

FRACTAL GRAPHICS AS MODERN IMAGING TECHNOLOGY

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ФРАКТАЛЬНА ГРАФІКА ЯК СУЧАСНА ТЕХНОЛОГІЯ
ОБРОБЛЕННЯ ЗОБРАЖЕНЬ

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Abstract. *Fractal graphics revolutionized computer graphics due to the concept of fractal. The fractal allows you to think figuratively, and to transfer any algebraic problem to the geometry region, where the correct answer is always obvious. The study of fractals gave an explanation of the general, that is, in the flora, natural landscape, the phenomenon of nature with the blood vessels of man. It is the only mean of structure: self-similarity. The fractal pattern does not have identical elements, but has similarity on any scale. The object of the study was all crooked, broken, rough, wrinkled – that is all around us. It found in this extremely complex forms its wonderful order, because it was able to describe the shape of the cloud – as if not spheres, mountain surfaces – not cones, lightning – as if not straight line. Fractal graphics can "grow" such plants that do not occur in the real world, but they are fine for their feature. Fractal is a strange boundary between the fields of knowledge and human activity. Fractal science has penetrated all scientific fields: from mathematics and physics to medicine and economics. A lot of research in the field of fractal graphics has been carried out, but there are still issues, questions and problems that deserve considerable attention and a more perfect solution. The purpose of this work is to reveal the reasons for the popularity and necessity of fractal graphics in science and art, which has successfully gained mass culture and computer desktops. The article analyzes the fractal graphics, the appearance of which was a completely new type of visualization and conceptualization of reality. The questions concerning the concepts of a fractal, their classification of computation and geometric construction are covered. It is shown that the success of fractal graphics is due to the fact that, with the help of very simple formulas, virtually any user of the computer is able to understand and get amazing in terms of the complexity and beauty of the image. The systematization of fractals in two directions is carried out; the principle of construction is specified and the distinction between the main geometric figures and sets of fractal graphics is made. Software for creating fractal objects is considered. The Ultra Fractal graphic program builds three types of Mandelbrot, Phoenix (Julia set), Nova (Mandelbrot) fractals. Of these, fractal compositions are arranged, which are located on 3D objects and on a plane. The use of fractal graphics in various spheres of society's activity is analyzed.*

Key words: *fractal geometry, fractal graphic, graphic environment, software*

Анотація. *Фрактальна графіка зробила революцію в комп'ютерній графіці завдяки поняттю про фрактал. Фрактал дозволяє мислити образно, а будь-яку алгебраїчну задачу перевести в область геометрії, де правильна відповідь завжди очевидна. Дослідження фракталів дало пояснення того загального, що є у рослинного світу, природного ландшафту, явища природи з кровоносними судинами людини. Це єдиний засіб структури: самоподібності. Фрактальний рисунок не має ідентичних елементів, але володіє подібністю у будь-якому масштабі. Об'єктом дослідження фрактальної графіки стало все нерівне, ламане, шершаве, зморщене – тобто все те, що нас оточує. Вона знайшла в цих надзвичайно складних формах свій дивовижний порядок, бо стала спроможною описати форму хмари – як не сфери, гірських поверхонь – як не конусів, блискавки – як не прямої лінії. Фрактальна графіка може «виروضувати», такі рослини, що не зустрічаються в реальному світі, але вони прекрасні своєю особливістю. Фрактал – дивна межа між областями знань та людською діяльністю. Фрактальна наука проникла в усі наукові напрямки: від математики та фізики до медицини та економіки. Проведено досить багато досліджень в області фрактальної графіки, але ще залишилися питання, задачі та проблеми, що заслуговують значної уваги та більші досконалого вирішення. Метою даної роботи є розкриття причин популярності та необхідності фрактальної графіки у науці та*

мистецтві, яка з успіхом завоювала масову культуру та робочі столи користувачів комп'ютерів. В статті проведено аналіз фрактальної графіки, з появою якої з'явився абсолютно новий тип візуалізації і концептуалізації дійсності. Висвітлюються питання пов'язанні з поняттями фракталу, їх класифікації обчислення та геометричної побудови. Показано, що успіх фрактальної графіки обумовлений тим, що за допомогою вельми простих формул, практично, будь-який користувач комп'ютера, здатний зрозуміти і отримати дивовижні за складністю і красою зображення. Проведено систематизацію фракталів за двома напрямками; указано принцип побудови і проведено розмежування основних геометричних фігур та множин фрактальної графіки. Розглянуто програмне забезпечення для створення фрактальних об'єктів. В графічній програмі UltraFractal побудовані три види фракталів Mandelbrot, Phoenix (Julia set), Nova (Mandelbrot). З них скомпоновані фрактальні композиції, які розміщені на 3D-об'єктах та на площині. Проаналізовано використання фрактальної графіки в різних сферах життєдіяльності суспільства.

Ключові слова:фрактальна геометрія, фрактальна графіка, графічне середовище, програмне забезпечення

The world around us changes with incredible speed, and society needs new impressions, feelings and interesting knowledge based on new discoveries. Despite the fact that over the past fifty years, there have been many outstanding inventions in various fields of science (Higgs Boson, accelerating the expansion of the universe, proof of the Big Fermat theorem, decoding the human genome ...) fractals are distinguished by their brightness. They are unique in that they can be found in all spheres of human knowledge because they describe the real world even better than traditional physics or mathematics. Fractals found that every science itself is fractal, like society in general. The solution to many modern problems of mankind is facilitated by fractal graphics based on the concept of "fractal".

The purpose of this work is to reveal the reasons for the popularity of fractal graphics, both in science and art, and among a variety of people who use computer graphics capabilities to create amazing projects.

Genial discoveries in science are able to drastically change human life. Some inventions, such as a disease vaccine, can save lives for millions of people. At the same time, the emergence of a new virus or the creation of lethal weapons, on the contrary, can take away these lives. Many inventions radically changed the lives of mankind, and now we can not imagine their existence without them. But there are such discoveries that few people pay attention to, while they have a significant impact on our lives. One of these "obscure" discoveries is fractals, which are aimed at the person's desire to know the world around him, trying to adhere to the logic of thinking.

Fractal is a geometric figure in which the same motif is repeated on the scale that gradually decreases. The fractal part contains information about the entire fractal. The small elements of the fractal object repeat the properties of the entire fractal [1].

Fractal is a form of extraordinary mathematical art, based on elementary formulas and algorithms, thanks to which get pictures of fantastic beauty and complexity. In the images of the built images, it is not uncommon to recognize the structure of familiar representatives of flora and fauna.

Fractals of a constructive (geometric) type are built in stages. First, the basis is depicted. Then some parts of the base are replaced by a fragment. At each subsequent stage, parts of the already constructed figure, similar to the replaced parts of the base, are again replaced by a fragment taken at the right scale. At the next stage, the scale decreases again. When changes become visually imperceptible, it is believed that the constructed figure brings the fractal closer together and gives an idea of its form. To get the fractal itself requires an infinite number of stages. Changing the basis and fragment, you can get many different geometric fractals.

Fractals of a dynamic (algebraic) type arise in the study of nonlinear dynamical systems. The behavior of such a system can be described by a complex nonlinear function (polynomial) $f(z)$. Any point z of the complex plane has its own behavior in the iterations of the function $f(z)$, and the whole plane is divided into parts. At the same time, the points lying on the boundaries of these parts have the following property: at an arbitrarily small displacement, the nature of their behavior changes dramatically – these are bifurcation points that have fractal properties that are the Julia set [2].

Fractals can be divided into two groups: mathematical, artificially created by scientists, and natural. In turn, the mathematical sections are divided into deterministic and not deterministic (stochastic) [3]. Deterministic fractals are of geometric and algebraic origin. In Table 1, the classification of fractals by the principle of construction and use of elementary basic object is carried out.

Table 1 – Classification of fractals

Key Features	Types of fractals	
	Constructive (geometric)	Dynamic (algebraic)
Principle of construction	It is built in stages: from the base to fragments with a gradual decrease in scale	Description of complex nonlinear function
Elementary object	An infinite curve that has no tangent, which consists of parts similar to the whole	Algebraic formula integrated with the feedback loop
Result	Koch Snowflake, Sierpinsky Triangle, Pythagorean Tree, T-Square, H-Fractal, Lévy C curve	Mandelbrot set, Julia set, Halta fractal, Fractal Newton

Geometric fractals, on the one hand, are the subject of serious scientific study, and on the other hand, they can be "seen", even a person far from mathematics will find something for them. Such a combination is exceptional in modern mathematics, where all objects are asked by means of obscure words and symbols.

Dynamic chaos and fractals have become part of the scientific picture of our life at the present time. Scientific developments related to fractals and dynamic chaos influence the perception of many traditional notions of reality. Fractals provide an opportunity to view our knowledge of the geometric properties of natural and artificial objects, and the dynamic chaos, radically change our understanding of the behavior of these objects over time.

The fractal allows you to think figuratively, and to transfer any algebraic problem to the geometry region, where the correct answer is always obvious. For a fractal image, science needed a separate direction. This direction has become fractal graphics. The basis of which lay fractal geometry. This amazing area of mathematics conceals the key to understanding the nature. It is closely linked to the theory of Chaos.

The basic concepts of fractal geometry are "Fractal Triangle", "Fractal Shape", "Fractal Object", "Fractal Composition". They allow fractal graphics to create abstract compositions, where many techniques are implemented: horizontal and vertical, diagonal directions, symmetry and asymmetry [2]. Fractal graphics, like the vector, are computable, but the difference is that no objects in the computer's memory are stored. The fractal image is created by the equation, so there is a need to store only formulas. When changing only the coefficients in the equation, you can radically change the fractal picture. Fractal image can be scaled without pixelation. Fractal image compression – arises when finding similar areas of the image. This algorithm is known to allow a high compression ratio (up to 10,000 times) that is not available for other compression algorithms in principle.

Fractal computer graphics as a kind of computer graphics has been widely used in all areas of science and art. Table 2 analyzes the use of this graph in all spheres of modern life.

Graphical processing environment fractals can be used to create custom logos of companies, organizations, institutions and students to explore fractals computer skills.

The tendency of fractals to be similar to mountains, flowers and trees, widely used by individual graphic editors, such as fractal clouds in the 3D studio MAX, fractal mountains in the World Builder.

Fractals are used to simulate the phenomena of nature: snow, rain, clouds, waterfalls, and are given by simple formulas that are easily programmed and do not decompose into separate triangles and cubes at approximation. This is used when creating animations and movies.

In geology and geophysics fractal algorithms are used to study the coasts of islands and continents, they describe rocks and fractions of petrochemicals.

Table 2 –Spheres of use of fractal graphics

	Branches of science and art	Purpose of use
1	Mathematics, fractal geometry, fractal analysis	Sunny hours, creating lightweight constructions, studying the Egyptian pyramids
2	Physics	Investigation of an atom, the behavior of electrons of a magnetic field, the study of the universe, turbulent flow of fluid
3	Chemistry	Investigation of the structure of the molecule, porous materials
4	Biology	Research of flora and fauna, development of the tree of the theory of evolution, structure of bacteria
5	Geology	Investigation of reliefs, calculation of the length of the coastline
6	Economics	Dynamics of economic processes and phenomena
7	Sociology	Research on social progress
8	Telecommunications, computer networks	Creating aeriels, researching traffic, creating decentralized networks
9	Medicine	ECG, bone and DNA studies, blood tests, X-rays, MRI, CT brain, ultrasound in gastroenterology
10	Natural and anthropogenic systems	Construction of fractal adaptations, flames, clouds, lightning and other natural phenomena
11	Architecture	Creating buildings in fractal style
12	Landscaping	Creating landscapes
13	Furniture design	Creation fractal design furniture
14	Cinematography, cartoons, computer games	Creation of landscapes, planets, landscapes, special effects
15	Music	Writing music tracks, fractal animation in video networks

Fractals in telecommunication are used to create fractal antennas. Fractal antenna with compact design provides broadband performance in a small form factor. Flexible enough to be installed in different locations, fractal antennas are used for marine, airborne vehicles, or personal devices.

Fractals are used in the military industry to create uniforms of camouflage of military form and equipment, which often contracts with the environment, and without the use of camouflage techniques, they will be visible against the background of surrounding objects.

For masking, materials are used, the patterns of which are executed so that their color range fits into the environment and meets the requirements of natural phenomena during the years of the year. These patterns also help smooth out the shape of objects and change their size. They represent fractal shapes, changing and combining the color of which one can simulate images of living and inanimate nature, and also comprise fractal composition from the resulting figures [4].

For the creation of camouflage patterns, both classical geometric fractals are used, and the Julia sets are a class of forms calculated according to complex numerical coordinates. Each point corresponds to a certain color depending on its behavior when performing a number of simple but mathematical operations that are repetitive.

The world leader in camouflage creation is Canadian Hyperstealth Corporation, which has developed digital and quantum camouflage that can scare the opponent's brain using advanced optical twists. This complex task includes not only the idea of fractals, but also knowledge of the science of color, the anatomy of the human eye and the logistics of the consciousness of the pattern. A fractal composition is created that can make a person invisible, and sew an inevitable cloak in which it can not be detected. Such an effect was obtained by using a geometric fractal and penetrating into the unknown region of quantum camouflage [5].

Biology and medicine use fractals to describe the research of internal organs (X-ray, ECG, ultrasound, MRI) of a person. X-ray images processed with fractal algorithms give a better picture, and accordingly more qualitative diagnostics. The theory of fractals can be used to analyze electrocardiograms. Another area in medicine, where fractals can be actively used, is gastroenterology.

A promising direction in medicine is the invention of maps of adhesion (grafting of surfaces of heterogeneous solid and/or liquid bodies) of surfaces of healthy and cancerous cells having fractal dimension. Probably this invention will help to open new effective methods of diagnostics and treatment of oncological diseases in the future.

The whole person, in essence, is a fractal. In each of us there are at least four grandiose fractals – the nervous, respiratory, cardiovascular and lymphatic systems, which closely co-exist in different organs. Fractality is observed in all systems and organs of man. Blood vessels, the total length of which is about 100 thousand km; lungs with a total area of the inner surface of 40-120 m², from the number of alveoli up to 700 million; liver, kidneys, immune nervous system, vestibular apparatus – all these are also fractal structures. So the filtration surface of the kidney reaches 1,5 m², and the length of the capillary system is about 25km. the total length of human nerve endings is about 75km. Note that the human brain, which consists of 80% of water and contains at the time of birth about 14 billion cells, is recursive in nature. This gives an opportunity for a person to think in time, to evaluate the present, to recall the past and to think about the future, which is a process of thinking. Recursion is the interaction of stability and chaos that makes a person human. This testifies to the fractal nature of the human body, which will be properly investigated using fractals.

Fractals are used in the analysis of economic and financial processes [6]. Graphs of quotations exchanges is a typical example of Brownian trajectory. Moreover, the general structure of the graph is maintained at the two-hour, daily and weekly scale.

The fractal generator is a computer program that generates fractal images. Fractal graphics are used by the following computer programs: Ultra Fractal, XenoDream, Fractracer, Apophysis, XaoS, Mandelbulb 3D, ChaosPro and others.

Most of these programs allow you to choose an algorithm for generating a fractal, increase one or another fragment of an image, change the color range, edit some topological parameters and save the resulting image in one of the popular graphic formats, such as JPEG, TIFF or PNG, and also save the parameters of generation of a particular fractal. that allows the reuse and modification of fractal images.

Many programs allow to enter their own formulas and implement additional controls, such as filtering of the image. Some packages allow you to generate fractal animation. Some graphical editors of general purpose, for example. GIMP, include filters or plugins for generating fractals.

Ultra Fractal is used to create a unique two-dimensional fractal images of professional quality. A fractal image is constructed on the basis of the selected workpiece, which is determined by the system of parametric equations, in which the parameters are easy to change at will. The basic set of ready-made fractal formulas is part of the program.

ChaosPro allows you to create three-dimensional fractals and full-fledged fractal animations based on established recursive fractal formulas uploaded from files or written by yourself in the editor.

XenoDream – uses IFS-fractal image techniques from which are exported to mesh objects for further processing in 3D editors.

Fractracer – here is the basis of fractal geometry, which is the average between a fractal generator and a 3D editor. There are two options for creating images: the use of set examples of fractal objects, which are then easy to modify as desired, and the creation of projects from scratch – based on the program code.

Apophysis is a simple program for generating two-dimensional fractals based on hundreds of built-in fractal formulas. Widely used in animation.

Fractal Extreme is a program for generating two-dimensional fractal images. It is based on about 20 fractal formulas, on which the images are constructed.

Chaoscope is program for generation of strange attractors. The principle of generation is the following: first, a fractal set is created, which is then visualized in the attractor.

XaoS is a crossplatform fractal generator that allows you to generate fractal images for basic types of fractal sets.

Mystica is the program used to create three-dimensional scenes (landscapes) in the development of computer games. Image generation is performed on the basis of the set of fractal formulas in the package with setting of many parameters.

Mandelbulb 3D is a free editor that allows you to create complex fractal 3D objects and animations. The program is based on a three-dimensional fractal created using a hypercomplex algebra based on spherical coordinates [7].

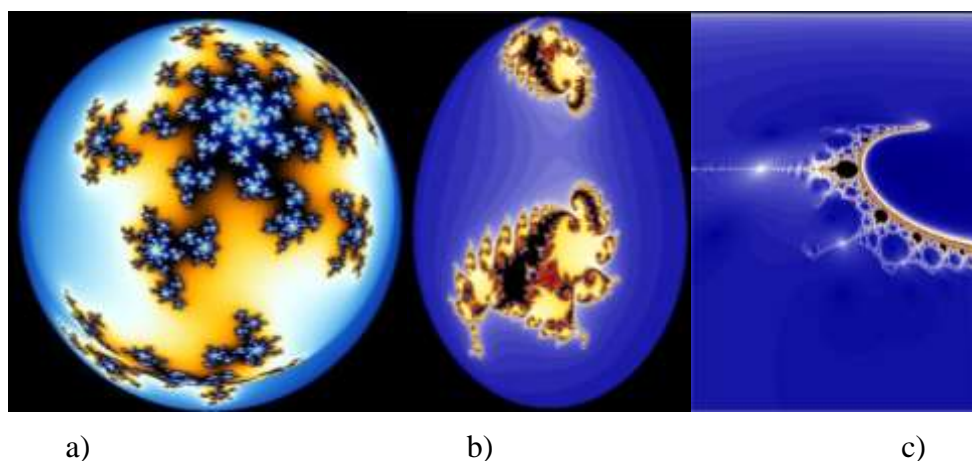


Figure 1 – Ultra Fractal's images on the sphere (a), on the egg (b), on the plane (c)

The images are made in software Ultra Fractal. Changed fractals of Mandelbrot, Phoenix (Julia), Nova (Mandelbrot) are downloaded from standard packages of software and are edited with function 3D-mapping. In the function we can choose three properties: Sphere, Egg, Plane. In result we see images like Fantastic Planet X, Ester Egg, Artificial Island in the ocean.

CONCLUSIONS

The article analyzes fractal graphics as a completely new type of visualization and conceptualization of reality. The questions concerning the concepts of a fractal, their classification of computation and geometric construction are highlighted. The secret of the success of fractal graphics is revealed, due to the fact that with the help of very simple formulas, any user of the computer is able to understand and get amazing in terms of the complexity and beauty of the image. The systematization of fractals in two directions is carried out; The principle of construction and delineation of the basic geometric figures and sets of fractal graphics is indicated. Software for creating fractal objects is considered. In the graphic program Ultra Fractal, three types of Mandelbrot, Phoenix (Julia set), Nova (Mandelbrot) fractals are constructed and modified, from which fractal compositions are arranged, placed on 3D objects and on a plane. The use of fractal graphics in various spheres of society's activity is analyzed.

Fractals is the area of strange mathematical art, when with the help of simple formulas and algorithms are created pictures of extraordinary beauty and complexity. It conceals a special mathematical magic, probably, precisely because of this it is so attractive to all creative people. The fractal reveals in one person various creative potentials: from an artist, a sculptor, a photographer, an inventor and a scientist in one person. Starting 'from scratch', from a mathematical formula, studying the mathematical results obtained, sometimes exceeding current studies of traditional physics and mathematics, it creates a kind of images while choosing a color palette. All those who at least once met fractal, are no longer able to refuse it in further work. It creates an understanding of the harmony of all living things with non-living: in the arrangement of stars, the sound of music, the structure of the human body, the proportions of the plant world. Therefore, a person instinctively stretches to fractal images. They attract attention, surprise with their unordinary character, fascinate and hypnotize. The great value of fractals is their use in all, without exception, the branches of science and industry. Whatever complex fractal graphics is, there is nothing superfluous, because the proportions and color, verified using mathematics, are in harmony between the Earth and the universe.

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