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The problems of stereo animations construction on modern stereo devices

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Abstract

This paper considers the problems of constructing stereo images and stereo animations with the help of modern stereo devices. The paper represents a part of the results of a general project for organizing stereo-animated presentation of computed results for mathematical physics problems. The creation of such animations is, as a rule, the final stage in the development of computational technologies for obtaining and presenting the results of modeling complex physical processes or the operation of complex technical devices. The paper presents practical experience in constructing stereo animated presentations. The results of the animations for the classic two-projector device with polarizing glasses and for autostereoscopic monitors that do not require glasses for viewing stereo animations are presented. In the latter case, the experience of using such methods as the construction of depth maps and multi-view frames is presented. Also the paper presents the experience of constructing textual information, namely, texts and formulas, in stereo presentations for a classic two-projector device.

Keywords: stereo animation, depth map, multi-view frame.

1. Introduction

The emergence, development and improvement of modern stereo devices, both passive and active types, made it possible to build stereo-animated presentations of scientific research results. The significance and relevance of new opportunities opened up by using stereo systems cannot be overestimated. Presentation of the numerical modeling results, reflecting the flow of complex physical processes in time or showing the operation of complex technical systems in a three-dimensional representation, allows a lot. First, the three-dimensional representation of the process development over time helps to verify the computational model and the algorithms used. Secondly, it provides the observer with a full understanding of the phenomenon being modeled. And finally, it promotes the research and its results for society, including for decision makers. All of the above makes theoretical and practical developments in the field of constructing stereo representations very important.

With the emergence and development of stereoscopes, more and more papers began to appear on the issues of constructing stereo images. It is possible to refer to similar articles [1,6-8].At first, most studies in the field of stereo images were related to the tasks of building virtual reality, simulators and training systems. However, the issue of building presentation complexes, which, among other things, made it possible to demonstrate the results of scientific research in stereoscopic mode, became very topical later [2-4, 11]. In [3], the results of the display of the Supernova explosion in stereo mode are presented. The article [11] presents the methods of stereovisualization for the task of displacing oil from porous media. The paper [4] is devoted to the creation of computational technology for modeling the operation of a three-dimensional node of the blades of a power plant with a flow past a viscous compressible heat-conducting gas. The construction of animated stereo representations of the calculation results was one of the important components of the developed technology.

2. Modern systems of image demonstration in volumetric representation

In general, systems for displaying images in a volumetric representation (stereo) can be divided into two main types: passive and active. Passive complexes are intended for demonstration of material according to a predetermined scenario, when the viewer is deprived of the opportunity to influence the process of the show; active (or interactive) complexes are distinguished by the fact that the viewer in some way influences the process of showing the displayed material.

Common to all these systems is the presence of a large screen (and even several screens), so the typical monitor resolution is often not enough to generate a frame displayed on the stereo screen. In addition, such systems should provide a display in a three-dimensional representation, that is, in stereo mode, when each frame is generated separately for the left and right eyes (right and left stereo channels). Thus, the requirements for computing resources for generating frames are doubled. Often, such stereos are not controlled by a separate computer, the power of which is not enough to generate frames in real time, but by a system of computers connected to a local network and providing composite stereo frame output on several screens. Specific problems that arise when using a computer system for generating and visualizing a composite multi-screen stereo frame, and methods for solving such problems are described in detail in [1,2].

The gradual spread of modern stereos has generated great interest in the development of practical algorithms for the stereo presentation of static and animated images, which is reflected in [3, 5 - 7]. This work relates to the general topic of building stereo images and stereo animations of the results of mathematical modeling of complex technical objects and physical processes in continuous media. This work presents a practical experience in stereo animations constructing for specific devices for devices available in Keldysh Institute of Applied Mathematics (KIAM RAS). The first type of device is a 3D projection stereo system for displaying stereo presentations, educational applications, graphics and films. This device includes a graphic station, a projection subsystem of two projectors (with a specialized screen), and a speaker system. This system is a classic stereographic system using two projectors, a screen and linear polarization glasses.

When creating stereo pairs required for stereo film frames, systems of this type use either linear or angular camera displacement, that is, linear or angular stereo base. In most cases, the linear stereo image is used when rendering objects of the scene with a far distant background. Linear displacement is used quite rarely, since most often you need to get an idea about the object of visualization from all sides.

In most cases, the result of the calculations is a rather encapsulated object that is not attached to the environment, such as a part of an airplane or a car. And first of all it is important for viewers to inspect this object from all sides. In such cases, angular displacement, i.e. angular stereo base, is applied. Most often, the center of spatial coordinates located inside the object is determined, and the angular displacement of the camera occurs.

In order to show the object of visualization from all sides, it is enough to fix the distance from the camera to this center of coordinates and make a full rotation of 360 degrees in the horizontal plane around the vertical axis OZ, successively changing only the angle. As a result, we get a stereo effect for the visualization object that "hangs in the air", and object center of coordinates is at a distance from the viewer's eyes to the screen plane.

The second type of device is a Dimenco DM654MAS autostereoscopic monitor. Autostereoscopic monitors provide stereo images show without the need to track the observer’s position, that is, there is no need to adjust the equipment depending on the observer’s position - as a rule, such monitors allow you to observe stereo images, providing several fixed segments in the observation space, so the viewer is able to see the displayed object in 3D from different angles of view. The principle of operation of an autostereoscopic monitor is the use of parallax partitions or Fresnel lenses installed behind a protective glass screen.

One of the most important advantages of autostereoscopic monitors is the fact that viewing images on such devices does not require the use of special glasses. In past years, installations of this type could not provide the quality of a stereo image, comparable to the classic two-projector projection stereoscopic images. However, modern devices make it possible to build stereo images on high-quality stereoscopic monitors, in no way inferior to classic projection installations. The (Fig. 1) shows the modern Dimenco autostereoscopic monitor with the following technical characteristics:
1) Weight - 72 kilograms;
2) Screen diagonal - 65 ”(165 cm);
3) Resolution - 3840 × 2160.
This monitor was used to build some of the stereo images presented in this article.

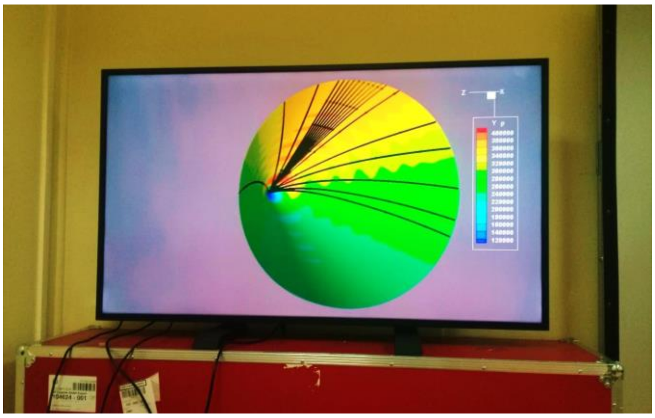

Fig. 1. Autostereoscopic monitor Dimenco DH654MAS.

To build a stereo frame on an autostereoscopic monitor, such methods are used as the construction of depth maps or the construction of a multi-view frame.

Next, we consider a number of methods and approaches used in our research for the practical construction of stereo animations on both types of modern stereos described above.

3. “Camera flying around " method with using angular stereo base

When creating stereo pairs required for frames of stereo animation, either linear or angular camera displacement is used, that is, linear or angular stereo base. In most cases, to visualize the results of calculations, it is necessary to consider the object of visualization from different sides, therefore, for these purposes, the most suitable method is “camera flying around the object" method with using angular stereo base.

Almost any CAD-system allows you to visualize a three-dimensional object with given coordinates of the position relative to the user. Therefore, the task is reduced to constructing a sequence of images of a CAD model with a fixed Z axis passing through its geometric center and offset by a certain angle. After each such shift, the model is rendered, which allows to achieve photorealism, and the result is saved as a graphic file in high resolution. For the left stereo channel, the initial position is set, which differs from the right stereo channel by the angle defining the parallax and allowing to achieve the volume of the object in the resulting stereo film. This method is also attractive because for a static model, that is, with a constant geometry and color distribution, it is possible to reuse already calculated frames, for example, if for the left stereo channel we use 1,2,3,4, ... frames, then for the right one a stereo channel is enough to start the sequence from the second or third frame (2,3,4,5, ...), automatically ensuring the object is shifted to the required stereo angle.

An additional gain of such a “camera flying around the object” method also consists in the fact that having only 360 mono frames you can organize a looping rotation of the visualization object in a three-dimensional view, that is, organize its continuous and arbitrary long time rotation, i.e. re-showing to the viewer all sides of the object (Fig. 2).

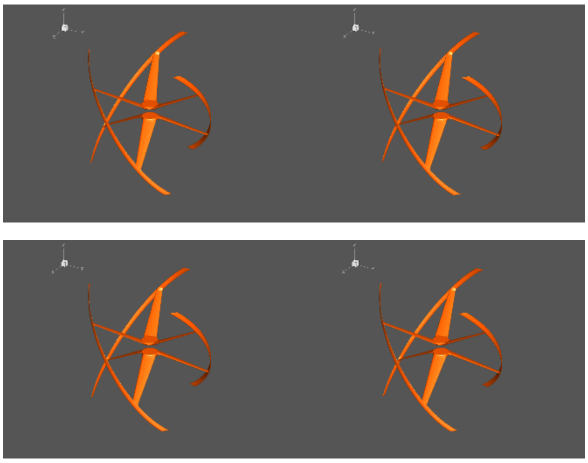

Fig. 2. Stereopairs with repeated use of calculated frames with angular displacement.

This method was successfully implemented when visualizing the modeling of the operation of a power plant with complex shape in the stereo-animation mode for both classical stereoscopic projection type and autostereoscopic monitor [4].

4. Depth maps

When creating a multi-view video for autostereoscopic monitors, there is a need to store a large amount of data - video streams for each angle. Even taking into account the fact that modern methods of digital video compression can effectively take into account temporal and spatial redundancy, the amount of data with multi-angle video increases many times. This is especially critical for autostereoscopic monitors.

One of the effective ways to solve the problem of large amounts of data is to use the so-called 2D + Z format. Any conventional (2D) image can be matched with information about the distance of each pixel from the observer (Z-coordinate). Such a representation of the image is called "2D + Z format", and the plane of the coordinates Z is called the "depth map". It can be represented as a monochrome image. In the depth map, grayscale indicates the distance of the image points from the observer. That is, the closest point to the viewer will turn white, and the farthest to black. Figure 3 below shows an example of the original image and its depth map.

Fig. 3. Original image and its depth map.

The 2D + Z format is a further development of the concept of representing image information by component. It is widely known that in analog and digital television the image is formed from brightness and two color components. Adding a depth map to these components, which characterizes the volume of the image, is a completely logical development and is quite consistent with the principles of compatibility.

The idea underlying the construction of a depth map using a stereopair is fairly obvious. For each point on one image, a pair point is searched for it on another image. And by a pair of corresponding points, you can determine the coordinates of their pre-image in three-dimensional space. Having the same three-dimensional coordinates of the pre-image, the depth is calculated as the distance to the camera plane.

The pair point must be sought on the epipolar line [8]. Accordingly, to simplify the search, the images are aligned so that all the epipolar lines are parallel to the sides of the image (usually horizontal).

Moreover, the images are aligned so that for the point with coordinates ($x0$, $y0$) the corresponding epipolar line is given by the equation $x = x0$, then for each point the corresponding pair point should be searched for in the same line in the image from the second camera. This process of image alignment is called rectification.
After the images are rectified, the corresponding pairs of points are searched.The simplest method is as follows: for each pixel of the left image with coordinates ($x0$, $y0$), a pixel is searched for in the right image. It is assumed that the pixel in the right picture should have the coordinates ($x0 - d$, $y0$), where d is a quantity called disparity. The search for the corresponding pixel is performed by calculating the maximum of the response function, which can be, for example, the correlation of neighborhoods of pixels. The result is a disparity map.
Below Fig.4 presents a stereo-animation of rotation for a synthesized image of a truck using a depth map.

Fig. 4. Stereo-animating the rotation of a synthesized image of a truck using a depth map.

It should be noted that this method of constructing a stereo image using a depth map when using it on an autostereoscopic monitor provides more opportunities for the viewer compared to conventional stereo animation, as the observer can view the image of the object from different angles using the logic of the monitor processor.

5. Composite multi-view frames

An autostereoscopic monitor also has the ability to show an object of visualization using a composite frame containing views of the object of visualization from different angles that form a certain viewing sector. Usually, the number of object views is nine (Fig. 5).

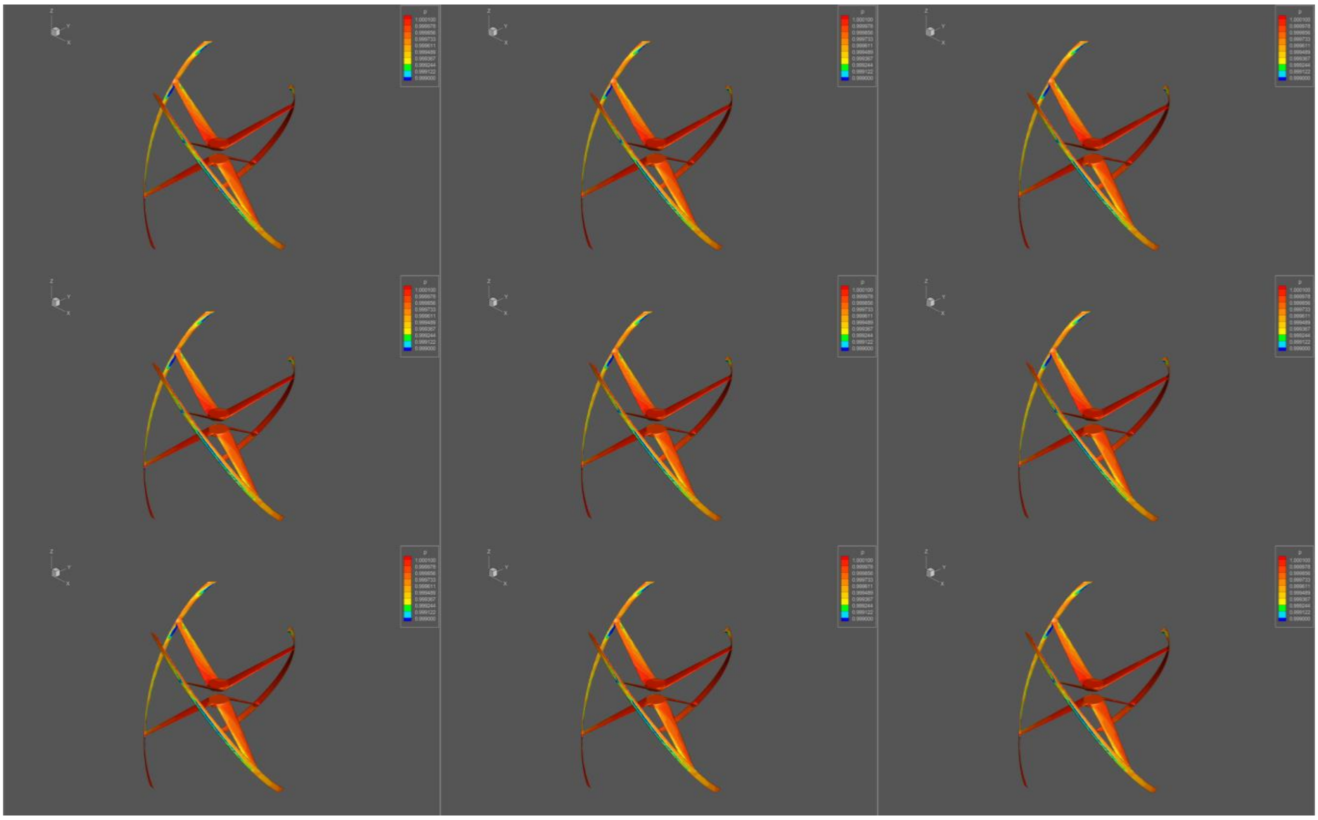

Fig. 5. Composite frame autostereoscopic monitor.

Moreover, these nine species form eight stereo pairs ([1 | 2], [2 | 3], [3 | 4], ..., [8 | 9]), and the observer can observe only one of the stereo pairs, depending on its position in angular sector of observation. Moving from sector to sector, the observer receives 3D information about the object, using all nine angles, that is, as if looking at the object of visualization from different sides. At the same time, we note that a "circling of the camera" actually occurs around the object, and, therefore, the same method of reducing the necessary for visualizing mono frames is quite applicable.

Indeed, in the case of an angular stereo base of one degree and with a consistent angle of displacement around the axis OZ, we get that the first frame consists of a sequence of angles with a sequential change in the camera fly angle:

1	2	3
4	5	6
7	8	9

the second frame will be:

2	3	4
5	6	7
8	9	10

accordingly, the third frame will be:

3	4	5
6	7	8
9	10	11

and so on. The last frame looks like

360	1	2
3	4	5
6	7	8

allows one to loop the sequence of angles, and, with a total of 360 mono-frames, you can get an arbitrarily long rotation of the object of visualization in a multi-angle view on the autostereoscopic monitor screen.

It should also be noted that this type of representation of the object of visualization in a volumetric form on the screen of an autostereoscopic monitor provides maximum quality compared to the usual stereoscopic presentation and even the method using depth maps, allowing you to view the object in a fairly wide viewing sector.

Building stereo animations using composite multi-view frames made it possible to achieve stereo quality on an autostereoscopic stereomonitor comparable to the quality obtained on a classical projection device. Because of this, the construction of multi-view frames has been applied in a whole range of computational technologies for various problems of mathematical modeling in the construction of stereo presentations of the results. We give below a number of examples illustrating the application of this approach.

This visualization method was successfully implemented when modeling the operation of a node of blades of complex shape in a power plant [4]. The construction of stereoanimation was an integral part of the computing technology organized in the form of a pipeline of algorithms: from building a CAD model to presenting the results of calculations in the stereo-animation mode (Fig.6). The overall goal of computing technology [4] was to find the optimal, from the point of view of force, characteristics of the blade node shape.

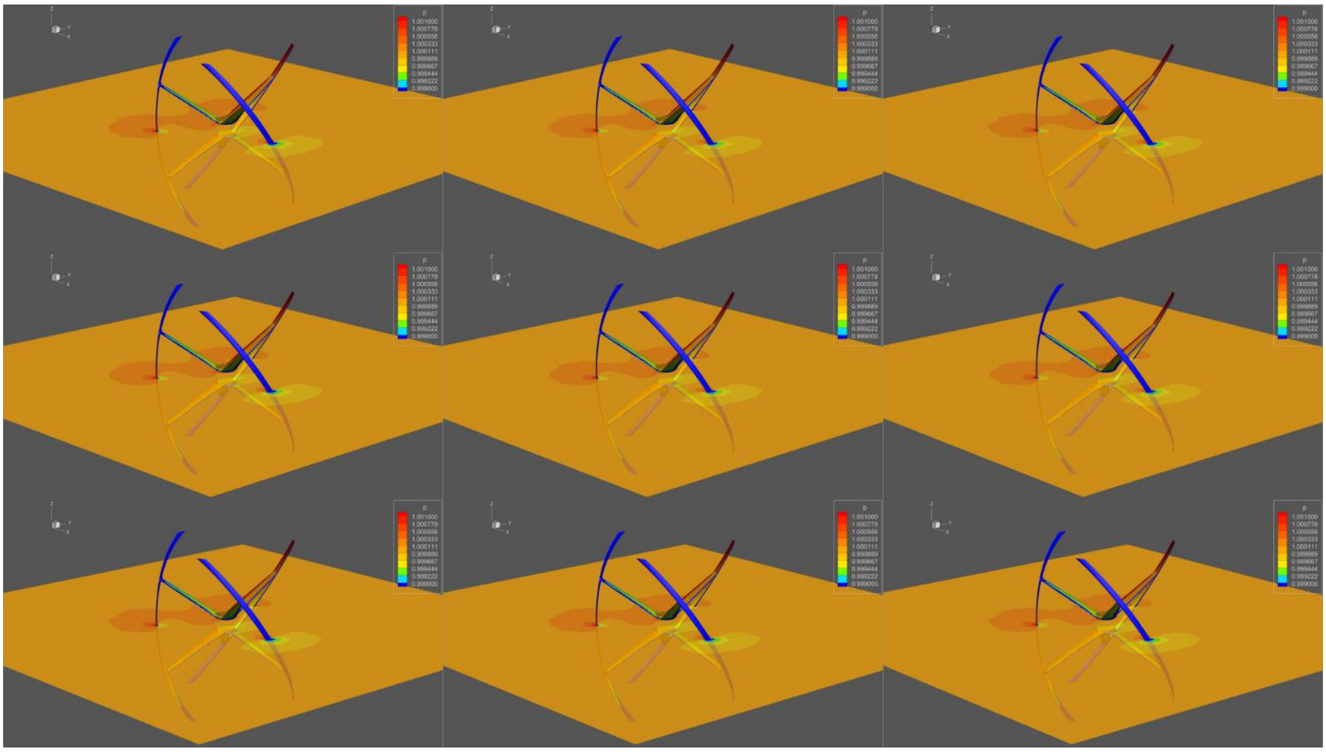

Fig. 6. A multi-view frame representing the simulation results for a wind turbine blade assembly.

Another example is shown in Figure 7, where a multi-view frame is shown for a blade node of another shape.

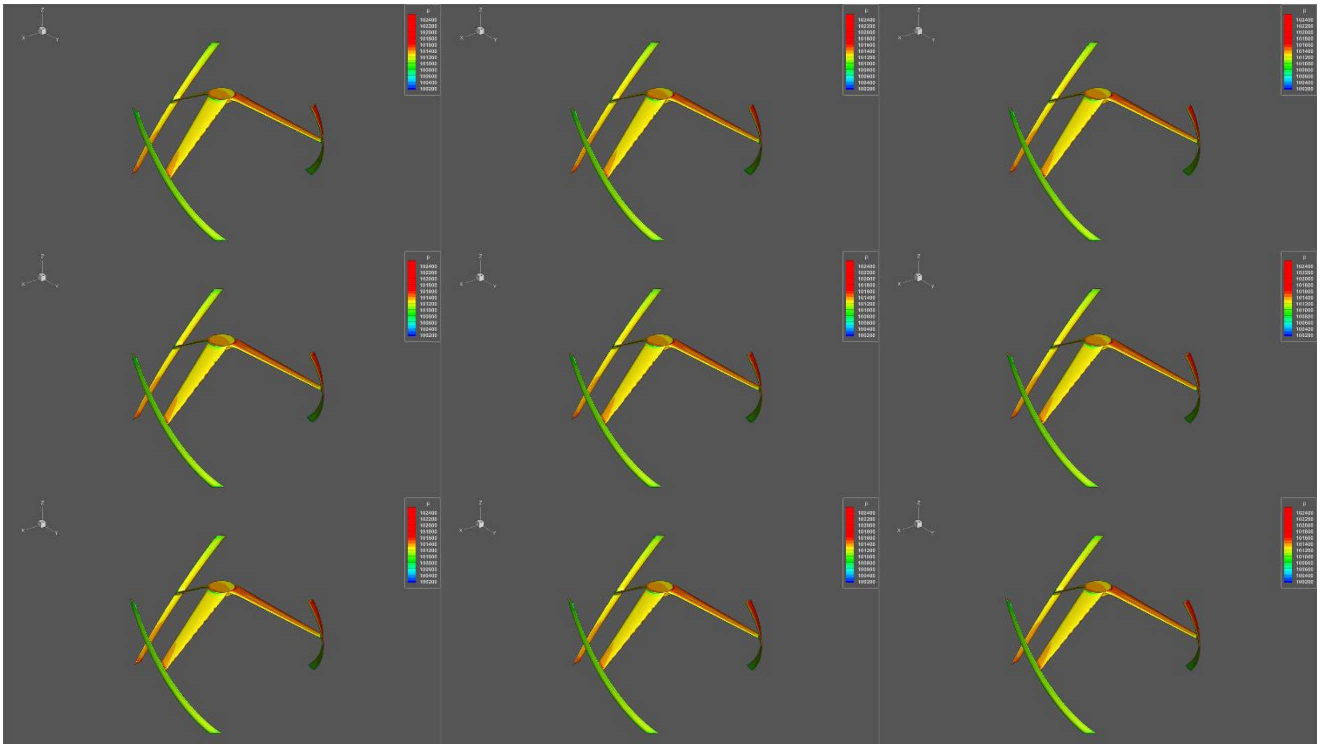

Fig. 7. A multi-view frame representing the simulation results of a different form of a wind turbine blade assembly.

Figure 8 shows a “multi-view” frame for stereo animation representing the results of a super-sonic flow around a cone at an angle of attack. The figure shows the distribution of pressure on the surface of the cone and the streamlines.

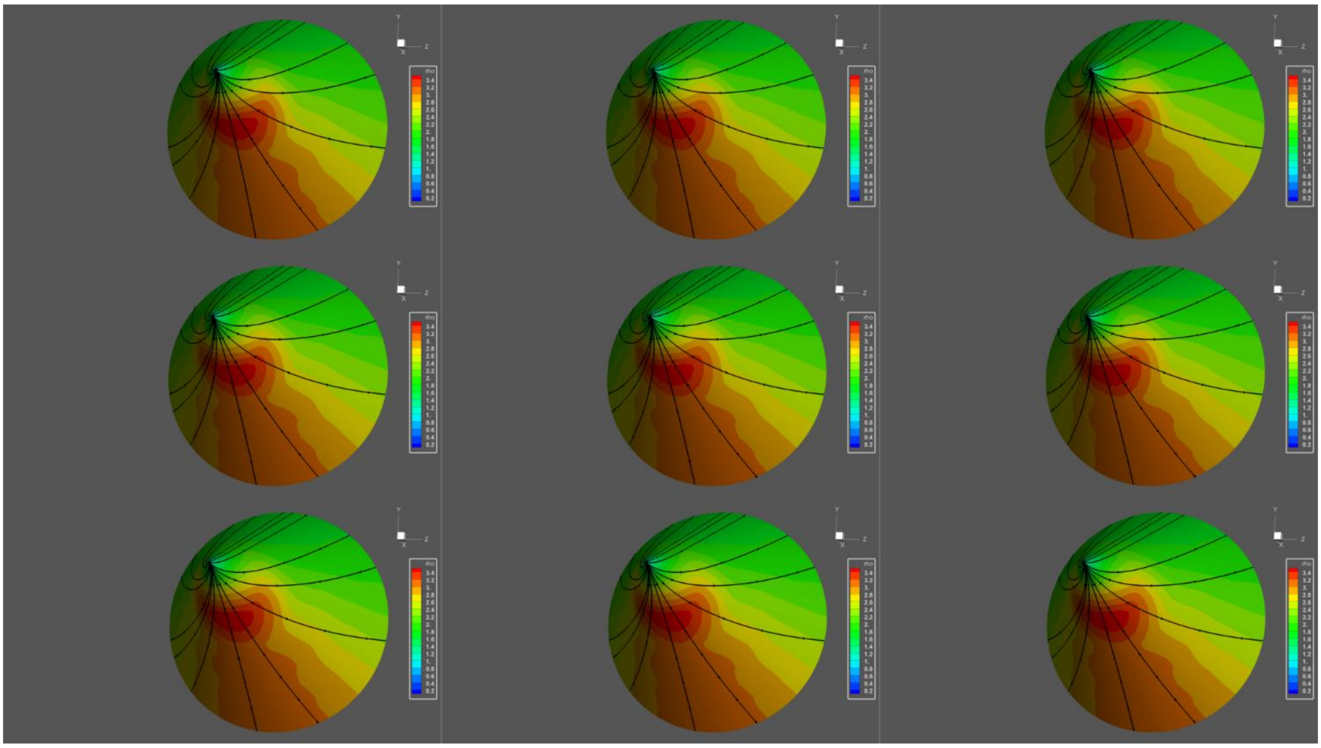

Fig. 8. A multi-view frame representing simulation results of a flow around a cone.

6. Constructing stereo images of text

When constructing stereo-animation, a rather important private structural subtask arises. The standard presentation of a scientific report, as a rule, includes not only the visualization of complex geometry or fields of physical quantities, but also explanations, usually represented by text and formulas. If for geometries and physical quantities the problems of constructing stereo representations have been developed sufficiently, then the tasks of constructing stereo images of texts and formulas with sufficient expressiveness and the necessary stereo effect remain open. Quite a few works are devoted to the development of specific practical approaches in this area. Here we can mention only the work [12], which describes the study in Japan of the perceptibility of stereo fonts on the screens of stereoscopic mobile devices. However, this study was more social in nature than it gave the recipes for constructing stereo images of texts and formulas.

The construction of stereo-images of texts and formulas in this research were carried out for the classical 3D projection system, that is, for the device involving the use of linear polarization glasses. The linear stereo image was chosen as the basis for constructing the stereo image. Thus, the construction involved the creation of a left and right frame for each text label.

When building the main goal was to follow a number of fairly simple principles, originally assumed. These principles include the following:

- The inscription should be three-dimensional, i.e. to have a volume, according to the conclusions of [2], where it was stated that the best stereo effect is obtained for three-dimensional figures. Because of this, it was recommended that all lines be presented in volumetric form. Therefore, to create labels and formulas, one must use volume fonts or effects that create volume.
- The inscriptions should be clearly readable, which is why it is recommended to use "strict" fonts.
- Inscriptions and formulas should clearly stand out against the frame, therefore, the background can not be too bright.
- In a stereo animated film presenting the results of scientific research, the main thing is the presentation of research results. Explanations in the form of text inscriptions and mathematical formulas play a secondary role. Therefore, the frame containing the accompanying information in the form of labels and formulas should not be brighter than the frames carrying the basic information.

Any program with a sufficient set of built-in fonts, as well as a wide range of options and special effects to ensure the creation of volumetric inscriptions and carrying out actions with them, is suitable for building test inscriptions.

To vary the stereo base, a grid was used, which made it possible to adjust the shear distance along the stereo base to arrange the left and right frames.

This approach allowed us to carry out the series of experiments to build the most appropriate frames with text labels and formulas. About 200 variants of various representations of inscriptions and formulas were built, where various parameters were varied.

Some of the constructed options are presented in the figures below. Figure 9 shows a variant of the construction of the inscription using the relief font Arial Black with the rotation of the entire inscription. Figure 10 presents a similar construction using a Cambria embossed font with a rotation of the entire lettering. The left and right frames are marked in the figures below respectively with the letters “L” and “R”.

Fig. 9. An example of constructing an inscription based on a relief font.
Arial Black with turning inscriptions.

Fig. 10. An example of constructing an inscription based on a relief font. Cambria with turning lettering.

For most of the test inscriptions, a variation of the shift over the stereo base was performed. The general method for constructing a test stereo image for the selected caption can be described as follows:
- selection of the main font;
- selection of font color and background;
- choice of degree of relief;
- the choice of turning the inscription entirely.

Next, from the created samples were selected those that are most consistent with the principles set out at the beginning of the section. For selected samples, the variation in the shear distance along the grid, that is, along the linear stereo base, was studied. Samples of stereo frames were checked on the stereo system in order to evaluate the stereo effect.

It should be noted that due to the inability to organize a full-fledged expert assessment, the selection of test options was based on the initially selected principles and assessment of the visual perception of the distance of the test inscription from the screen plane. When the test inscription shifted to 3.5 intervals of the grid to the right and left, the viewers who were 4 meters away from the screen perceived the inscription as being approximately 1 meter away from the screen plane, which was considered sufficient.

As a result, it was decided that the most optimal way to represent the inscriptions is the representation based on the relief font Arial Narrow on a light background, shaded at the bottom, without turning the inscription. An example of such a representation of the inscription is shown in Figure 11.

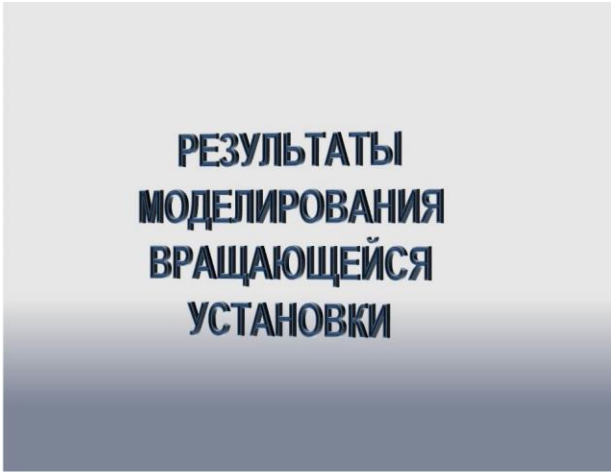

Fig.11. An inscription on the basis of the relief font Arial Narrow with rotation of the inscription at a small angle.

The results of the experiments have found practical application. When developing a computational technology that ensures the construction of the optimum form of a blade for power plants [4, 9, 10], a full cycle of power plant modeling was assumed from building the original CAD model to organizing the visual presentation of the results in stereo. The results of the experiments were used in the construction of stereo films in the developed computing technology [9]. All titles, inscriptions and formulas in this stereo film were made on the basis of experiments on the presentation of inscriptions and formulas presented in this work. The version of the stereo film is available using the link [9] and can be viewed on the classic passive-type 3D projection stereo with linear polarization glasses.

7. Conclusion

This paper presents a part of the results of a general project for organizing stereo-animated presentation of numerical simulation results for mathematical physics problems. The implementation of such animations is the final stage of computational technology for obtaining and presenting the results of modeling complex physical processes and the operation of complex technical systems. The results of animations for the classic two-projector projection device and for autostereoscopic monitors are presented. In the latter case, such methods were used as the construction of depth maps and multiple frames. The experience of constructing textual information, namely, texts and formulas, in stereo presentations for the classical type of stereo device is presented also.

8. Acknowledgments

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