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On the Application of Stereoscopic Technologies in Biological Research

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Abstract

The work is devoted to the application of previously developed algorithms and methods of stereo animations construction in the field of biological research on the example of stereo images for functional tomogram of the brain. The construction of stereo images on the autostereoscopic monitor provides an opportunity to obtain an in-depth understanding of the studied object. The autostereoscopic monitor allows viewing stereo images without glasses, while providing a quality not inferior to that of a classical 3D projection stereo system. This work continues the cycle of research conducted at the Keldysh Institute of Applied Mathematics. The specificity of the displayed data allowed to improve authoring libraries for creating stereo images. The research is aimed at developing technologies for constructing stereo images and animations for presenting the results of scientific calculations on classical stereo devices and autostereoscopic monitors. Constructing a stereoscopic visual representation of the results of biological research will enable researchers in the field to gain a deeper understanding of the object under study and its properties.

Keywords: Construction of complex stereo images, autostereoscopic monitor, biological studies, functional tomograms.

1. Introduction

With the gradual spread of stereo devices there is a possibility of research and application of stereo-animation technologies in scientific researches. There is also an active development of creation of different types of stereo demonstration complexes. At the moment there are more than thousands of virtual environment devices and tens of thousands of presentation complexes in the world, which are successfully applied in different fields. Serious results have been achieved in aviation and automobile simulators, crew training systems for merchant ships and warships, car design tasks, research and development of nano-technologies, surgical operations training and other fields. Stereo technology is being actively explored and applied in media services as well. The introduction of three-dimensional visualization into these areas successfully contributes to the development and application of the latest achievements of technology in various fields of activity.

Stereo image construction has two main directions: presentation and research. Presentation direction allows to present the results of scientific or design works to expert groups and decision makers in the most informative and accessible way, as three-dimensional representation promotes popularization of carried out researches. Stereo image allows them to get a complete picture of the modeled object.

The research direction of stereo images allows researchers to see an object or physical phenomenon in volume and gain a deep and clear understanding of the object, phenomenon or process being studied. With the help of stereo images, researchers can gain a new perspective and a better understanding of their research. A three-dimensional stereo model helps to verify computational models or complex designs, and provides a more complete understanding of the simulated phenomena to the observer.

In the scientific and technical sphere, stereo image construction is a universal tool that can be effectively applied in various fields. It finds its application in engineering and design developments, mathematical modeling of complex objects and, in particular, in medical technologies. It is important to note that the joint work of scientists and specialists in various fields of science, such as medicine, computer graphics and mathematical modeling, is of great importance and has wide application prospects.

2. Previous works

Currently, the direction of stereoscopy and stereoimage creation is being actively researched and developed in application to various fields of science. This was preceded by a large cycle of works devoted to the research and development of methods for creating stereo images of various objects under study [1-10]. For example, specific problems arising when using a system of computers for generation and visualization of a composite multiscreen stereo frame and methods of solving such problems are described in [1-3].

The papers [3-6] describe the results of studies made at Keldysh IPM RAS on the basis of available stereo devices of the main two types. One of them is the Dimenco DM654MAS autostereoscopic monitor capable of displaying stereo images without the need to track the observer's position. The second type is a classic type of stereo device. Typically, autostereoscopic monitors provide an opportunity to observe stereo images by providing several fixed segments in space for observation, between which the viewer can move, viewing the object under study in 3D from different angles of view.

Autostereoscopic monitor is capable of demonstrating the visualization object using two methods: either using a composite frame containing views of the visualization object from different angles (Fig.1), which form a certain viewing sector - this method is called multi-view - or using depth maps. When constructing a complex stereo frame, the stereo scene construction itself and object placement on it, volume, object depth and even color play a great role. In works [4, 5] the step-by-step process of developing such technology of constructing stereo images combined with stereo text as multi-view representation was considered in detail. This technology allows to achieve the highest stereo effect for visualization of results for mathematical modeling calculations, which are performed by Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences [6, 9, 19].

Figure 1 shows an image of the simulation results of supersonic cone flow at angle of attack with the corresponding inscription. This is one of the results of earlier studies - a multiview image of the results of modeling the supersonic flow of a cone at the angle of attack with the corresponding inscription [6]. Here the image of the modeled cone itself and separately the inscriptions to it are combined. Each of them is rotated to a different experimentally detected angle. As shown in the figure, a matrix of images is further compiled, which in turn form a single stereo image. In the end, the inscription was located on top of the cone, but behind its tip, which in turn was perceived by viewers as protruding from the screen by several tens of centimeters.

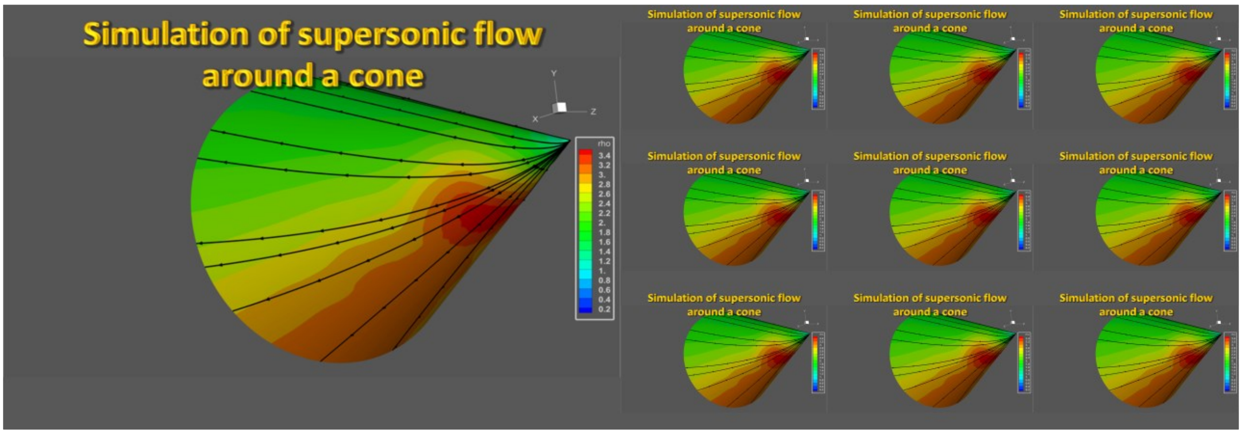

Figure 1. Image of the simulation results of supersonic cone streamline with the corresponding inscription

Currently, the problems of stereo image construction are considered in various research areas [3-18]. For example, paper [3] presents the results of displaying a SuperNova explosion in stereo mode. The work [9] is devoted to the creation of computational technology for modeling the operation and visualization of a three-dimensional assembly of blades of a power plant in the flow of viscous compressible heat-conducting gas. Many works are devoted to the issues of searching for the optimal stereo effect [13-18], but universal recipes for obtaining the most optimal stereo effect have not been created yet.

Stereoscopy can also be used in medical research. For example, in [19], computer tomography data were visualized, including stereo images. Such visualization allows specialists in medicine to detect pathologies in patients more effectively. The possibility of using stereo images in maxillofacial surgery to demonstrate to patients future models of changes in the oral cavity and patient's appearance and more accurate prognosis on the prescribed treatment is also envisioned. This will allow for more accurate correction of the physician's actions and achieve physician-patient rapport. Figure 2 shows the results of craniofacial computed tomography of a patient, visualized in volumetric form on the autostereoscopic monitor screen and accompanied by an appropriate caption.

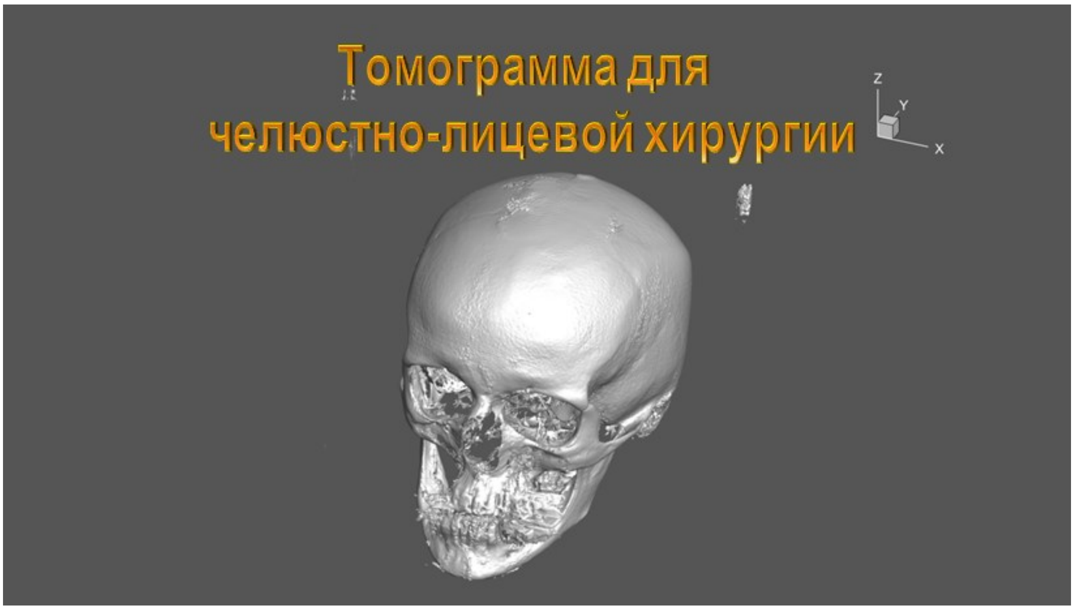

Figure 2. A frame constructed for an autostereoscopic monitor for visualizing CT scan results.

3. Application of stereotechnologies in the field of biological research

Stereo images become no less demanded in the field of biological research, in particular, in the study and analysis of electric fields of the human body. In this work, stereo imaging technology was used to visualize functional tomograms of the brain and the results are presented.

As the data of biological studies, we used the data of tasks, which have been dealt with by the team of IMPB RAS (a branch of the Keldysh Institute of Mathematics and Mathematics of the Russian Academy of Sciences) for quite a long time. An example of such a task is the research devoted to the analysis of functional tomograms of complex systems and consideration of methods of filtering of registered signals to obtain a reliable spatial configuration, with visual display of which users can work [20].

Figure 3 shows a functional tomogram in different frequency ranges [20]. The results are shown as three-dimensional images presented from different angles. Similar three-dimensional images can be visualized in stereo mode.

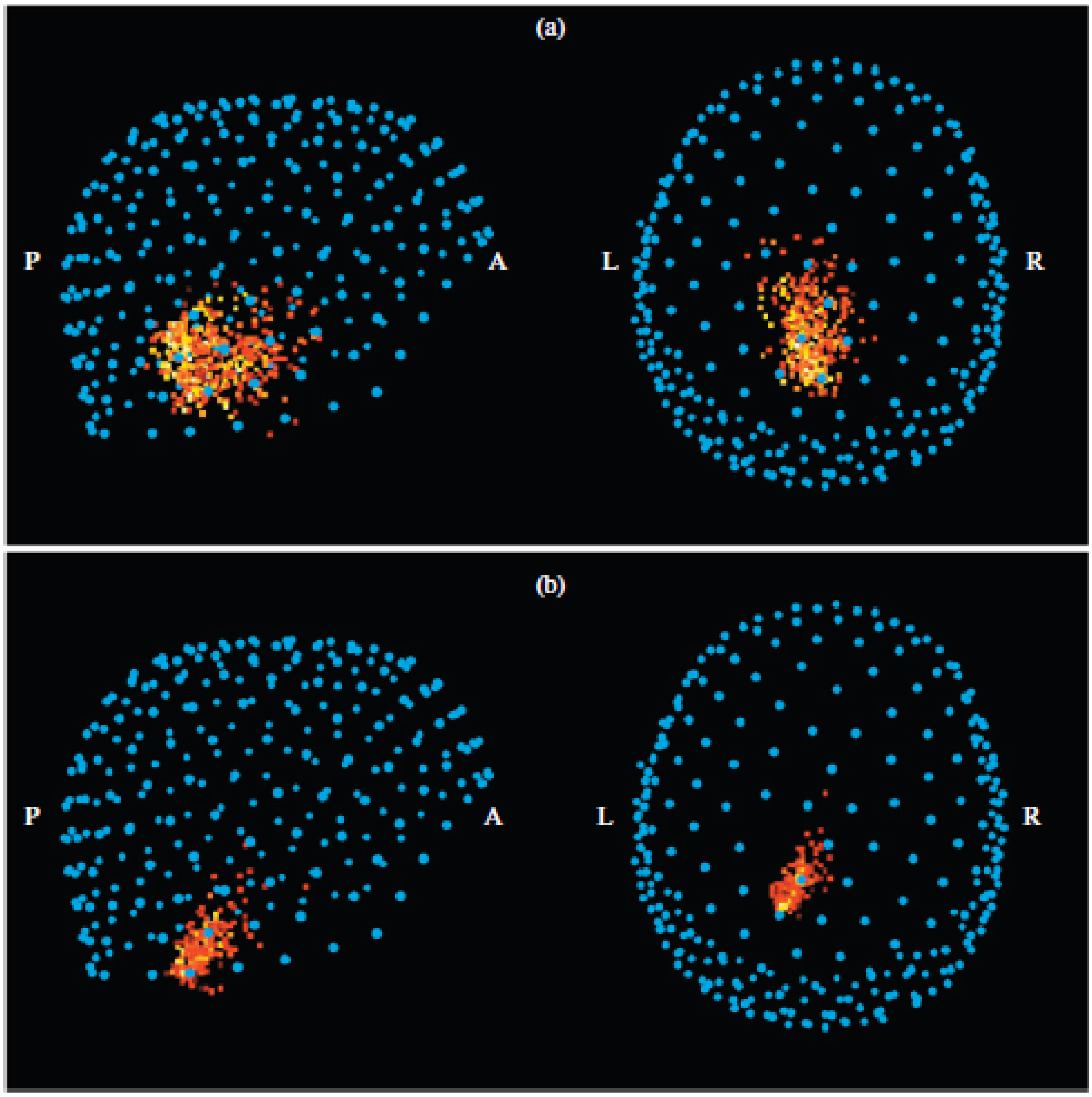

Fig. 3. Functional tomogram in different frequency bands. Panel A shows a functional tomogram in the 8–13 Hz band (alpha-rhythm). Panel B shows a functional tomogram in the 30–100 Hz band (muscle activity) [20].

A functional brain tomogram was chosen for demonstration. The method for calculating such functional tomograms is described in detail in [21].

Magnetic encephalogram (MEG) recordings were obtained from a healthy adult male subject, 32 years of age, at the Center for Neuromagnetism at New York University School of Medicine. The subject was asked to relax but remain awake during the 5-minute recording. The recording was made in the “eyes closed” state. Three reference markers were used to determine head position during recording (one each on the right and left preauricular points and one on the bridge of the nose). Magnetic encephalogram (MEG) measurements were taken in a magnetically shielded mu-metal room on a 275-channel magnetic encephalograph (CTF Systems), with the subject sitting upright, and the sampling rate was 1200 Hz. A 3rd order synthetic gradiometer was used to suppress artifacts and distant noise. The instrument's own noise and distant noise were recorded before each measurement session.

The magnetic encephalogram was analyzed using the functional tomography method, based on the Fourier transform and solving the inverse problem for all frequencies. In this method, each frequency component is assigned one spatial position.

The next stage of the analysis was segmentation of magnetic resonance imaging (MRI), the result of which is an annotated three-dimensional map of the brain, in which each elementary cell (voxel) of the tomogram has a sign of belonging to one or another part of the brain.

A voxel mask of the brain was constructed and its intersection with the full functional tomogram was plotted. The result was a list of all sources related to the brain. In the next step, all unique source positions were found, and the sums of powers were calculated for them. To graphically display the obtained power values, a LUT table was built that connects power and color.

The Blender software package was used to construct the three-dimensional representation. The coordinates and color values of the elements of the functional tomogram were transferred to it, from which a three-dimensional scene was constructed using the blenderplots library [22].

When using 3D scene data as initial data for constructing a stereo image, the following curious circumstance was revealed. Existing proprietary libraries for constructing stereo images were primarily focused on ordered data in certain areas. Similar data is provided by data visualization systems such as Tecplot. However, these systems are very poor at visualizing a disordered set of points. It was precisely this data, visualized in the Blender visualization system, that needed to be used to construct a stereo image in this task. This problem was solved by reorienting the author's libraries for constructing stereo images to work with data obtained using Blender. On the one hand, this circumstance brought certain difficulties to the work, but on the other hand, it significantly expanded the capabilities of existing proprietary libraries for constructing stereo images and the proprietary software package StereoMaker 2.0, designed for constructing stereo images with accompanying objects (labels, additional icons, etc.).

As a result, an image was constructed that was adapted to be presented in multi-view mode on an autostereoscopic monitor.

Figure 4. Frame of an autostereoscopic monitor for visualizing the results of a functional tomogram

To construct the multi-view image presented in Figure 5, a special composite frame was created, when demonstrated on an autostereoscopic monitor, the user could see the modeling results in a three-dimensional and informative form.

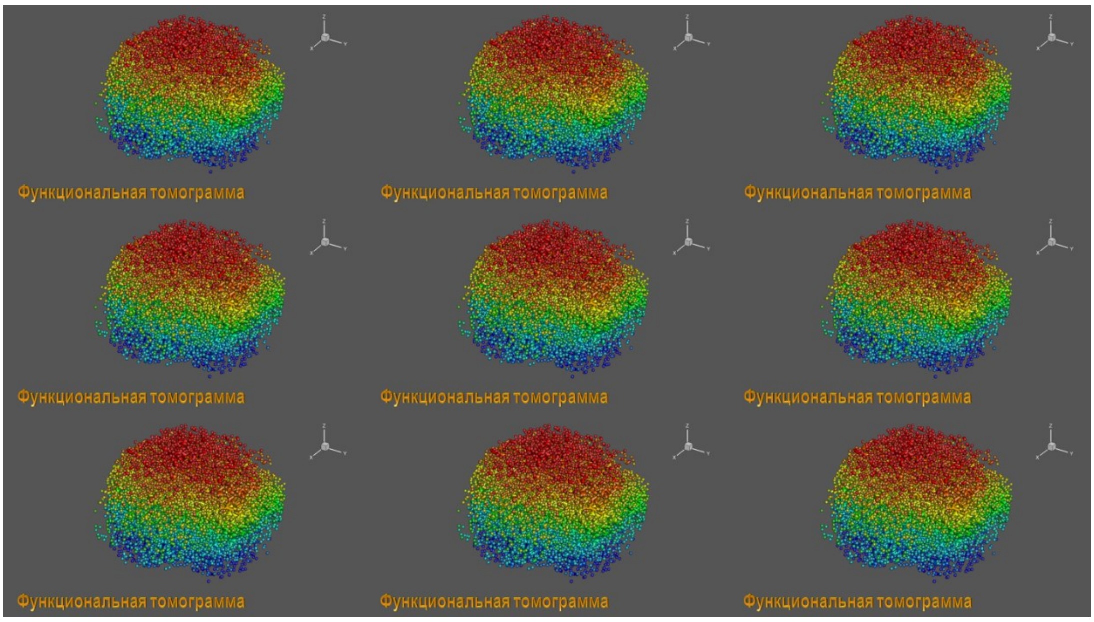

Figure 5. The resulting composite frame of an autostereoscopic monitor for visualizing the results of modeling a functional brain tomogram

4. Conclusion

This work is a continuation of a series of works devoted to the implementation of a project to study and construct stereo images of the results of solving mathematical modeling problems. The construction of stereo frames was carried out in a previously developed mode of combining the main image object and the corresponding text inscriptions and designations in one stereo frame. The constructed stereo frames provide the researcher with the opportunity for a deep and thorough visual analysis of the results obtained. The results of work on constructing a functional tomogram of the brain on an autostereoscopic monitor are presented.

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