two points in time and reconstruction of the change in conductivity in the object between the initial and final point in time is provided.

To create this web portal, it was decided to use the following technical means:

– programming language: Python [24, 25];
– web framework: Django [25];
– DBMS: PostgreSQL [26].

The choice is due to the presence of object-oriented functionality in PostgreSQL, which allows to support complex structures and various built-in and user data types. Another advantage is PostgreSQL's commitment to full compliance with ANSI/ISO SQL standards.

Table 1 shows a comparison of PostgreSQL and MS SQL DBMSs in terms of speed, which is critical for solving large-scale problems.

Table 1

Testing results of databases performance

Criteria	MS SQL	PostgreSQL
Max speed, 1 stream (average)	32,404.67 Kb/s	33,472.67 Kb/s
Max speed (average)	51,744 Kb/s	86,323.67 Kb/s
Recommended count of users (average)	42	70

The combination of Python and Django has good support and is developing intensively. Also, these tools are open source products, so they can be used unlimitedly for commercial purposes. The advantages of these products include speed, security and scalability [27]. In addition, the Python programming language has a simple and understandable syntax, which positively affects the speed of code creation and its readability.

5. Description of the web portal services

Fig. 4 shows a simplified block diagram of the developed web portal.

The main web services provided by the EIT web portal, as shown in Fig. 3, are:

1) image reconstruction and processing service. Designed to create a platform for reconstruction and analysis of the obtained tomographic images using various EIT methods. In addition, the service allows users to create their own reconstruction algorithms;

2) informational service. Provides the user with information on the area of EIT, such as the latest news, upcoming exhibitions, conferences, etc.;

3) service for storing scientific and technical information. Contains links to bibliographic resources on the subject of EIT, including books and scientific publications.

This service allows users to reconstruct measurement data using the reconstruction algorithms existing on the portal. To do this, the user needs to download measurement data for reconstruction and visualization. In this case, the data must be brought to the form specified in the user's manual for working with this service. Before the reconstruction, it is necessary to select the following reconstruction parameters:

– type of reconstruction: static or dynamic;

– one or more reconstruction algorithms;

– one or more color maps of the conductivity distribution.

After setting the necessary parameters, the reconstruction of the downloaded files is performed, after which the user will see a table with the reconstructed images.

The implementation of several reconstruction algorithms makes it possible to visually assess the quality of reconstruction by a given algorithm.

As a result of the selection of reconstructed images according to a given algorithm and color map, the user goes to the reconstruction data page, where he is given the opportunity to view the graph of the integral conductivity change, as well as view the reconstructed data for each frame in the form of a table or GIF image.

In Fig. 5, the roles presented in the web portal are described.

The presented roles allow to differentiate the rights of users working with the portal. If unauthorized users can only carry out image reconstruction, then authorized users can create and test reconstruction algorithms. Administrators of the web portal also provide site administration and user support.
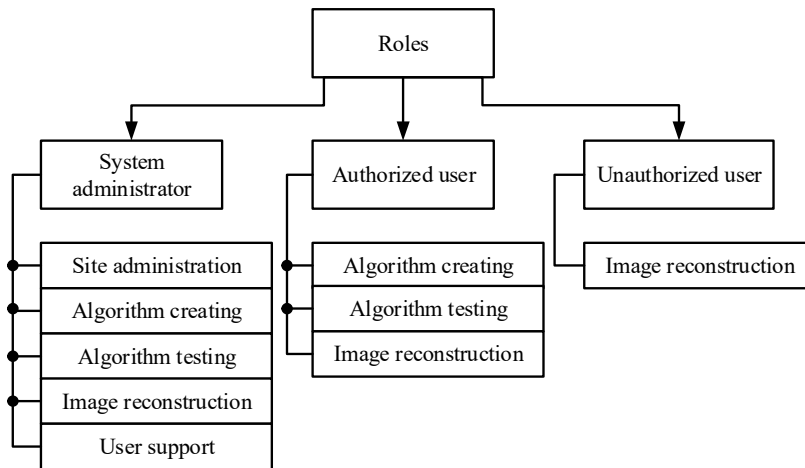

Fig. 5. Roles in the presented web portal

6. Developing of the testing algorithm

The service also provides an opportunity for registered users to independently create reconstruction algorithms. In the current implementation, the Python programming language is available for developing custom algorithms. On the page for creating the algorithm, the user must specify its name and type of reconstruction. At the same time, it is possible to download auxiliary files with source code for the created algorithm.

When saving the algorithm, the source code and auxiliary files are preliminary checked for syntax errors, after which reconstruction is performed according to specially prepared measurement data by the written algorithm. If the result is successful, the obtained images are compared with the images obtained by the reference algorithms. If the images coincide with an accuracy of 70 %, the algorithm is saved and becomes available when reconstructing the measurement data. Otherwise, the user is invited to contact the administrator with an informational message that the algorithm has worked correctly.

The block diagram of the verification of the created reconstruction algorithm is shown in Fig. 6.

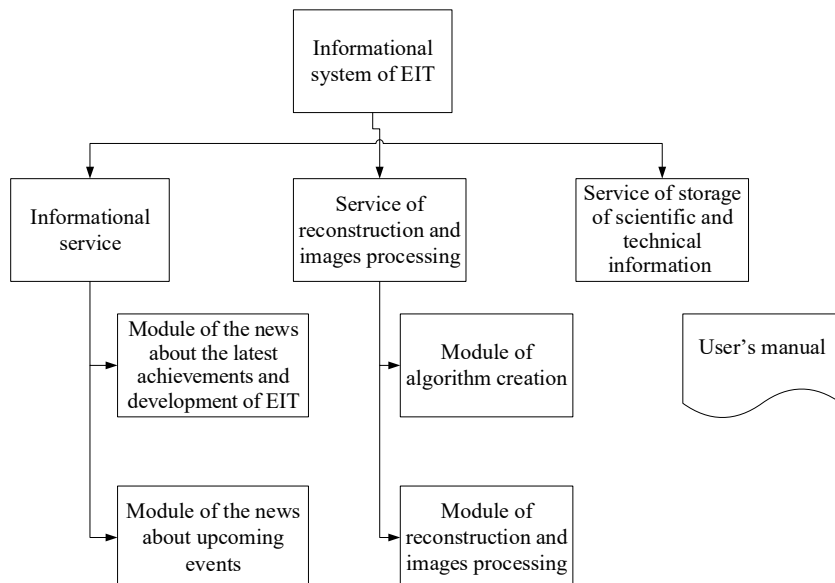Web portal users are given the opportunity to independently create

Fig. 4. Block diagram of a web portal for research support in the area of EIT

reconstruction algorithms. This allows flexible adjustment of reconstruction parameters depending on the patient being analyzed and the needs of portal users. Fig. 7 shows the image of the page for creating the reconstruction algorithm.

To store user data on the reconstructions, a database was developed, the ERD model [28] of which is shown in Fig. 8.

The developed database allows to store detailed information about the parameters of the reconstruction, the data of which is stored in the form of files on a web server. Also, for the convenience of the user and notifying him of the completion of the reconstruction procedure and visualizing the reconstructed data, a user notification function has been developed.

Consider the main entities presented in the database of the developed web portal.

Table 2 lists the database tables shown in Fig. 8.

ed data and visualized images. Table 3 describes the fields in this table.
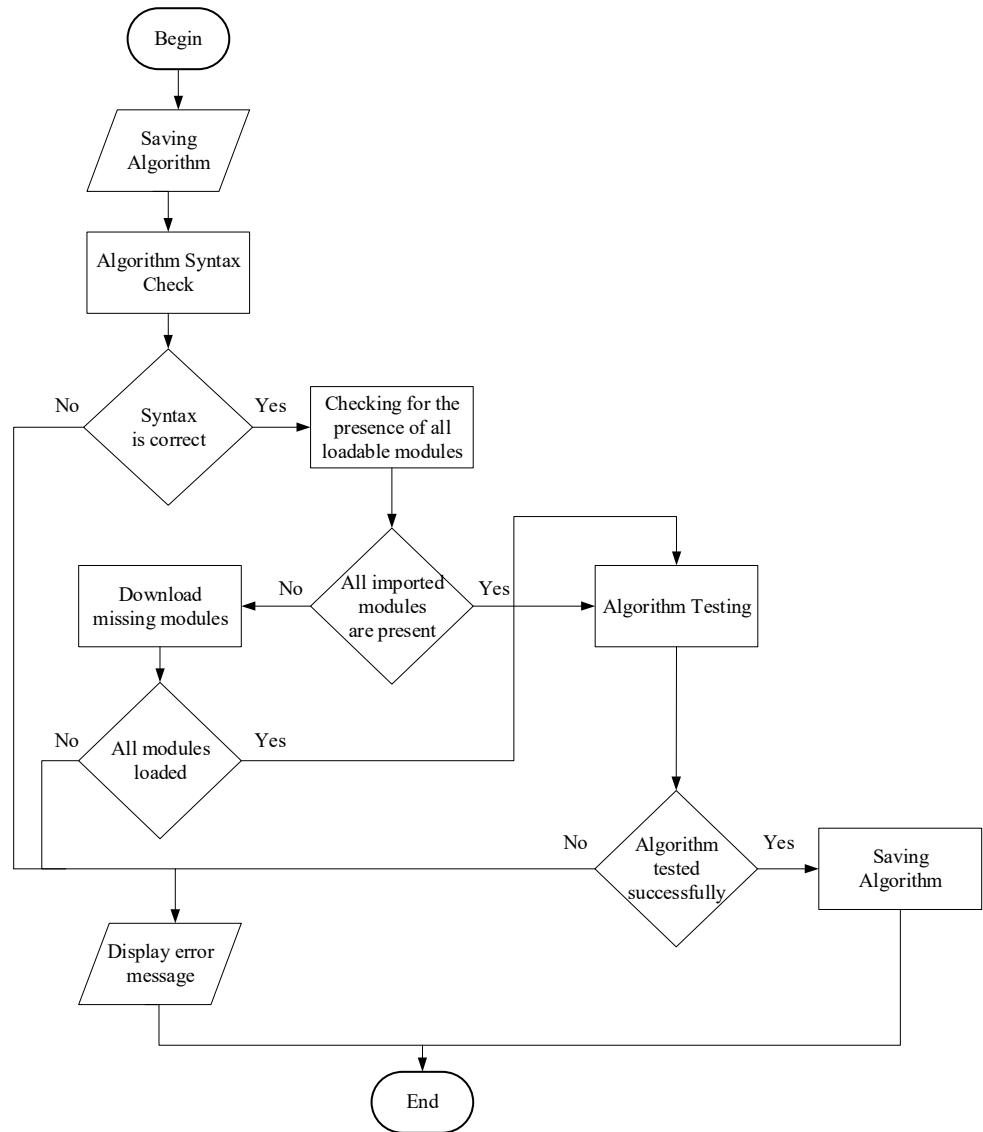
Fig. 6. Block diagram of the developed reconstruction algorithm verification

Table 2

Description of developed database tables

Table name	Table purpose
Reconstruction	Designed to store information about the created reconstruction of measurement data
Reconstruction-Notification	Designed to store notifications of the status of the reconstruction
User	Designed to store user data
Colormap	Designed to store data on color maps of conductivity distribution
Reconstruction-Model	Designed to store data on reconstruction models
Algorithm	Designed to store data on existing reconstruction algorithms

Table *Reconstruction* is the main one and stores the paths to the original measurement data, reconstruct-
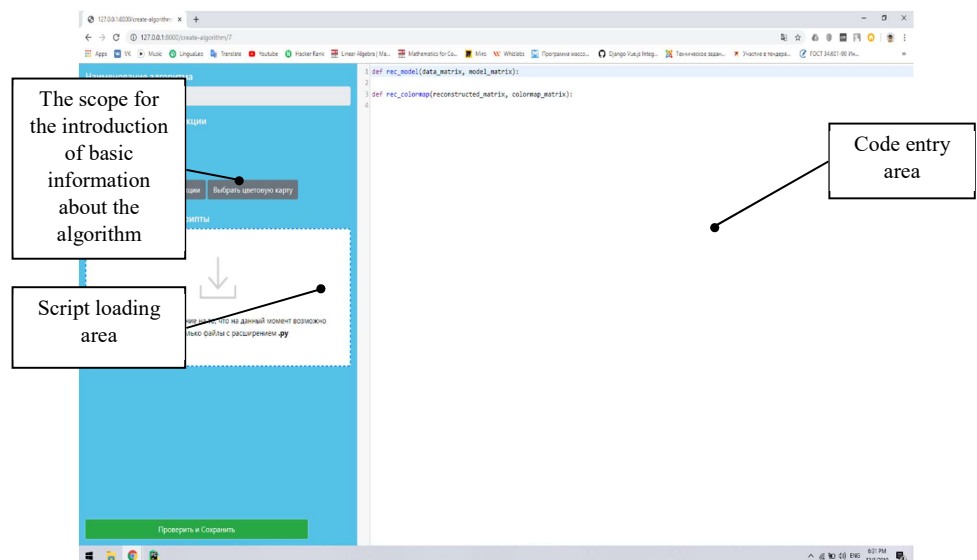

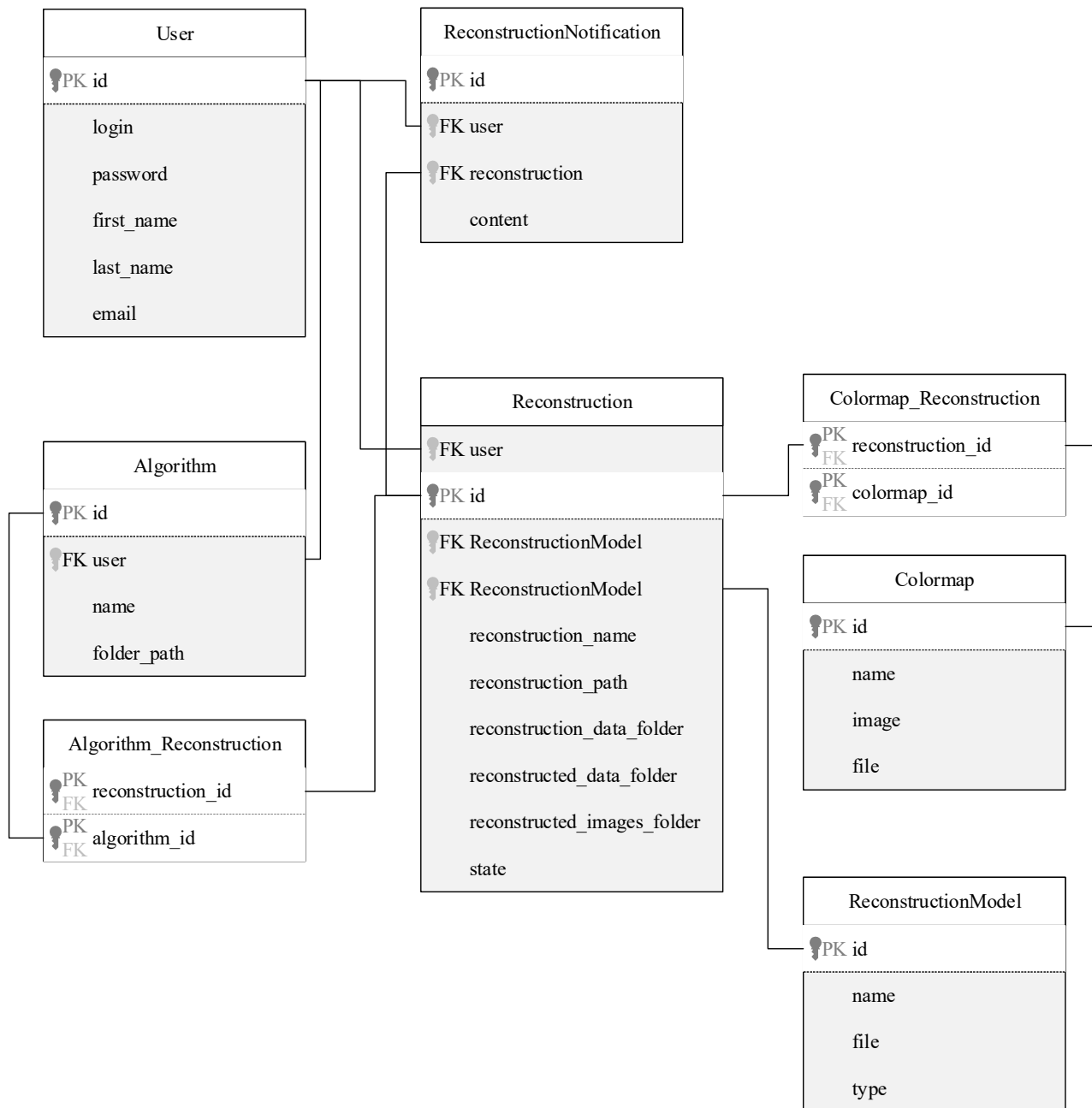Fig. 7. Image of the reconstruction algorithm creation page

Fig. 8. ERD database diagram for storing reconstruction information

Table 3

Description of table fields *Reconstruction*

Field name	Data type	Purpose	Note
id	Integer	Reconstruction ID	Not Null, Primary Key
User	Integer	Foreign key to table *User*	Not Null, Foreign Key
ReconstructionModel	Integer	Foreign key to *ReconstructionModel* table	Not Null, Foreign Key
Reconstruction_name	Varchar(200)	Name of the reconstruction process	Not Null
Reconstruction_path	Varchar(550)	Path to the root of the reconstruction process directory	Not Null
Reconstruction_data_folder	Varchar(550)	Path to the source data of the reconstruction process	Not Null
Reconstructed_data_folder	Varchar(550)	Path to reconstructed data of process reconstruction	Not Null
Reconstructed_images_folder	Varchar(550)	Path to visualized images of the reconstruction process	Not Null
State	Varchar(50)	Status of the reconstruction process (Processing/Completed)	Not Null

All user data on the developed reconstruction algorithms and performed reconstructions on the measurement data are in the user's personal account. At the moment, this account is intended only for work with the service in question. In the

future, it is planned to expand the use of a personal account to all of the specified services that the web portal provides.

The user's account allows to track the status of the reconstruction algorithm, at the end of which a notification is sent to the user's e-mail and a record of completion of the reconstruction process is added to the *ReconstructionNotification* table discussed earlier. This record is deleted from the table when it is read by the user.

Fig. 8 shows the image of the user's personal account in the selection section of the created reconstruction algorithm. Fig. 9 shows the image of the personal account on the selection section of the ongoing/conducted reconstruction processes.

As you can see from Fig. 10, in the upper right corner there is an alert icon that works asynchronously and updates information about the availability of new notifications every second. Each notification is a link to a page with the results of the reconstruction and is deleted from the database when the user opens a page with the completed reconstruction process. Currently, visualized images and a graph of measurements are available on it. The appearance of the reconstruction results page is shown in Fig. 11.
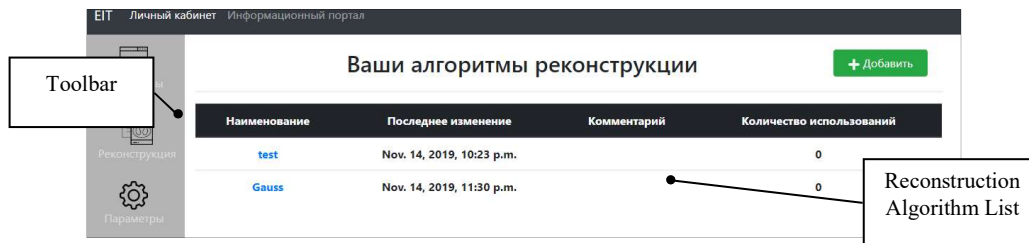
Fig. 9. Image of the user's personal account on the selection section of the created reconstruction algorithm
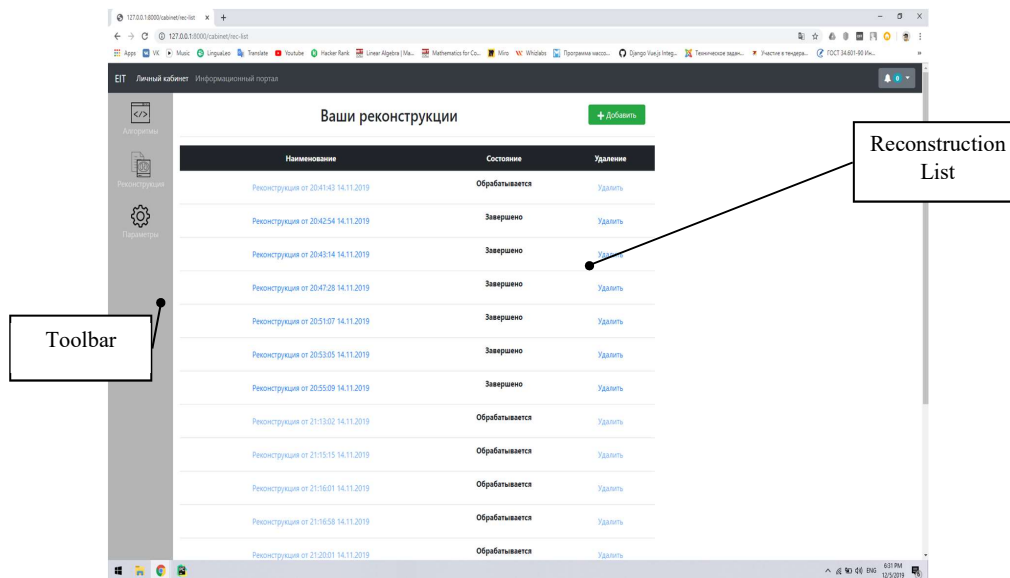
Fig. 10. Image of the user's personal account on the reconstruction section

Fig. 11. Image of the reconstruction process results page

7. Time evaluation of the web portal work

For an experimental study of the capabilities of the developed web portal, as well as the correspondence of the results of the implemented algorithm, studies were carried out consisting in the organization of EIT research using the information-measuring system developed earlier by the authors [29–31] on volunteers. The installation is shown in Fig. 12. The measurement circuit is shown in Fig. 13. Previously, volunteers obtained consent to the study under this article.

In the study, the following current parameters were used, presented in Table 4:

Table 4

Current parameters

Parameter	Value
Current, I	5 mA
Frequency, f	50 kHz

In the study, the nearest neighbor method was used for injection.

The input data for the reconstruction algorithm are the potential differences on the measuring electrodes, presented in the form of a set $F=\{\varphi_1, \dots, \varphi_n\}$, $F'=\{\varphi'_1, \dots, \varphi'_n\}$, where:

– φ_i, $i=1, \dots, n$, – the difference in potential values on the measuring electrodes during the first measurement;

– φ'_i, $i=1, \dots, n$, – the difference in potential values on the measuring electrodes during the second measurement;

– n – the number of measuring electrodes pairs.

The measurement process takes 40 ms. After measurement, the data is converted to JSON format and uploaded to the web portal. Conversion and download time is 17 ms. Further, the data is downloaded to the server, the parameters of which are presented in Table 5. The scheme of data transfer to the server and vice versa is shown in Fig. 14.
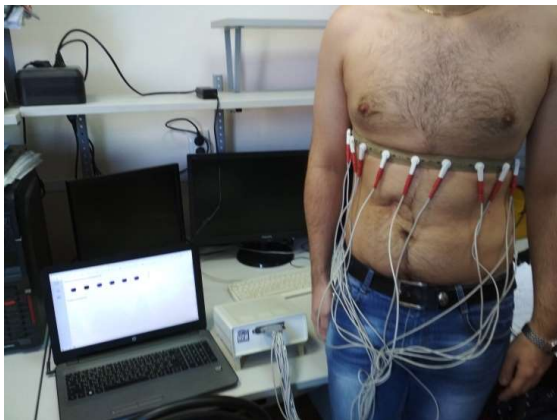

Fig. 12. Appearance of the experimental setup with a volunteer connected to it
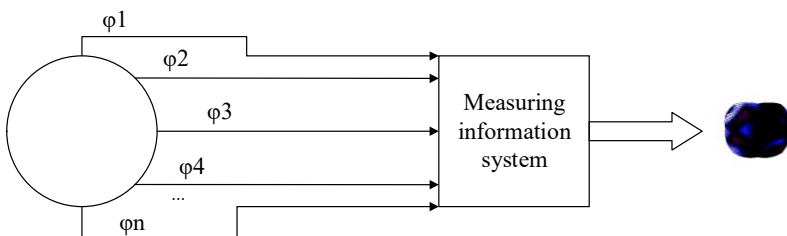

Fig. 13. Potential Measurement Scheme
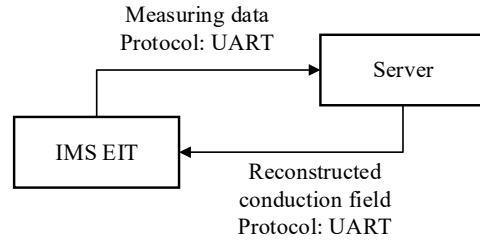
Server specifications are presented in Table 5.

Fig. 14. Scheme of interaction of the information-measuring system with the web portal server

Table 5

Server specifications

Parameter	Value
Processor frequency	3.3 GHz, 4 cores
RAM	8 GB
Operating system	Windows 10

After downloading the data to the portal, the conduction field is reconstructed using the formula:

$$\sigma=H^*(F'-F), \text{ where}$$

H is a pre-generated reconstruction matrix stored on the web portal.

Table 6 shows the time of calculating the conduction field for different sizes of the reconstruction matrix.

In the implemented web portal, experiments were carried out on the operating time of the program depending on the dimension of various reconstruction models. The dimension and the corresponding measurement time are presented in Table 6.

Table 6

Experiments with different dimensions of matrices

Reconstruction model size	Number of finite elements	Reconstruction time, ms	Number of measurements
($a2t2$)	64	0.24	9
($c2t2$)	576	0.99	9
($d2t2$)	1,024	1.69	9
($f2t2$)	2,304	4.66	9

The results show that calculations in the server occur quickly even in the case of large matrices. Therefore, the web portal can be further refined to visualize the conduction field in real time.

8. Discussion of experimental results of EIT web portal research

The obtained timing results of the web portal work for various matrix dimensions, presented in Table 6, allow to calculate the conduction field in quasireal time. For this type of tasks, an effective time limit for dynamic visualization frequency is 24 frames per second. Thus, the

obtained experimental data when testing the web portal allows to conclude that the proposed software solutions can be applied to solve practical problems of EIT.

This is due to the application of EIT dynamic reconstruction methods and the use of pre-generated reconstruction matrices. In addition, the achievement of the time values indicated in Table 4 is due to the technical study and elimination of the problem areas of the EIT algorithms.

Since the presented system is the web portal, it allows to provide online multi-user access to the dynamic EIT reconstruction, which is not available in existing software products.

Upon that, the main drawback of the proposed information measuring system due to its implementation in the form of a multi-user web service is the lack of capabilities of a number of software systems, for example, EIDORS. These include static reconstruction, dynamic construction of a finite element mesh, etc.

The limitation of this study is the lack of the possibility of reconstructing the conduction field based on data obtained from several belts (or from a multidimensional matrix of electrodes), which does not allow providing of 3D reconstruction (three-dimensional electrical impedance tomography).

Another limitation that may currently limit the capabilities of the web portal is the use of pre-generated meshes of finite elements. The construction of meshes during the algorithm operation will expand the range of forms and models available to the user.

A promising direction in the proposed web portal development is the technical implementation of 3D reconstruction and visualization algorithms on the server.

It should be noted that improving the efficiency and capabilities of the web portal is possible when it is built using calculation algorithms implemented in C++. In addition, in the case of using C++, data transmission to the web server directly from the measuring device can be implemented.

9. Conclusions

1. The structure and functioning principles of the web portal are developed. The web portal includes a number of web services that allow scientists involved in research in the field of EIT to use the resources of the portal without installing additional software. A feature of the web portal is the implementation of differential reconstruction of the conduction field, which makes it the first web portal to provide such an opportunity for users. A web portal user guide describing the functionality of services has been developed.

2. Web services of tomographic reconstruction, storage of media content and bibliographic information storage have been developed. The peculiarity of the tomographic reconstruction web service is to provide an interface for interaction with the calculation module to the user via the Internet. Python, Django, and PostgreSQL were chosen as tools for implementing the information system. Roles and rights of system users are defined: unauthorized users who can only conduct reconstruction of the conduction field, authorized users who can also create and test reconstruction algorithms, and portal administrators.

3. An algorithm for testing user-added EIT algorithms has been developed and implemented in an information system. This algorithm allows to evaluate the accuracy of the proposed algorithms in comparison with the reference algorithms. A feature of the algorithm is the ability to compare the accuracy of the reconstructed conduction field with reference algorithms both on the data provided by the portal and on the data downloaded by the portal user.

4. An experiment on the operating time of a system with different matrix dimensions showed that the operating time does not exceed 5 ms even in the case of an object with a maximum number of finite elements. This calculation time allows visualization of the reconstructed conduction field in quasireal time with a sufficient number of frames (more than 24 frames per second).

References

1. Pekker, Ya. S., Brazovskiy, K. S., Usov, V. N. (2004). Elektroimpedansnaya tomografiya. Tomsk: NTL, 192.
2. Draeger medical. Technical Data for PulmoVista 500 (2011).
3. Electrical impedance tomography. Available at: http://www.eit.org.uk/about.html
4. Elektroimpedansnaya tomografiya (EIT). Available at: http://www.cplire.ru/rus/etomo/
5. Zheng, J., Peng, L. (2017). A platform for electrical capacitance tomography large-scale benchmark dataset generating and image reconstruction. 2017 IEEE International Conference on Imaging Systems and Techniques (IST). doi: https://doi.org/10.1109/ist.2017.8261465
6. COMSOL Multiphysics® v. 5.4. Available at: https://www.comsol.com/
7. Kryszyn, J., Wanta, D., Kulpanowski, P., Smolik, W. T. (2018). LabVIEW based data acquisition system for electrical capacitance tomography. 2018 International Interdisciplinary PhD Workshop (IIPhDW). doi: https://doi.org/10.1109/iiphdw.2018.8388388
8. Yang, Y., Jia, J. (2017). A multi-frequency electrical impedance tomography system for real-time 2D and 3D imaging. Review of Scientific Instruments, 88 (8), 085110. doi: https://doi.org/10.1063/1.4999359
9. Hidayat, I., Darpita, I. D., Wijaya, S. K., Prajitno, P. (2019). The development of magnetoacoustic tomography system with current injection. Proceedings of the 4th international symposium on current progress in mathematics and sciences (ISCPMS2018). doi: https://doi.org/10.1063/1.5132443
10. Jang, G. Y., Ayoub, G., Kim, Y. E., Oh, T. I., Chung, C. R., Suh, G. Y., Woo, E. J. (2019). Integrated EIT system for functional lung ventilation imaging. BioMedical Engineering OnLine, 18 (1). doi: https://doi.org/10.1186/s12938-019-0701-y

11. Aleksanyan, G. K., Shcherbakov, I. D., Kucher, A. I., Sulyz, A. V. (2018). Development of software monitoring module for multi-angle electric impedance tomography method research. MATEC Web of Conferences, 226, 02024. doi: https://doi.org/10.1051/matecconf/201822602024

12. Liu, B., Yang, B., Xu, C., Xia, J., Dai, M., Ji, Z. et. al. (2018). pyEIT: A python based framework for Electrical Impedance Tomography. SoftwareX, 7, 304–308. doi: https://doi.org/10.1016/j.softx.2018.09.005

13. EIDORS: Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software // URL: http://eidors3d.sourceforge.net.

14. Dimas, C., Sotiriadis, P. P. (2018). Electrical impedance tomography image reconstruction for adjacent and opposite strategy using FEMM and EIDORS simulation models. 2018 7th International Conference on Modern Circuits and Systems Technologies (MOCAST). doi: https://doi.org/10.1109/mocast.2018.8376604

15. JSR 168: Portlet Specification. JSRs: Java Community Process. Available at: https://www.jcp.org/en/jsr/detail?id=168

16. Elmanova, N. (2001). Web-portaly: klassifikatsiya i naznachenie. KOMP'YUTER PRESS, 2, 172–176.

17. Voriyskiy, F. S. (2003). Informatika. Noviy sistematizirovanniy tolkoviy slovar'-spravochnik. Moscow: FIZMATLIT, 760.

18. Mashnin, T. (2012). Web-servisy Java. Moscow: BHV-Peterburg, 560.

19. Aleksanyan, G. K., Gorbatenko, N. I., Tarasov, A. D. (2014). Development of Hardware-Software Complex for Electrical Impedance Tomography of Biological Objects. Research Journal of Applied Sciences, 9, 1030–1033.

20. Goryaninova, E. R., Pankov, A. R., Platonov, E. N. (2012). Prikladnye metody analiza statisticheskih dannyh. Moscow: Izdatel'skiy dom Vysshey shkoly ekonomiki, 310.

21. Izmailov, A. F., Solodov, M. V. (2008). Chislennye metody optimizatsii. Moscow: FIZMATLIT, 320.

22. Petrov, I. B., Lobanov, A. I. (2006). Lektsii po vychislitel'noy matematike. Moscow: BINOM, 523.

23. Tyrtyshnikov, E. E. (2007). Matrichniy analiz i lineynaya algebra. Moscow: FIZMATLIT, 480.

24. Kennet, R., Shlyusser, T. (2017). Avtostopom po Python. Moscow: Piter, 336.

25. Berri, P. (2017). Izuchaem programmirovanie na Python. Moscow: Izdatel'stvo «E», 624.

26. Obe, R., Hsu, L. (Eds.) (2014). PostgreSQL: Up and Running. O'Reilly Media, 234.

27. Plyusy i minusy Django. Python 3. Available at: https://python-scripts.com/django-obzor

28. ERD (OpenModelSphere) – kontseptual'naya model' dannyh. CyberPedia. Available at: https://cyberpedia.su/12xdf47.html

29. Aleksanyan, G. K., Shcherbakov, I. D., Kucher, A. I., Volchenkov, E. A. (2018). Development of a power supply for multi-angle electric impedance tomography complex. MATEC Web of Conferences, 226, 02025. doi: https://doi.org/10.1051/matecconf/201822602025

30. Karenovich Aleksanyan, G., Ivanovich Gorbatenko, N., Igorevich Kucher, A., Mikhailovich Shirokov, K., Nam Phong, C. (2015). Developing Principles and Functioning Algorithms of the Hardware-software Complex for Electrical Impedance Tomography of Biological Objects. Biosciences, Biotechnology Research Asia, 12, 709–718. doi: https://doi.org/10.13005/bbra/2251

31. Gorbatenko, N., Aleksanyan, G., Grechikhin, V., Shirokov, K., Dubrov, V., Lankin, M. (2015). Development of a computer-based stand for testing algorithms of electrical impedance tomography. Research Journal of Applied Sciences, 10 (4), 173–175.