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Fractal tomography and its application in 3D vision

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Abstract. A three-dimensional artistic fractal tomography method that implements a non-glasses 3D visualization of fractal worlds in layered media is proposed. It is designed for the glasses-free 3D vision of digital art objects and films containing fractal content. Prospects for the development of this method in art galleries and the film industry are considered.

1. Introduction

The method of fractal tomography - the method of artistic static and dynamic glasses-free 13D vision, based on the projection onto transparent screens of 3D multifractal sections, is offered. Unlike holography, the proposed method provides not a glasses-free 3D vision of an object "around", as in holography, but a vision of 3D spaces and objects through, and the total image changes when the observer's position changes. The proposed method uses the "cutting" of a 3D fractal space or object. The calculated images on the slices are projected onto several transparent screens displayed in the depth of the 3D fractal space or object.

2. Prehistory

3D vision in artificial systems, as a rule, is associated with stereokinetomatograph [1], [2], Autostereoscopic systems [3], holographic [4] and systems simulating a holographic image [5]. Biologically, the 3D vision is based on the fact that the eyes, as the input devices of a biological computer, get slightly displaced relative to each other two images of the visible world. The brain, analyzing and taking into account differences in graphic images, "calculates" the resulting picture, which already contains three-dimensional objects and creates a sense of depth. Stereoscopic vision was first described in 1838 by Charles Whetstone [6], but it should be noted that artists and scientists have been studying the three-dimensional vision long before this. Based on the analysis of the prehistory of the problem, it is clear that for the artificial (technical) realization of the glasses-free 3D vision, the brain needs to be provided with information: 1. about the presence of a 3D object (function F0); 2. and give the brain to understand that the visible space (object) has depth (functions F1-F8).

2.1. Signs of depth in 3D vision

In order to transform the sense of depth into functions (F1-F8) and algorithms, it is necessary to consider a combination of 3D vision features, "signals" for the brain, to which the following set of properties can be attributed: 1. F1 - the variable shape of various objects with a slight lateral displacement of the observer; 2. F2 - the presence of perspective. Remote objects appear to be smaller than closely located objects. "Parallel" lines intersect at infinity; 3. F3 - overlapping of objects. If one object closes part of the second object, then the brain understands that the first object is located closer. Overlap allows you to evaluate the relative positioning of objects in the image along the observation axis; 4. F4 - the shadows. Presence of areas of different illumination. Shadows, allow to add information to the brain about the relative location and height of objects; 5. F5 - the presence of parallax is determined by the change in the visible part and position of the object relative to the distant background, depending on the position of the observer. 6. F6 - the clarity of close textures on objects. Depending on the clarity or fuzziness of textures on 3D objects, the brain can estimate the distance to the object. The vague texture on the object, as a rule, speaks of its remoteness; 7. F7 - allowance for the thickness of the air. The greater the depth, the through the thicker layer of air filled with impurities (fog, suspended matter) are visible objects. Remote objects, as a rule, are covered with haze, and closely located objects are seen more clearly; 8. F8 - accommodation (focusing). The closer the 3D object, the more intense the muscles of the eyes, to ensure the sharpness of the image. Tension of the eyes gives the brain information about different distances to objects. At distant objects, eyes are relaxed. Artists and directors are familiar with the listed properties of 3D vision, and use them in their pictures, photographs and films.

3. Technical and information needs of artificial 3D vision without glasses

To implement artificial glasses-free 3D vision, which is the essence of the proposed method of mathematical (fractal) calculated tomography, consider its technical (devices) and information (functions, algorithms) needs: 1. technical needs include on what you can represent, reproduce calculated graphic information; 2. and information needs include the functions of 3D properties glasses-free 3D vision, as well as technologies and algorithms for preparing graphic information containing the signs of 3D vision. In addition to the raster and holographic method of the glasses-free 3D vision, there is another option that combines the solution of 2 problems: 1. the technical problem. Creating a multi-layer system for displaying specific graphic information containing all the features of 3D vision; 2. Information task. Synthesis of specific graphic information for each layer of the technical solution.

3.1. Overview and analysis of multi-layer visualization solutions

An example of a layered presentation of graphic information can serve as multimedia exhibitions, where a multi-screen moving image is projected onto all possible planes of the room [7,8]. Another example of multi-layer visualization and attempts to create a 3D vision effect are rocking technologies. For the first time, the scenes, emphasizing, among other things, the depth of the stage, were applied in 1619 at the Farnese Theater in Parma, Italy [9]. In modern theater, the stage is equipped with only soft backstage, which can be projected, as a rule, independent images [10]. The peculiarity of these projects is that flat images of independent objects are applied in layers.

3.2. The closest analogue of the technical solution

The closest analogue of the proposed 3D system is a multiscreen display of this type is Patent No. 2429513 - Three-dimensional display [11], where "a display with a three-dimensional screen consisting of a package of light-scattering liquid crystal modulators and a microprojector-based video projector forming images of sections of a three-dimensional object in the planes of location of light-scattering liquid crystal modulators". Features of this solution is a small area of 3D visualization, a large hardware cost and complexity with dynamic visualization. It is proposed to form a three-dimensional object using a series of screens, on each of which a corresponding section of the object is reproduced.

4. Technical implementation of the fractal tomography method

When creating a demo version of the installation for glasses-free 3D visualization from the prototype, the principle of projection on transparent screens and layered visualization of sections of 3D objects was taken. The **main difference** from the prototype is the way to create **graphic information in layers**. A schematic view of the installation is shown in Figure 1. This figure shows five transparent slightly diffusing screens, or planes, onto which different planes (sections) of a 3D object synthesized

mathematically or by a special method will be projected. When creating the model of the technical solution, the following assumptions were made: The screen does not absorb light, passes 90% of light, and everything else - 10% is reflected with a uniform indicatrix. The last image has less brightness than the first, since each screen absorbs a part of the light coming from the previous screens. It follows that, the number of screens should be limited, and the brightness of each subsequent should be increased, based on the absorption of light by the material of the screens. But this is an ideal case. In reality, we must also take into account the scattering of the transmitted light and its reflection from the next layers towards the viewer. For the experiment, three projection planes of the images were selected, based on the available number of projectors. The installation scheme with three projectors is shown in Figure 2. Since the projector is tilted at a large angle to the screen (Figure 3), the distance from the projector to the screen plane L1, L2 is different for the bottom and top parts of the screen, and therefore the width of the image h1, h2 on them will be different.
So there are trapezoidal distortions.

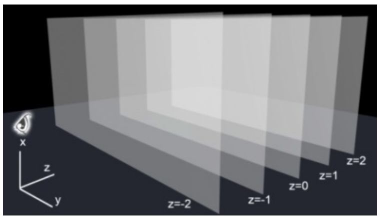


Fig. 1. Type of installation containing 5 transparent screens

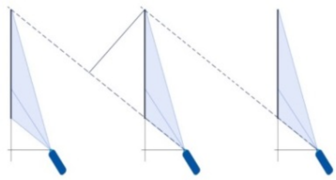


Fig. 2. Installation scheme with 3 transparent low-diffusing screens and 3 projectors

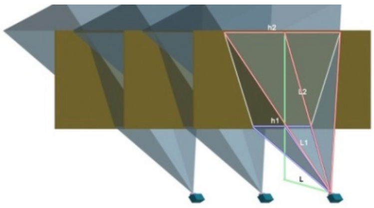


Fig. 3. The appearance of distortions of the trapezium type

Solve this problem by either introducing pre-distortion into the projected picture, or using the built-in projector to correct such distortions, or by using an ultra-wide-angle projector specially designed for this type of display, located at a distance L from the screen.

4.1. Technology and algorithms for creating and converting graphic information for layers of a multi-layer installation of fractal tomography

The content or information component of the method of fractal tomography is 3D multifractals, mathematical 3D objects that have the ability to computer "cut" and "endow" sections (slices) of this object with all the properties of artificial 3D vision (F1-F8).

4.2. Create 3D object - 3D fractal world

For example, consider the creation of the main 3D object, the sections of which will be subjected to various mathematical transformations, for the information realization of all the signs of an artificial 3D vision. For the experiment, a 3D multifractal consisting of 4 fractal functions (FF) was selected, which visualizes a 3D fractal world with objects similar to trees (1). The result of the calculations is shown in Figure 4. Consider the various possibilities of this 3D fractal world for use in the fractal tomography method, and the technology that provides its 3D-free 3D visualization.

{ FF1=_Rotate(X=0.75; Y=0; Z=0.375); FF2=_RotateC(X=22.875; Y=-48.375; Z==190.125);
FF3=_FlipXYc(c=1); FF4=AmazingSurf(Scale=1.2203125; MinR=0.125; Fold=1.15;
X=5.421875; Y=1.9296875; Z=-14.4296875; ScaleVary=0; Sphere_or_Cylinder=0)) (1)

4.3. The ability to "cutting» 3D World

To illustrate the calculation of the cross-section (slice) of a 3D fractal world, consider the "cutting" model depicted in Figure 5. The results of the cutting - sections or sections of the 3D multifractal are shown in Figure 6. The cross sections (slices) of the 3D multifractal are presented in 5 layers (for the transparent screens of the installation in Figure 5).

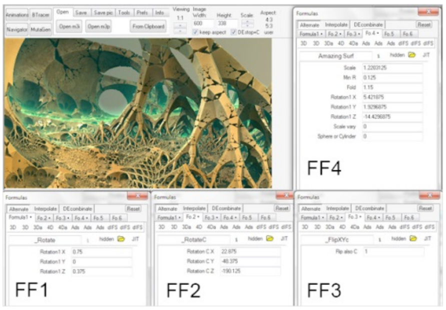


Fig. 4. 3D mathematical object - fractal world - 3D multifractal and fractal functions, describing it

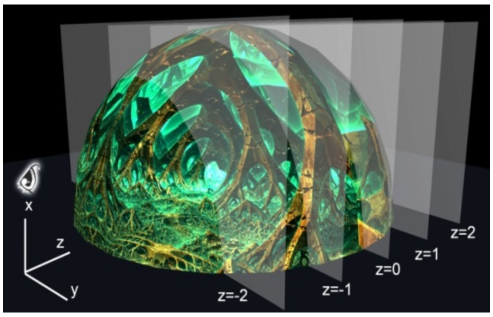


Fig. 5. Calculation of sections (slices) of 3D multifractal

The "cutting" of the 3D fractal object was carried out in the Mandelbulb3D program for different sections in different ways: 1. the base section z = 0 was calculated at the maximum value of the depth parameter (Depth); 2. the front sections (z = -1, z = -2) were obtained by decreasing the Depth calculation parameter of the multifractal; 3. the rear sections were obtained in the calculation using the Cutting function with the parameter for the Z axis of the coordinate of the cutoff of the rear section of the fractal 3D object.

4.4. Algorithms for calculating the cross sections of a 3D multifractal with the implementation of 3D vision techniques with the signs F1-F8

In addition to the main feature of the multifractal - 3D model of the object, after establishing the possibility of its mathematical and computer "cutting", let's consider the techniques (algorithms) of providing in the sections of 3D fractal world eight depth signs for 3D vision: 1. F1: the shape and size of various objects that are changed in layers; 2. F2: Presence; 3. F3: Overlapping objects in layers; 4. F4: Areas of different illumination. Shadows; 5. F5: The presence of parallax; 6. F6: Clarity of close textures on objects; 7. F7: Accounting for the content and thickness of the air to the object in the section of the 3D object; 8. F8: Accommodation.

4.4.1. F0: the volume of objects - 3D fractal world or 3D computer model.

The sign of dimensionality is embedded in the mathematical (for 3D multifractal) and computer (3D computer model) description of the object itself. Changing the spatial parameters gives a change to the 3D view of the object.

4.4.2. F1: the shape and size of various objects that are changed in layers;

This feature (F1) is provided by calculating the cross sections (cut) of the 3D multifractal corresponding to the depth of space. For computer implementation, the function of the cutoff from the back Depth (Depth) and the cutoff function from the front Cutting are used.

4.4.3. Complex realization of signs of volumetricity and shadows: F0: 3D objects or models of objects (model + shadows) and F4: Areas of different illumination. Shadows

As already noted, the bulk (feature F0) of the multifractal cross section is a consequence of its 3D mathematical model, and various shadows of the multifractal that enhance the bulkiness (sign F4) are obtained by including the Hard Shadow and Ambient Shadow modes.

5. Experiments on combining layers of 3D fractal world

To find the optimal variant of combining in 3 layers of 5 sections of the 3D fractal world, 3 algorithms were considered.

5.1. 1st algorithm of 3D visualization of the fractal world

The first algorithm for 3D visualization of the fractal world and the result of its use are shown in Figure 6. The algorithm is as follows: 1. on the transparent screen close to the viewer, the 3D cross section of the 3D multifractal is projected (Depth = 10000, Cutting (Z) = 0; Z is the coordinate by which the world is cut off. Fractal world is visible behind the plane of the section; 2. on the middle transparent screen, the cut from the front of the 3D multifractal slice is shown, Depth = 10000, Cutting (Z) = 0,14; 3. on the rear transparent screen, a more cross-cut 3D multifractal slice is shown, Depth = 10000, Cutting (Z) = 0.3.

5.2. 2nd algorithm of 3D visualization of the fractal world

The 2nd algorithm for 3D visualization of the fractal world and the result of its use are shown in Figure 7. It differs from the first by the sequence of the arrangement of sections (sections) on transparent screens. The 2nd algorithm for 3D visualization of a fractal world is as follows: 1. on a transparent screen close to the viewer, the cross-section of the 3D multifractal maximized at the rear (Depth = d1) is projected; 2.on the middle transparent screen, the 3D section of the 3D multifractal, Depth = d2, d2 <d1; 3. on the rear transparent screen, the base 3D multifractal Depth = 10000 is not cut off from behind or from the front. In Figure 7, clearer foregrounds of the 3D fractal world are visible, which creates a stronger effect of no glasses 3D visualization by fractal tomography. Hence it can be concluded that on the front transparent screens you need to have slices (sections) having darkened noninformative areas through which the images on the rear screens will be better seen.

5.3. 3rd algorithm of 3D visualization of the fractal world

The result of the 3rd algorithm of the fractal world 3D visualization use are shown in Figure 8.

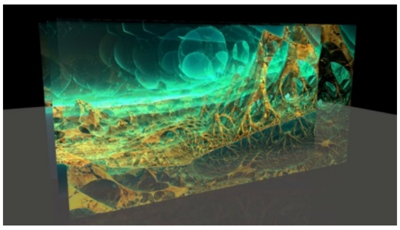


Fig. 6. A side view of the layered image of 3D multifractal according to the first algorithm

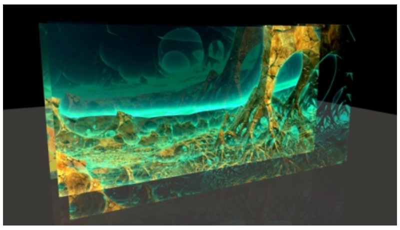


Fig. 7. A side view of the layered image of 3D multifractal according to the second algorithm

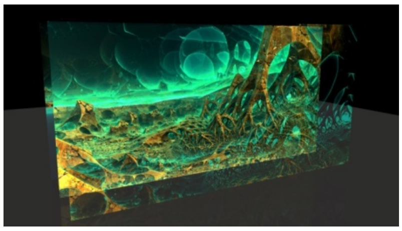
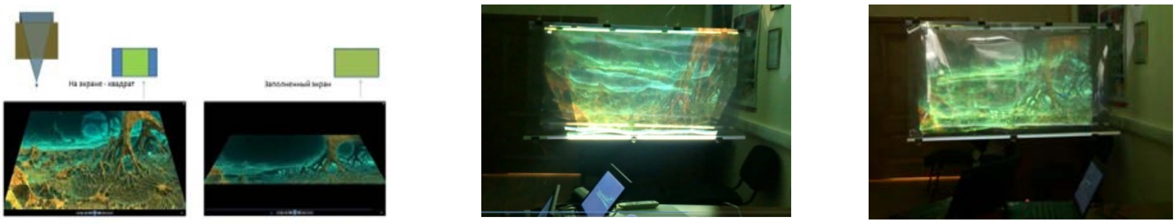


Fig. 8. A side view of the layered image of 3D multifractal according to the 3rd algorithm

It differs from the first and second algorithms in the sequence of arrangement of sections (sections) of 3D multifractal on transparent screens. The sequence of images on the screens in depth is as follows: the front section - the base 3D fractal world - the back cut. The third algorithm of 3D visualization of a fractal world is as follows: 1. on the transparent screen closest to the viewer, the maximum cross-section of the 3D multifractal; 2. on the middle transparent screen, the base 3D multifractal, Depth = 10000; 3. on the rear transparent screen, a more cross-cut 3D multifractal slice is shown, Depth = 10000, Cutting (Z) = 0.3. This algorithm is used when not only the front, but also the 3D multifractal backgrounds are important. The check of the developed method of fractal tomography was carried out on the mobile demo installation assembled by the author.

6. Mobile demo installation of the method of fractal tomography and Dynamic 3D visualization

In a real mobile installation, projectors with an image located on the axis of the lens were used. Figure 9b shows that the trapezoidal distortions are not eliminated. Since the usual projectors were used in the experiment, correction of trapezoidal distortions was carried out during the installation of the film by introducing distortions opposite to those that would be introduced when the projector was displayed at a large angle to the screen. The result is shown in Figure 9a. As a result of the correction, rectangular stratified cross sections were obtained, creating a total 3D non-zero visualization of the regular rectangular shape (Figure 9c). Using the developed method and a multi-screen installation, not only static but also dynamic 3D defect-free visualization of the fractal world in layered media was demonstrated, which can create the prerequisites for the development of a new cinema, created according to the "layered" principle of graphical information sections, using fractal mathematics as described in this article, as well as the additional use in the layers of 3D computer objects and real shootings in the technology of chromakey, and this is the project of the 3D free-glasses vision a new full-fledged artistic cinema.



a b c

Fig. 9. View of a real mobile demo installation, with dynamic 3D visualization containing three screens from the perspective of the viewer

7. Conclusion

The method of artistic fractal tomography for glasses-free 3D visualization of art objects in light galleries and films in 3D cinemas is proposed. A layered model of free-glasses 3D visualization of fractal worlds is proposed, where each layer corresponds to a cut (cross-section) along the depth of the multifractal. An algorithm for calculating the cross sections of 3D fractal worlds has been developed, which makes it possible to obtain its cross sections in depth. Algorithms for layered free-glasses 3D visualization for various display requirements are developed. The basics of technical implementation for free-glasses 3D visualization of fractal worlds in layered media are developed. A demo version of the mobile installation for the free-glasses 3D visualization of fractal worlds was created, which can be used both in art galleries of fine art and show films with fractal content on it.

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