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Stereoanimation in Maxillofacial Surgery

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Abstract

The work is devoted to the application of previously developed algorithms and methods of stereo imaging in the field of maxillofacial surgery. Construction of stereo images can be useful for solving the problem of visual aids in medicine. Such problems arise when teaching students of medical universities, at doctors' advanced training courses, at councils when discussing specific plans and methods of treatment with patients, when holding international medical conferences, when solving problems of telemedicine. The work is based on the developed algorithms and software tools for representing 3D objects in stereo mode on modern autostereoscopic monitors. Test examples of three-dimensional 3D animations of the results of real CT scans of patients are constructed and presented as illustrations. A similar approach can be used for virtual volumetric 3D visualization of human organs in various fields of medicine.

Keywords: maxillofacial surgery, stereo-animation, auto-stereoscopy, visualization systems.

1. Introduction

Vision is the main source of information about the surrounding world, a person receives through the visual analyzer (eyes) more than 80% of conscious information [1]. For example, medical students in their initial courses are taught about the normal anatomy and physiology of the human body. For this purpose they hold lectures and seminars with the use of photos, videos, visual aids and materials. Students need to understand the mutual arrangement of organs and tissues, but this often causes difficulties for students when using flat images in textbooks and atlases (see Fig. 1, 2).

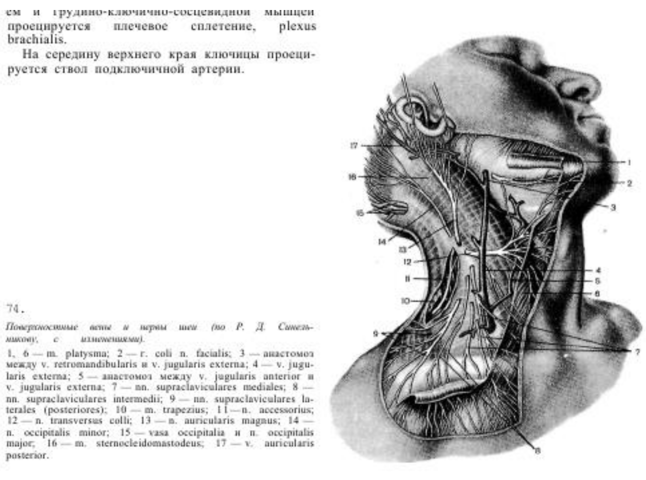

Fig.1. Illustration from a textbook for medical students [2].

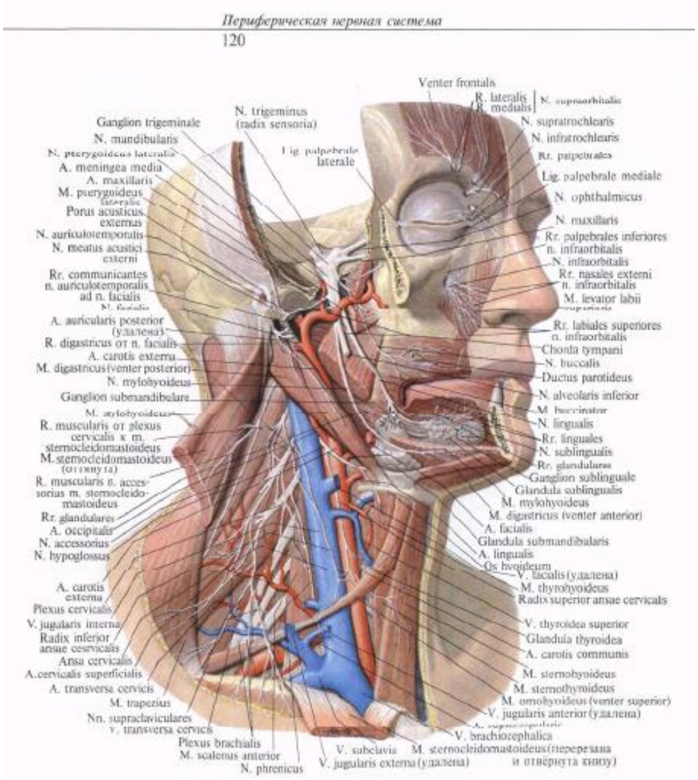

Fig.2. Illustration from anatomical atlas [3].

To improve students' perception of the taught material, they also conduct classes in the anatomy room or, for example, use visual models made of plastic (Fig. 3). However, problems often arise. For example, teachers can have a hard time teaching large numbers of students in the anatomy lab when every student needs to see the object of study, and the plastic models sometimes cannot show the relationship of anatomical structures in all its complexity. In addition, plastic models are often structurally complex and their parts often get lost or fall into disrepair.

Fig.3. Model of the skull [4].

After receiving a diploma, a physician must specialize and renew his or her qualifications every 5 years. Throughout his or her professional career, the doctor must attend training courses and keep his or her knowledge up to date. Often, training courses include video broadcasts from an operating room, which, for obvious reasons, cannot accommodate all trainees. Similar difficulties arise at international medical conferences with a large number of participants from different countries.

However, the current level of development of visualization tools and algorithms allows to use computer technology in medicine to solve such problems.

2. Advantages and Use of Modern Volumetric Computer Imaging in Medicine

Introduction of stereoanimation - a method of visual presentation of information in volumetric form - opens up promising opportunities in the field of medical students training, postgraduate training of doctors, conducting remote medical consiliums and even conferences. The use of stereo-animation is a new level of mutual understanding between a doctor and a patient at the stage of preoperative preparation and planning of surgical treatment.

Volumetric visualization will allow to understand better the relative positioning of organs and tissues, thus avoiding the disadvantages of flat illustrations in textbooks and atlases. In some cases it is impossible to show anatomical structures in full size on plastic models, which can be easily solved by the scalability of virtual images. With the help of stereo-animations one can clearly show deep anatomical structures which are difficult to highlight on anatomical preparations (cadaverous material). Another advantage of stereo animation is that there is no need to create anatomical halls for demonstration and no need for specialized rooms for storing preparations.

The presence of equipment that creates a realistic three-dimensional image gives students the opportunity to better assess the proportions and relationships of objects in the operating field, which, for example, in dentistry and maxillofacial surgery is a decisive criterion, both for restoring a tooth with a filling, and when performing surgical movement of the jaw.

Also, in recent years, at international conferences it has become increasingly common to see reports without a speaker in the room: the content of the report and the speaker's video broadcast are displayed on screens that play back images in real time in parallel. It is difficult to overestimate the presence of realistic three-dimensional stereo image of some parts of the medical report in such presentations.

The maxillofacial region has a complex anatomical and topographic structure, and many methods for planning and visualizing treatment results for patients with maxillofacial defects and deformities have been developed to date, but planning reconstructive surgery in this area is still a non-trivial task.

The planning and execution of treatment in the maxillofacial region often requires the interaction of physicians from different specialties. For example, reconstructive surgery in the jaw region requires stepwise involvement of an orthodontist and a maxillofacial surgeon, who may be hundreds or even thousands of kilometers apart. The use of volumetric imaging would radically reduce the number of patient transfers from one locality to another, i.e., be used as a means of telemedicine.

Reconstructive surgeries of the facial skeleton are often performed not only for functional, but also for aesthetic reasons (to eliminate a hooked nose, reduce the size of the lower jaw, increase the cheekbones), and the doctor and patient sometimes need a fair amount of time to come to an understanding of the compromise between the patient's wishes and medical capabilities. Today, doctors for this purpose draw pictures on paper, create temporary structures on the teeth, use computer modeling in specialized software, and make stereolithographic models for treatment planning. Despite the use of all methods of visualization of the planned treatment, the patient may be dissatisfied with the aesthetic result. In such cases, stereo imaging can provide an objective tool for evaluating the treatment.

Thus, the application of stereoanimation is a new and promising method of visualization, which allows to increase the efficiency of training of medical students, interns, residents, and doctors undergoing advanced training. This method can also have clinical application in aesthetic surgery both for planning of surgeries themselves and for presentation of a visual treatment plan to patients.

3. Applications in medicine of modern systems of visualization of objects in volumetric representation

It should be noted that the practical application of the joint work of scientists, specialists in various fields of science, such as, for example, medicine, computer graphics, mathematical modeling, is quite in demand and is of great importance. For example, the algorithms and practical application of mathematical methods in dentistry are described in [5-8].

In this paper, we consider the possibility of applying three-dimensional volumetric imaging in maxillofacial surgery using modern imaging systems to practically solve the problems described in the previous chapter.

Wide spread of modern systems allowing to visualize objects in volumetric view has generated great interest to development of practical algorithms of stereo representation of static and animated images which is reflected in works [9-12]. Nowadays stereo visualization arouses interest both in entertainment sphere (3D movies in cinemas on a big screen, widespread distribution of household smart TVs allowing to watch 3D movies using special glasses at home) and in scientific sphere using modern computer systems and technologies.

Note that quite a number of computer programs used by doctors, for example, to visualize the results of computed tomography of patients, allow representing research objects in three-dimensional stereoscopic view (i-CAT Vision [13], OnDemand3D Viewer [14], RadiAnt Dicom Viewer [15]). Thereby confirming the importance of such representation in medicine. However, all these programs use rather primitive methods of volumetric visualization using the anaglyph method [16]. Using anaglyph requires practically no special equipment other than cheap, readily available anaglyph glasses (Fig. 4) and allows the use of an ordinary computer monitor.

Fig.4. Cardboard anaglyph glasses.

In this case, the image displayed on the screen when observing without such glasses looks blurred (Fig. 5).

Fig.5. Example of an anaglyphic image.

But the use of anaglyph method has low quality of visualization, and has other significant drawbacks, which is problematic for practical application in medicine to solve the problems described above. The main disadvantage of the anaglyph method is its unsuitability for visualization of color images. In this case after a short-term stay in anaglyph glasses an observer's color sensitivity decreases for quite a long time, a headache occurs and a feeling of discomfort from perception of the usual world appears.

The use of modern systems for representing objects in the volumetric view allows to solve the problems described in the previous chapter, devoid of such drawbacks, and even there are devices that allow displaying visualization in the volumetric view without the use of additional devices such as stereo glasses or helmets. Thus, in works [17-18] in particular described methods of developing algorithms for volumetric visualization of results of mathematical scientific calculations on such devices as autostereoscopic monitors. Using autostereoscopic monitors not only to visualize the results of scientific calculations, mathematical modeling, but also in medicine, in particular in maxillofacial surgery, dentistry and other areas of medicine, is, according to the authors, an important and promising direction, allowing to solve the problems described above in practice, when used to teach medical students, postgraduate training for doctors, conducting remote medical consultations, conferences and as a tool of telemedicine.

4. Autostereoscopic monitors

The principle of operation of autostereoscopic monitors is described in sufficient detail in [17]. The technical side of the principle of autostereoscopic equipment is the use of parallax baffles or Fresnel lenses, installed behind the protective glass of the screen (Fig. 6).

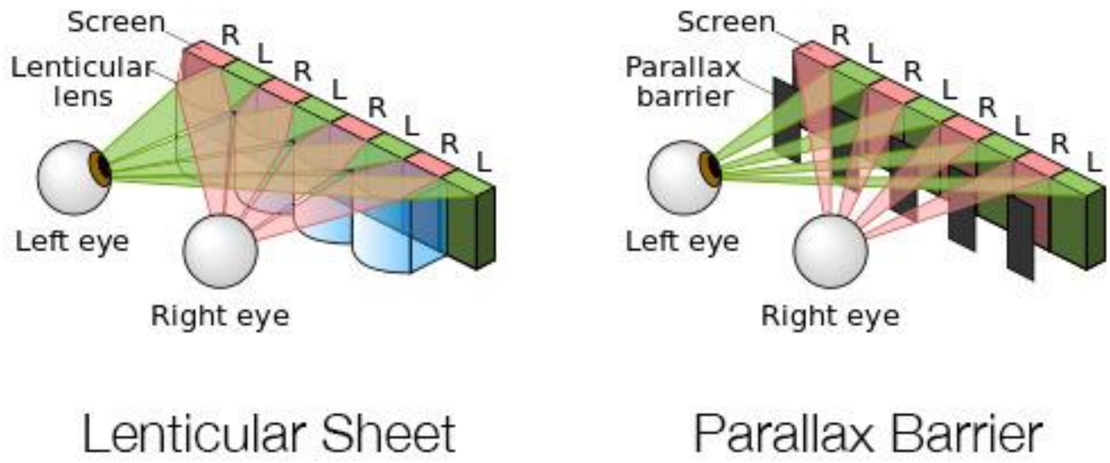

Fig.6. The principle of operation of the autostereoscopic monitor.

Such monitors allow viewing stereo images by providing several fixed segments in space for observation, and the viewer can move from one segment to another, getting the opportunity to view the demonstrated object in 3D from different viewing angles. When the observer's head is in a certain position in front of the autostereoscopic monitor, his right and left eyes receive different images (stereo pair). In this way, a convincing illusion of 3D depth is created. At the same time, as mentioned above, there is no need for viewers to use any additional devices for observation in the form of special stereoscopic glasses.

The most important feature of the autostereoscopic monitor is the ability to demonstrate the visualization object using a composite frame containing views of the visualization object at different angles, forming a specific sector of view (Fig. 7).

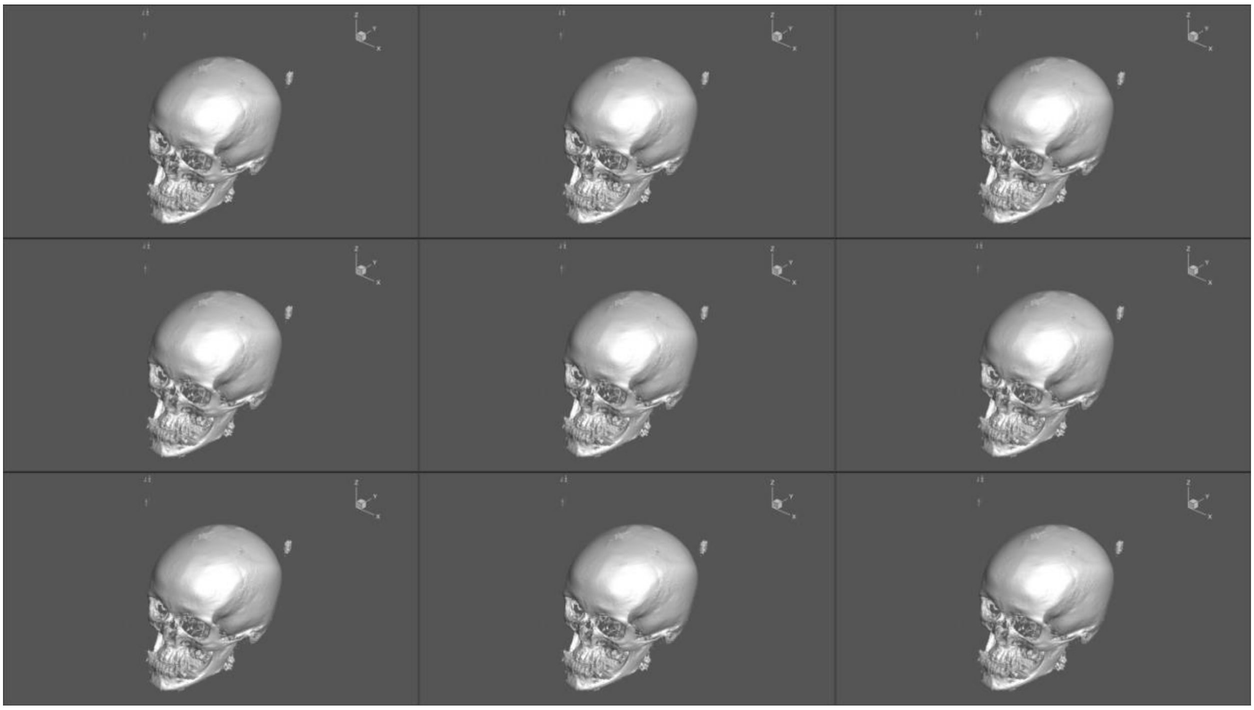

Fig.7. Composite frame of autostereoscopic monitor for visualization of CT scan results.

It should be noted that this type of representation of visualization object in the volumetric view on autostereoscopic monitor screen provides maximum quality compared to conventional stereoscopic representation, not to mention the anaglyph method, allowing to view objects in a sufficiently wide sector of view. These nine views form eight stereo pairs ([1|2], [2|3], [3|4],..., [8|9]) and an observer can view only one of the stereo pairs depending on their position in a particular sector of view. Moving from sector to sector, the observer receives volumetric information about the object, using all nine perspectives, that is, as if looking back, for example, the results of computer tomography from different sides.

5. Creating and using stereo animations for displaying on an autostereoscopic monitor

It should be noted that so far we have described advantages of visualization of above described example of computer tomography on autostereoscopic monitor screen only for static image. But invaluable contribution is creation of stereo-animations for displaying on the screen of autostereoscopic monitor for practical application in medicine, i.e. creation of full multiframe video films, each frame of which is composite, consisting of 9 kinds of object. At the same time the operator of the stereo unit can pause the animation demonstration at any moment (e.g. for comments of the lecturer during demonstration, at the request of viewers or giving viewers an opportunity to "look around" an important detail of the demonstrated organ from different points of view when moving viewers to different viewing sectors in front of the plane of the monitor).

At the same time, there is a problem of obtaining and processing the huge amount of data needed to build such animation. For example, a normal movie in PAL video format implies using 25 frames per second, and even 30 frames per second in NTSC video format. In addition, it should be remembered that, as mentioned above, each frame for an autostereoscopic monitor consists of nine ordinary frames, but each of these nine ordinary frames is a new kind of object. As a result, even when creating a one-minute video film for the autostereoscopic monitor in PAL format we need to have 13500 frames.

But, as indicated in [18], the authors have found a solution for a similar problem arising in the visualization of the results of scientific calculations and called by the authors "method of camera flying" around the object. This solution consists in the use of angular stereobase (Fig. 8) and the method of reuse of already obtained frames.

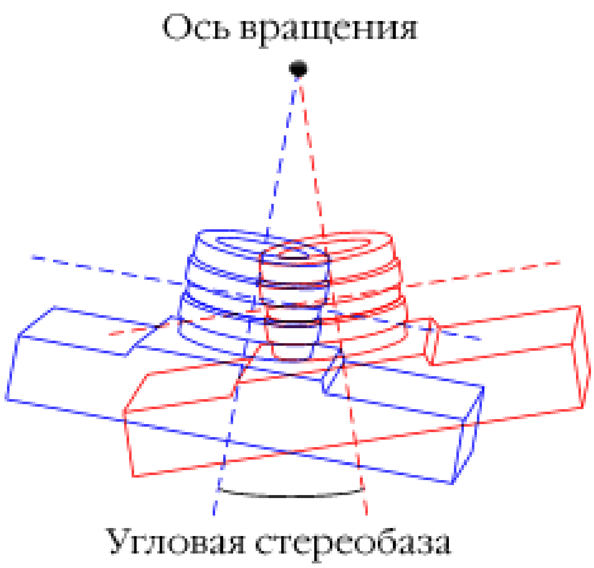

Fig.8. Angular stereo base.

Indeed, in the case of a one-degree angular stereobase and with a successive displacement angle around the OZ axis, we obtain that the first frame consists of a sequence of perspectives with a successive change of the camera angle:

1	2	3
4	5	6
7	8	9

the second frame will look like this:

2	3	4
5	6	7
8	9	10

accordingly, the third frame will look like:

3	4	5
6	7	8
9	10	11

and so on. The last frame having the form:

360	1	2
3	4	5
6	7	8

will allow to loop the sequence of views, and having only 360 monoframes, it is possible to obtain any long rotation of imaging object in multiview representation on autostereoscopic monitor screen. Of course, as our experience [17-18] shows, 360 frames is not enough to obtain a high-quality volumetric visualization, and we used in practice a finer breakdown of the full rotation of the object around the axis, but the principle of camera overflight remains the same.

This solution is also applicable in the case of creating multiview stereo animation for autostereoscopic monitors for volumetric visualization of medical data. For example, creating a stereo animation of the results of computed tomography of the patient's head in maxillofacial surgery.

Fig.9. Computed tomography of the maxillofacial region.

The result of computed tomography is essentially a set of graphic files, each of which represents a view of a "slice" of a patient's organ. There are quite a number of software tools used in medicine that allow transforming these slices of CT results into a three-dimensional model to be used in CAD systems (Visurgery [19], Implastation [20]). Thus it is possible to obtain a certain view of an object from a given point of observation, with possibility to save this view as a certain part of a composite 9-view frame for stereo-animation.

Of course, it is impossible to apply this camera-overlapping solution to all practical applications of this technology. So, quite often it is necessary to create a volumetric animation for gradual enlargement of a particular local area of the patient's organ in order to consider the features of this area in detail. In such cases, the solution described above is not applicable, but the authors have created an additional set of software tools to automate the process of creating the required set of composite multispecies frames. The use of the created tools does not significantly reduce the time required to calculate the composite frames, as with the camera overflight method, but it does not require manual intervention and control.

6. Practical results

The authors investigated the possibilities of practical application of stereo-animation technology for several real cases in maxillofacial surgery. A Dimenco DM654MAS autostereoscopic monitor [17] inKeldysh Institute of Applied MathematicsRussian Academy of Sciences, was used as a volumetric visualization device. The monitor was used in the imaging mode using a composite frame containing views of the imaging object at different angles, providing maximum quality.

Real results of computed tomography of several patients were used as test imaging objects. When creating stereo-animations both camera overflight method and specially created software tools for automation of creation of multidimensional composite video frames were used.

In most cases (Fig. 10, 11) we were able to successfully apply the method of camera overflight to create volumetric visualization of CT scan on autostereoscopic monitor screen. Figure 10 shows the results of computed tomography of craniofacial part of a patient visualized in volumetric form on the screen of autostereoscopic monitor. Figure 11 is a composite frame of such imaging.

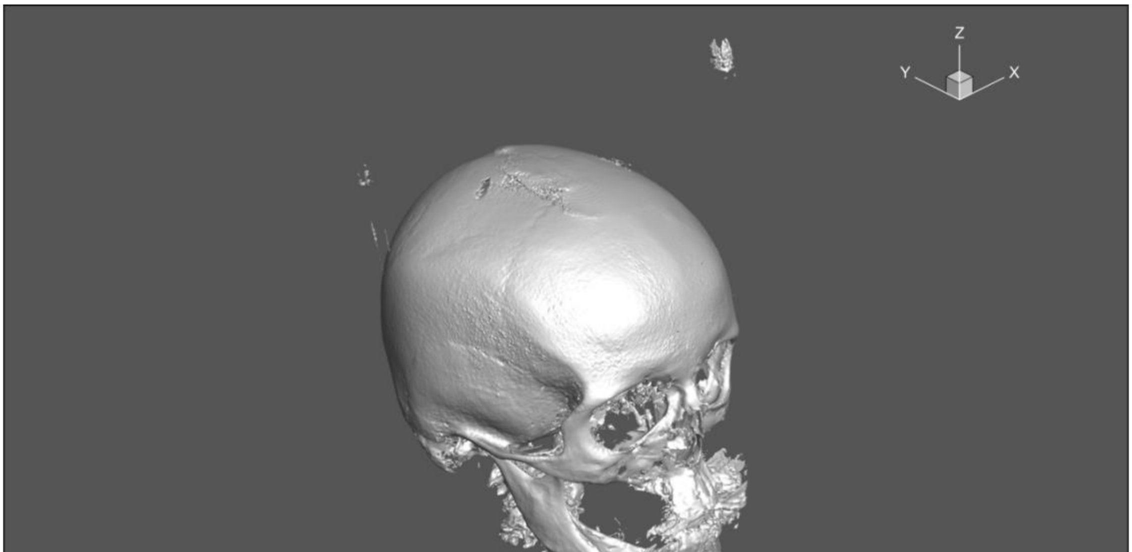

Fig.10. Volumetric stereo-animation of computed tomography of a patient created using the camera flyover method.

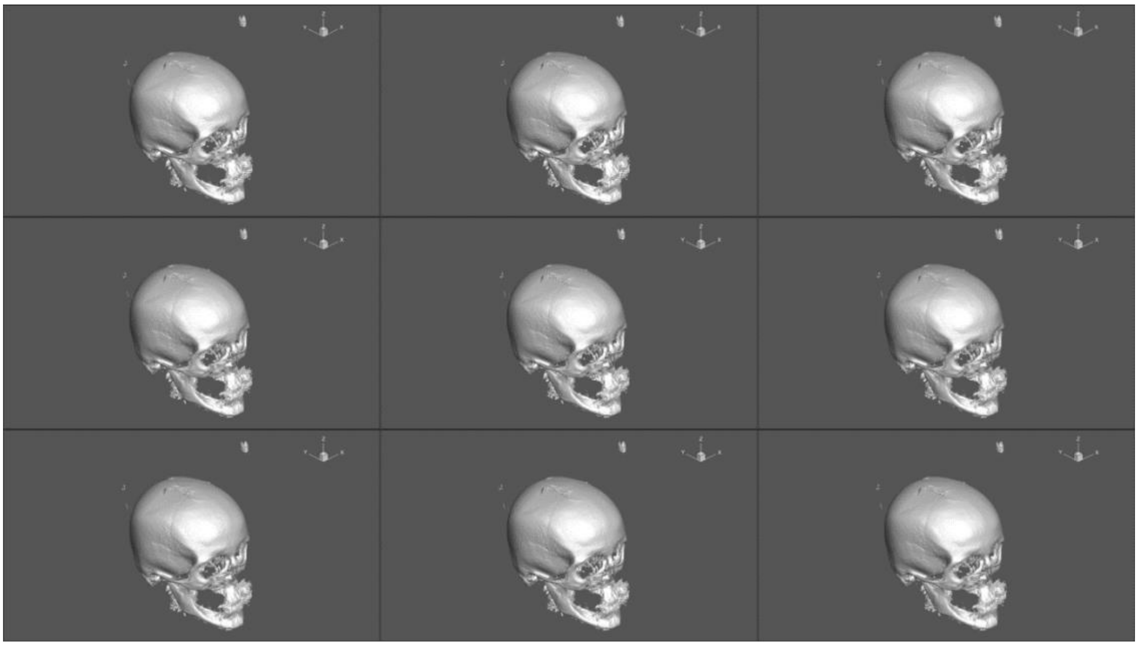

Fig.11. Example of the resulting composite frame.

In this case, most often there was no need to increase the individual areas of the visualization object, which can significantly reduce the time to calculate the composite animation frames.

In other cases, when a more detailed study of individual areas of the organ of the object of medical research was required, a set of software tools created by the authors was successfully applied (Fig. 12, 13, 14).

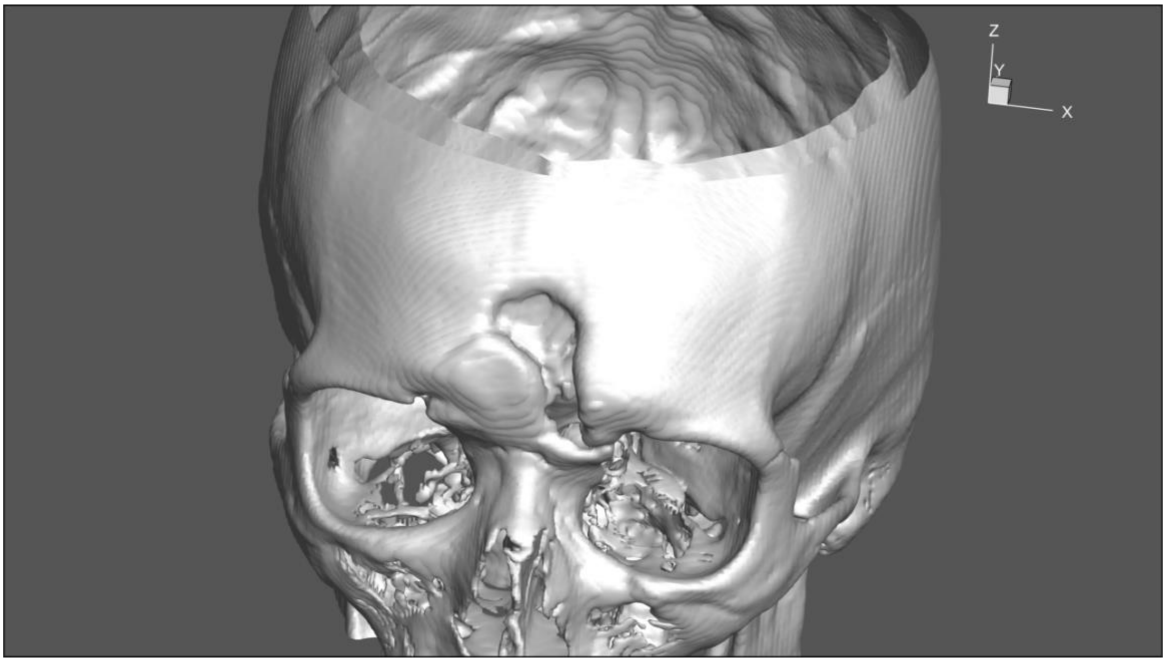

Fig. 12. Volumetric stereo animation visualizing the patient's frontal bone defect.

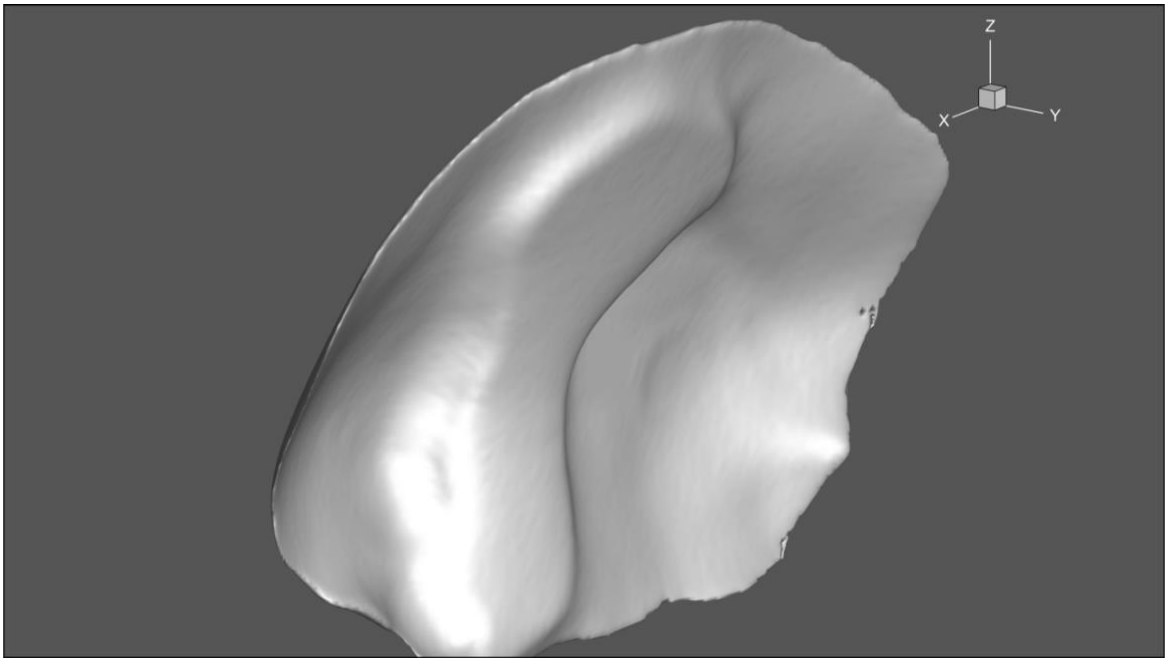

Figure 13: Volumetric imaging of a Teflon implant to correct a defect, reverse side.

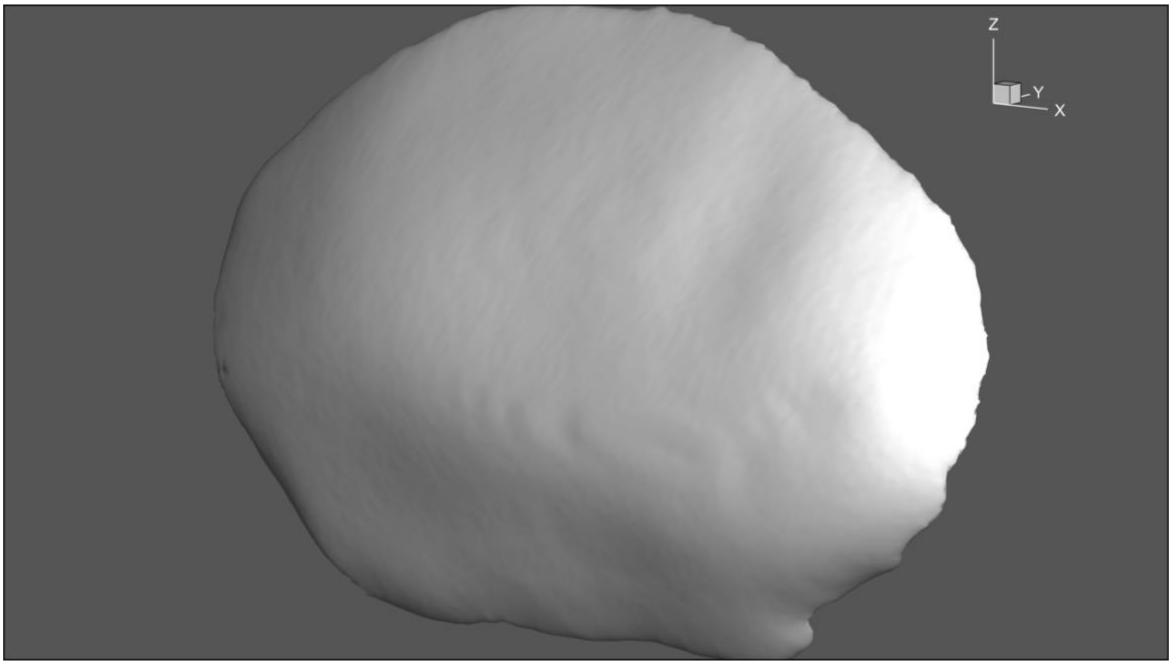

Figure 14: Volumetric imaging of a Teflon implant to correct a defect, frontal side.

Figure 12 is a volumetric imaging CT scan of a patient with a frontal bone defect. Figures 13 and 14 are volumetric renderings of a Teflon implant created to correct the defect on the dorsal and frontal sides.

7. Conclusion.

The use of stereo-animation is a new and promising method of visualization, which allows to increase the efficiency of training of medical students, interns, residents, and doctors undergoing advanced training. This method can also have clinical application in aesthetic surgery both for planning operations and for presenting a visual treatment plan to patients. The use of modern devices for three-dimensional visualization, such as autostereoscopic monitors, which provide the highest quality of presentation of graphic information in 3D, significantly improves this process and ensures comfortable perception of visual information by specialists.

The algorithms and software used by the authors to create stereo animations in maxillofacial surgery on stereoscopic monitors can also be used in other fields of medicine.

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