

Isaac Newton's Contribution to Computer Graphics

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Abstract

This article presents and develops one of Isaac Newton's most significant discoveries and traces its application in computer graphics and 3D modelling. Newton was the first scientist to introduce the concept of limit, which is used in modern mathematical analysis and differential geometry. Newton's theory was further developed in this study. A new boundary method is presented, which finds application in geometry, physics, and computer graphics. Using the new approach, it is possible to draw a regular polygon. Subsequently, it can be used to construct more complex geometric objects, such as prism and pyramids. Based on the primitives: triangle, quadrilateral, cube, circle, sphere, cylinder (prism), cone, etc., arbitrary 3D models can be constructed. This article presents new authors mathematical software called StereoMV, which enables the export of 3D stereometry objects in files with the extension .obj. The generated 3D objects can be imported into a 3D modelling program like Blender. On their basis, using a variety of techniques, arbitrary and more complex models other than those of stereometry can be recreated. Thanks to the new method, it is possible to use a 3D library and, from there, visualization through virtual reality systems. This is the most significant contribution of the proposed boundary method. With the traditional programming approach using trigonometry, this is a difficult task to make it. The application of this innovative way of modelling can be added to a wide variety of projects, such as a 3D serious extreme game involved in the analysis of cardiac data.

Keywords: Method of limits • Boundary method • 3D modelling • 3D game • Heart rate variability

Introduction

Computer Graphics (CG) is part of the computer science discipline. Another important concept related to computer graphics is interactivity, the user's interaction with the software. Also important is the device which visualize the graphics; this can be a virtual reality system with or without immersion. There are two types of graphics, two-dimensional and three-dimensional. Nowadays, CG is used in almost all scientific fields. The concepts of model and image are essential. A model is a construction of a natural or fictional object. A texture representing an image obtained, for example, from a camera, can be applied to it. There are many file extensions for representing 3D models. The most widely used of these is .obj. It represents objects as a mesh of polygons. Here the main primitives are of two types based on triangles or quadrilaterals. An early colour theory was presented by Isaac Newton, who observed light passing through a prism [1]. Here Newton arranges the colors from red to blue. The proposed colour wheel became the basis for all subsequent theories.

This article aims to introduce a new way to create arbitrary 3D models, which is based on an author's method of constructing a regular polygon and a 3D modelling program.

Newton's method of limits and computer graphics

Through the method of fluxions, Isaac Newton laid the foundations of mathematical analysis and, from there, of differential geometry [2]. This method is related to the method of limits presented by the scientist in 12 lemmas [3]. In his book, he clarifies the concept of the physical-mathematical boundary. According to him, to reach the limit in mathematics, the quantities must be reduced or increased to infinity, regardless of what they are. It is known that the differentiation is the limit of a function. On the other hand, integration is the opposite operation of differentiation. He also introduced the same term limit known in mathematics as limes. Based on this finding, a new boundary method for figure drawing is presented in this paper. They are part of two-dimensional and three-dimensional graphics and directly relate to the computer and its graphics capabilities. A regular polygon is the basis of all drawings. It can be used to construct (pyramid, cone, prism, cylinder, circle and sphere). It is known that all objects, fictional or real, are modelled with them. The basic primitive for drawing a geometric model is the triangle. It is the most suitable and can be most easily applied to various processing techniques, such as extruding, colouring by material and texture, and other types of visualizations. 3D modelling is a way of specifying a mathematical description of real or imaginary objects in coordinate space. All this is

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done with the help of edges, vertices and polygons. The 3D model can also be formed by a sequence of points that are connected using specific rules and primitives based on the following: triangles, lines and curves [4]. Thus, shapes can be created in three ways:

- Algorithmic.
- Through a 3D modelling program.
- By scanning.

Materials and Methods

Through procedural modelling, it is possible to create models through techniques following specific rules of computer graphics. Objects created in this way can be added to various projects, such as a 3D extreme game. All techniques known in programming follow specific algorithms, which are subsequently applied to construct 3D objects. In this article, algorithmic modelling is presented, which is based on mathematical laws. A new method for modelling polygons, polyhedra, and bodies of rotation is presented. Newton, in his book, explains the concept of physical-mathematical boundaries. Now the first lemma that he proves [5] will be stated. After that, its mathematics equivalent will be presented, which is related to the proposed new boundary author method.

Lemma: 1 Quantities, and also a ratio of quantities, which constantly tend to equality during an arbitrary finite time and which before the end of that time approach each other closer than an arbitrarily given difference finally become equal.

Newton's proof: If we deny this, let the magnitudes be ultimately unequal, and let their last difference be D . Hence they cannot approach equality more than the given difference, contrary to a contradiction [6].

Lemma computer equivalent newton's method: Let us understand by magnitudes a regular polygon inscribed in a circle starting with three vertices. We assume that the number of vertices of the circle can vary to infinity. The side length of the polygon decreases.

Case I: We assume the circle has an arbitrary finite number of vertices. Starting to increase the number of vertices of the polygon, the face of the polygon and the circle constantly tend to equality. The aspect ratio of the faces of the figures will be 1:1. The polygon changes to a circle.

Case II: The number of vertices of the polygon and the circle constantly tend to equal and grow simultaneously. After their faces align, the number of vertices continues to grow. After the magnitudes become equal, they continue to change ad infinitum, but with the condition that they cannot pass. This process can stop at any moment.

Basics of computer lighting and coloring

The foundations of the understanding of light and colours were laid by Isaac Newton. He discovered that the rainbow refracts the light with a prism and separates the colours into red, orange, yellow, green, blue, etc. In other words, white light consists of 7 types of colour. The cone cells in our eyes allow humans to understand and see the colours of the rainbow. Newton proved that red, green and

blue are the basis of all colours. Newton's colour wheel helps designers create a palette of colours.

Extrude the graph

The purpose of the extruding technique is to create arbitrary 3D models by driving two-dimensional graphics; the same technique can be applied to three-dimensional ones. Here, the actuation itself is done by (translation, rotation and movement using an arbitrary two-dimensional curve), which is of two types: Spline and Bezier. The presented new stereoscopic system-StereoMV uses second types of curves in constructing rotational body. For example a cubic Bezier curve with two segments is used for the solid cylinder body. A quadratic curve and 6 segments were used to generate the inclined and straight cylinder without upper and lower bases. The sphere and cone are generate with rotational and translation movement.

The idea behind the approach is to extrude a circle to form a three-dimensional object. The reason for this is that so far, in the development of the stereo system, it has come to generate a polygon with 12 vertices. Before extruding the 2D or 3D curve through the modelling program, in this case, blender, it is necessary to import the .obj file generated by StereoMV into the program. Next is a conversion to a Bezier curve, after which the curve can be extruded.

3D modeling using blender

All 3D graphics are based on geometric models, such as quadrilateral, cone, cylinder, sphere, etc. Arbitrary 3D models can be created. Modelling options in blender are 10 in number and are shown in Figure 1 the program also has an additional opportunity to extrude a regular polygon and curve, followed by 3D processing [7].

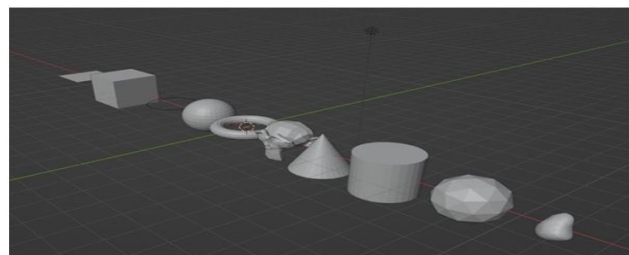


Figure 1. Basic primitives in blender.

This paper presents a new approach for creating objects. First, a 3D file of a stereo metric object is generated. After that, it is imported into blender. In this environment, the most diverse techniques known from three-dimensional programming can be applied to the geometric object. After that, the models created in this way can be added to a wide variety of projects, such as a game designed for virtual reality that can participate in cardiac data analysis. Application of the innovatively created 3D models

Serious games differ from traditional games in that they are developed for a purpose other than entertainment. They can be divided into cognitive and reaction time. The first type is designed so that the player has to answer questions and lasts between 8 and 10 minutes. The second are games that require quick response and precision. When analyzing cardiac data, they are preferable. By simulating a stressful situation representing a 3D game with the help

of Virtual Reality (VR) it is possible to examine a patient's cardiac condition. The goal is to perform a Holter recording during virtual reality and at rest. After which, make a mathematical analysis of the obtained data [8-10]. 3D technology can support the analysis of cardiac data. Here, the joint participation of programmers and doctors is necessary to make an accurate diagnosis and correct treatment. This new approach can be applied to people who cannot undergo active physical work and sports. This can be older people and sick children. The presented new programming polygons are mathematically more accurate and can be more easily processed. They are significantly more flexible than the traditional programming polygons characterized by trigonometry. Thanks to the new boundary method, it is possible to use a 3D library, and the main advantages of polygons come from there. Virtual reality devices can be divided into immersive and non-immersive systems. Developed serious games can be visualized both ways thanks to the new method. It is assumed that the greater the immersion in VR, the greater the effect of the game on the heart rate variability will be the greatest. Java 3D has several rendering related modes of operation, two of which can handle the new to programming polygons proposed in this article. These are the Immediate and Mixed Immediate modes. The second mode was used in the development of the mathematical software StereoMV. It is also involved in the design of the serious games. All techniques in generating the stereo metric objects are part of the 3D project (serious game) designed to analyze cardiac data.

Results and Discussion

The new programming regular polygons proposed in this article are based on more precise mathematical laws than traditional polygons based on trigonometry. As mentioned, they are more flexible and can be handled more efficiently by a 3D modelling program. Using the new method, a parametric representation of the figures depending on the length of the side of the polygon is possible. One of the most significant advantages is that virtual reality systems can visualize the new polygons with and without immersion: CAVE,

FishTank, HMD, 3D active technology and 3D passive technology. The idea of the new boundary method presented in this article, which is based on Isaac Newton's method of limits, is to notice the dependence of numbers representing an infinite numerical series. The first represents a relation of parallel segments in the case of a regular polygon inscribed in a circle. Next is a determination of numbers from the vertices of a regular polygon to pyramid with a regular base polygon with ten vertices. In Figure 2 shows the information of an .obj file for a regular polygon with ten vertices. First, the ratio of parallel segments is determined, after which the values of the vertices are calculated. All this is done using the new boundary method. Dependence between the upper and lower bases of an isosceles trapezoid is used. Table 1 presents the information on the computer drawing of a regular prism Figure 2 with a regular base polygon with ten vertices. The coordinates of the vertices are calculated, and the base is drawn based on the triangle primitive. The vertices must be traversed in the same clockwise direction. Next is the addition of the upper base, representing another like the first regular polygon. The surrounding walls are based on quadrangles. The difference between the two bases is in the coordinate value along the ordinate.

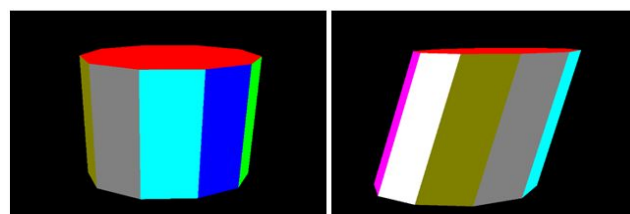


Figure 2. Regular prism (straight and inclined).

The main goal of the proposed new method is to represent the geometric objects mathematically in a precise, *i.e.* parametrically. Tables 1 and 2 present information on generating a regular prism with bases, a regular polygon with ten vertices.

| Number of vertex | X | Y | Z | Wall surrounding |
|------------------|------------------------------------|---|---|------------------|
| 1 | $a/2$ | $a \cdot \sqrt{0.40} + 0.91 \cdot a$ | 0 | 1,10,20,11 |
| 2 | $1.28 \cdot a$ | $0.91 \cdot a$ | 0 | |
| 3 | $1.28 \cdot a + 0.59/2 \cdot a$ | 0 | 0 | 2,1,11,12 |
| 4 | $1.28 \cdot a$ | $-0.91 \cdot a$ | 0 | |
| 5 | $a/2$ | $-(a \cdot \sqrt{0.40} + 0.91 \cdot a)$ | 0 | 3,2,12,13 |
| 6 | $-a/2$ | $-(a \cdot \sqrt{0.40} + 0.91 \cdot a)$ | 0 | |
| 7 | $-1.28 \cdot a$ | $-0.91 \cdot a$ | 0 | 4,3,13,14 |
| 8 | $-(1.28 \cdot a + 0.59/2 \cdot a)$ | 0 | 0 | |
| 9 | $-1.28 \cdot a$ | $0.91 \cdot a$ | 0 | 5,4,14,15 |
| 10 | $-a/2$ | $a \cdot \sqrt{0.40} + 0.91 \cdot a$ | 0 | |
| 11 | $a/2$ | $a \cdot \sqrt{0.40} + 0.91 \cdot a$ | H | 6,5,15,16 |
| 12 | $1.28 \cdot a$ | $0.91 \cdot a$ | H | |
| 13 | $1.28 \cdot a + 0.59/2 \cdot a$ | 0 | H | 7,6,16,17 |

| | | | | |
|----|------------------------------------|---|---|------------|
| 14 | $1.28^{\circ}a$ | $-0.91^{\circ}a$ | H | |
| 15 | $a/2$ | $-(a^{\circ}\sqrt{(0.40)+0.91^{\circ}a})$ | H | 8,7,17,18 |
| 16 | $-a/2$ | $-(a^{\circ}\sqrt{(0.40)+0.91^{\circ}a})$ | H | |
| 17 | $-1.28^{\circ}a$ | $-0.91^{\circ}a$ | H | 9,8,18,19 |
| 18 | $-(1.28^{\circ}a+0.59/2^{\circ}a)$ | 0 | H | |
| 19 | $-1.28^{\circ}a$ | $0.91^{\circ}a$ | H | 10,9,19,20 |
| 20 | $-a/2$ | $a^{\circ}\sqrt{(0.40)+0.91^{\circ}a}$ | H | |

Table 1. Parametric values of a regular prism with bases and 10 vertices.

| Number of vertex | X | Y | Z | Wall |
|------------------|--------|--------|---|------------|
| 1 | 0.5 | 1.542 | 0 | 1,10,20,11 |
| 2 | 1.28 | 0.91 | 0 | |
| 3 | 1.575 | 0 | 0 | 2,1,11,12 |
| 4 | 1.28 | -0.91 | 0 | |
| 5 | 0.5 | -1.542 | 0 | 3,2,12,13 |
| 6 | -0.5 | -1.542 | 0 | |
| 7 | -1.28 | -0.91 | 0 | 4,3,13,14 |
| 8 | -1.575 | 0 | 0 | |
| 9 | -1.28 | 0.91 | 0 | 5,4,14,15 |
| 10 | -0.5 | 1.542 | 0 | |
| 11 | 0.5 | 1.542 | 2 | 6,5,15,16 |
| 12 | 1.28 | 0.91 | 2 | |
| 13 | 1.575 | 0 | 2 | 7,6,16,17 |
| 14 | 1.28 | -0.91 | 2 | |
| 15 | 0.5 | -1.542 | 2 | 8,7,17,18 |
| 16 | -0.5 | -1.542 | 2 | |
| 17 | -1.28 | -0.91 | 2 | 9,8,18,19 |
| 18 | -1.575 | 0 | 2 | |
| 19 | -1.28 | 0.91 | 2 | 10,9,19,20 |
| 20 | -0.5 | 1.542 | 2 | |

Table 2. Precise values of setting of a prism with a base of 10 vertices.

The walls column shows information about the surrounding walls, which are ten in number. The primitive for the surrounding walls is a quadrilateral, and it is a triangle for the top and bottom bases. In Figure 3, a regular polygon with ten vertices is extruded along a trajectory defined by an arbitrary curve. In Figure 4, the regular polygon generated by the new method is extruded along a trajectory representing a curve based circle. Before applying the modelling technique in three-dimensional space, the geometric figure must be converted into a curved that is show on Figure 5. In Figure 6 polygon is extruded to a prism without upper and lower bases. First, it must be converted to a curve and given an extruded value.

The traditional way to generate a prism and pyramid is to extrude a polygon. Blender makes it possible to construct a pyramid and a prism. Figure 7 shows a .obj file obtained by extruding a polygon along a path defined by a spiral, which represents a curve, in Figure 8 prism is a region specific extrusion through the blender program. In Figure 9 presents a regular polygon with five vertices generated by the new method. Next is its import into the blender program. After that, a smoothing technique called subdivision surface modelling is applied. The level view parameter varies with values between 0 and 6. In this case, it is set to a value of 5, which defines the correct polygon in a circle. Also, the program can process polygons and arbitrary curves (including

surfaces based on them). In Figure 8, the 3D model is loaded into Java 3D using the language's standard loader. Figure 6 extrudes a polygon with ten vertices along a spiral curve. In Figure 7, the regular pyramid with a base of 10 vertices is smoothed, *i.e.* converted to a cone. This is done through the tool named Screw from the add modifier menu in Figure 10 of the prism and pyramid, the Remesh technique is applied; through it, the stereo metric object can be processed in 4 ways (Blocks, Smooth, Sharp and Voxel).

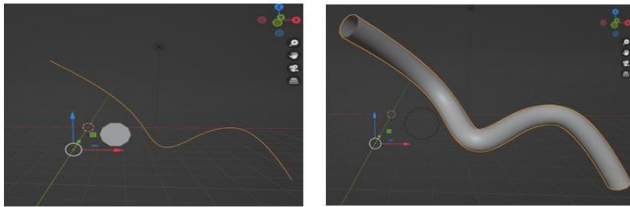


Figure 3. Extruded polygon along a curve.

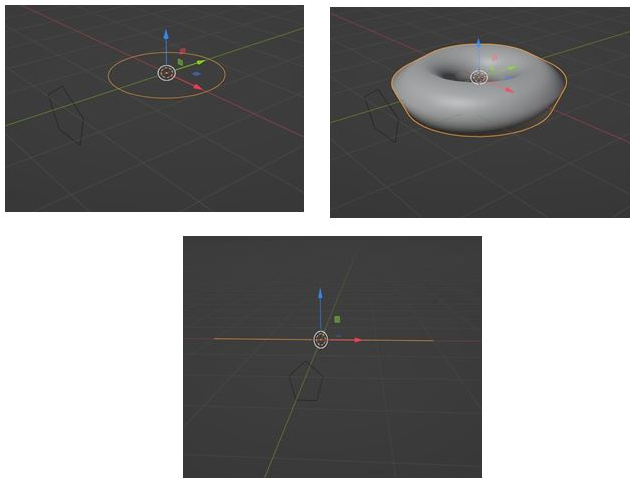


Figure 4. Extruded polygon on a circle.

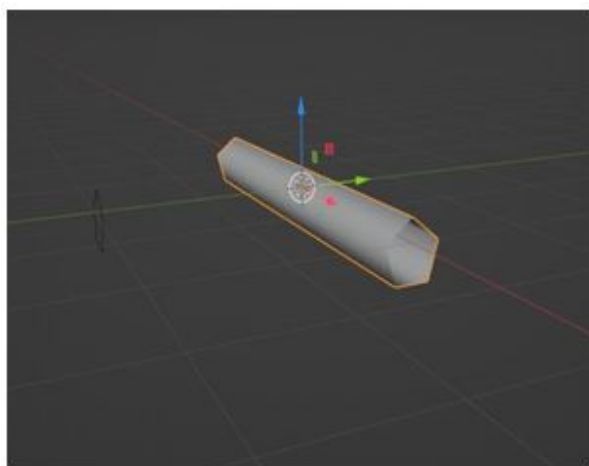


Figure 5. Extruded polygon along a line.

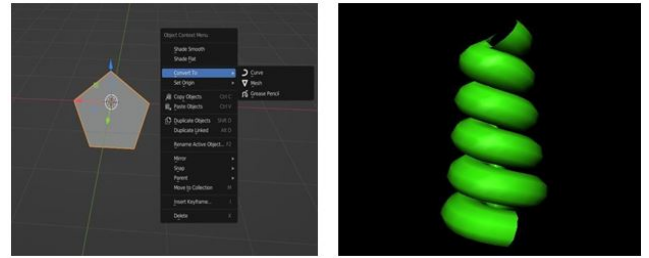


Figure 6. Extruded curve/spiral polygon.

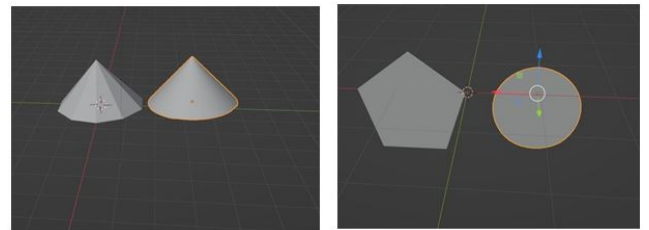


Figure 7. Pyramid and polygon smoothing.

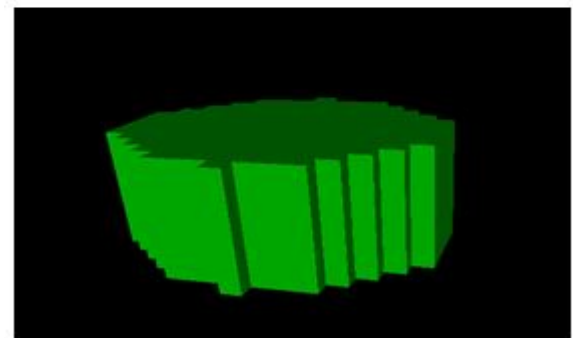
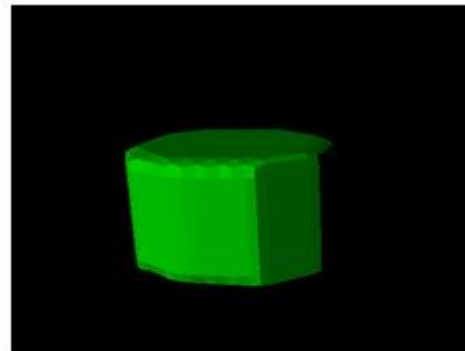


Figure 8. Applying the remesh technique to a prism.

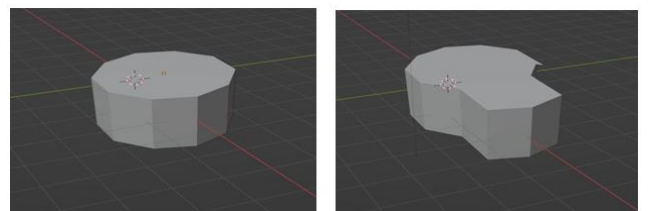


Figure 9. Extrude a region with Blender.

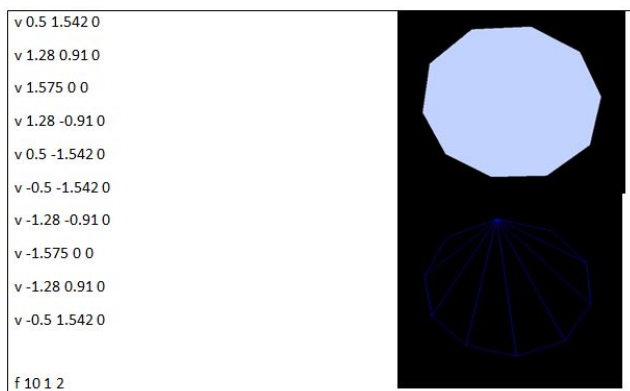


Figure 10. A regular polygon with 10 vertices.

Conclusion

This article presents a new way to model objects that can be real or fictional. Isaac Newton used a method that can find applications in computer graphics. The paper presents a new lemma related to the boundary method describing Newton's approach computationally. The Java 3D programming language and blender, a program for modelling three-dimensional models, were used to describe the results. It is known that based on geometric objects regular polygon, prism, pyramid, cone, sphere and cylinder, arbitrary models can be constructed by applying a large set of techniques in 3D modelling. To this end, a new software system for stereometry training is presented in this paper. After exporting the shape to a .obj file, it is imported into blender, after which the object is modeled. After it is completed, it is exported again in .obj format and finally added to a 3D project, which can be a serious extreme game involving cardiac data analysis.

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