where z_3 - is the number of ripened fruits on the plant;

x_{31} - planting density;

x_{32} - dose of nitrogen application;

x_{33} - dose of phosphorus application;

x_{34} - irrigation rate;

x_{35} - sum of effective temperatures;

x_{36} - soil surface temperature;

x_{37} - relative humidity;

Crop yield as the final state of the plant, depending on the states at the previous stages, is described by the following equation

$$z_4 = f_0 + f_1 y + f_2 z_1 + f_3 z_2 + f_4 z_3.$$

Therefore, a key component of every socio-economic system is agriculture and the agro-industrial complex. This can be attributed to the fact that these industries and management domains supply food to people, which is a necessary prerequisite for human survival and meets their basic needs [1]. Furthermore, it should be mentioned that as food is produced by the agro-industrial complex and serves as a building block for human bodies, there is a direct correlation between high-quality agricultural products and people's present health and lifespan [2; 3]. The issue of food shortages will only worsen due to the expanding global population and the widespread need for judicial justice.

As per the authors' perspective, artificial intelligence technologies play a major role in automating various tasks related to economic and management processes. These tasks include optimizing sowing work, harvesting, monitoring crop conditions, correctly composing feed mixtures, eliminating pests, automating animal feeding, and other related tasks. This article's goal is the aforementioned. It entails organizing and generalizing information about potential artificial intelligence applications in agriculture. These applications can be effectively applied to both the fundamental duties of the agro-industrial complex—namely, supplying the population with wholesome food—and to gain new farming competitive advantages over rivals in the near future.

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REZYUME. Maqolada tuproq unumdorligini hisobga olgan holda yuqori mahsuldor ekin navlarini etishtirish bo'yicha ko'rsatmalar yaratish hamda global muvaffaqiyatlarga tatbiq etiladigan blokcheyn texnologiyasi va sun'iy intellekt mexanizmlari asosida ekinlar va yer unumdorligini baholash dasturini yaratish muhokama qilinadi. Bundan tashqari, zamonaviy axborot texnologiyalari tuproq sifatini yaxshilash, xomashyoni qayta ishlash va mahsulot ishlab chiqarishni optimal boshqarish masalalari tahlil qilinadi.

РЕЗЮМЕ. В статье рассматривается создание методических рекомендаций по выращиванию высокоурожайных сортов сельскохозяйственных культур с учетом плодородия почвы, а также создание программы оценки урожайности сельскохозяйственных культур и земель на основе технологии блокчейн и механизмов искусственного интеллекта, которые имеют глобальные успехи. Кроме того, анализируются вопросы современных информационных технологий улучшения качества почвы, переработки сырья и оптимального управления производством продукции.

SUMMARY. The article discusses the creation of guidelines for the cultivation of high-yielding crop varieties, taking into account soil fertility, and the creation of a program for assessing crop and land productivity based on blockchain technology and artificial intelligence mechanisms, which are applied to global successes. In addition, issues of modern information technology are analyzed improvement of soil quality, raw material processing and optimal management of product production.

COMPARISON OF BOUNDARY AND VOLUME BASED REPRESENTATION TYPES IN 3D GRAPHICS APPLICATION AREAS

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Tayanch so'zlar: 3D grafika, chegaraga asoslangan tasvirlash, hajmga asoslangan tasvirlash, polygon to'rlar, NURBS, voksellar, konstruktiv qattiq jism geometriyasi, kompyuter grafikasining qollanilishi, CAD, tibbiy tasvirlash.

Ключевые слова: 3D графика, представление на основе границ, представление на основе объема, полигональные сетки, NURBS, воксели, конструктивная твердотельная геометрия, применения компьютерной графики, САПР, медицинская визуализация.

Key words: 3D graphics, boundary-based representation, volume-based representation, polygon meshes, NURBS, voxels, constructive solid geometry, computer graphics applications, CAD, medical visualization.

Introduction. Computer graphics is a dynamic field where professionals from various disciplines collaborate to create visual "windows" into digital worlds. These visual representations, displayed on devices like monitors and smartphones, help us interact with digital models. At the core is the generation of computer-rendered images, transforming data such as 3D scenes or scientific measurements into visuals. With advancements in processing power and algorithms, computer graphics has become essential across many domains, including:

Entertainment: Visual effects, 3D environments, and video game graphics.

Architecture and Engineering: Design visualization and virtual prototypes.

Medicine: Virtual training and complex procedure planning.

Boundary-based representation types

The wide application of 3D graphics requires robust representation methods. Choosing between boundary-based and volume-based techniques is crucial, as each has distinct advantages for different fields. This paper compares these methods to assess their effectiveness in various applications [1].

A 3D model is defined by its shape and visual features. Representation methods fall into two categories: surface and volume. Boundary-based methods, like polygon meshes and NURBS, focus on an object's surface, while volume-based methods, such as voxels and CSG, describe the entire volume. Polygon meshes consist of interconnected surface elements like triangles or quadrilaterals, as shown in Figure 1.1.

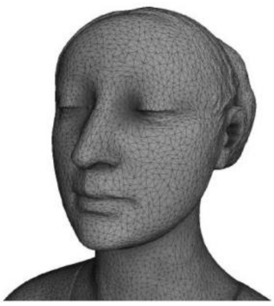

Figure 1.1*: An example of polygon mesh (about 22,000 faces).*

Formally, a mesh M can be defined as a tuple (V, K) where V = $\{v_i \in R^3 | i = 1 . . . N_v\}$ represents the set of vertices of the model (points in R^3) and K contains the adjacency information. In other words, K describes how vertices are connected to form edges and faces within the mesh. For instance, a mesh consisting of a single triangle could be represented as ($\{v_0, v_1, v_2\}$, $\{\{v_0, v_1\}, \{v_1, v_2\}, \{v_2, v_0\}, \{v_0, v_1, v_2\}\}$), where the first part lists the vertices, and the second part lists the edges and the triangular face formed by them [2].

In computer graphics, the most common mesh types are triangular and quadrilateral meshes. For rendering, points of segments or triangles are typically rendered. Consequently, quadrilateral meshes are often converted into triangles by dividing each quadrilateral into two triangles.

Polygon meshes have limitations due to their discrete nature, as curved surfaces are approximated by flat faces, losing smoothness and detail. NURBS (Non-Uniform Rational B-Splines) offer a solution by representing a broader set of curves using blending functions. The term "non-uniform" refers to the flexibility of the knot sequence, allowing more control over curve shapes. A NURBS curve of order *k* is defined as:

$$P(t) = \frac{\sum_{i=0}^{n} w_i P_i N_{i,k}(t)}{\sum_{i=0}^{n} w_i N_{i,k}(t)}$$

In this context, *n* represents the number of control points, P_i are the control points, $\{N_{i,k}(t)\}$ is the blending function similar to that used in B-spline curves, and w_i are weights that adjust the curve's shape. Using the tensor product surface approach, we can extend the NURBS curve definition to create NURBS surfaces in a manner similar to Bézier patches:

$$S(u, v) = \frac{\sum_{i=0}^{n}\sum_{j=0}^{m} w_{ij} P_{ij} N_{i,k}(u) N_{j,m}(v)}{\sum_{i=0}^{n}\sum_{j=0}^{m} w_{ij} N_{i,k}(u) N_{j,m}(v)}$$

NURBS inherit B-splines' local control property, meaning adjusting a single control point only affects the local surface, allowing for easy manipulation of large areas. This makes NURBS essential in advanced modeling software like Maya and Rhino. Figure 2.1 shows a 3D model created with NURBS.

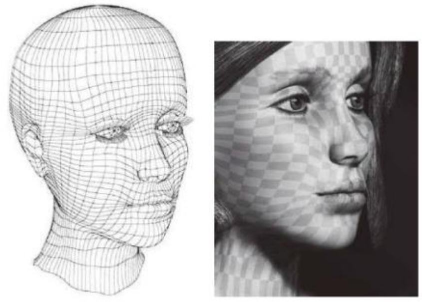

FIGURE 2.1*: NURBS surfaces modelling. (Left) NURBS head model from the "NURBS Head Modeling Tutorial" by Jeremy Bim (available at http://www.3drender.com/jbirn/ea/HeadModel.html.) (Right) The grid on the final rendered version shows the UV parameterization of the surface.*

Volume-based representation types

Voxels are commonly used to represent volumetric data, serving as a natural extension of two-dimensional images into three dimensions. Similar to how a digital image is made up of a matrix of pixels, a volumetric image consists of volume elements, or voxels, organized in a regular 3D grid (see Figure 3.1).

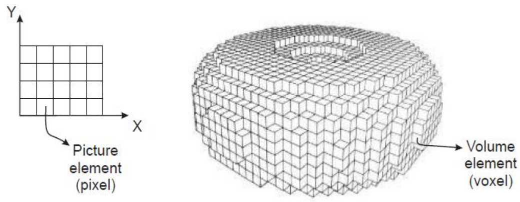

FIGURE 3.1*: From pixels to voxels.*

Each voxel in a 3D grid represents a specific volume, storing data such as density, temperature, or color. Voxels are widely used in medical imaging, like CT and MRI, to create volumetric representations of anatomical structures, encoding data like tissue types (see Figure 3.2) [4].

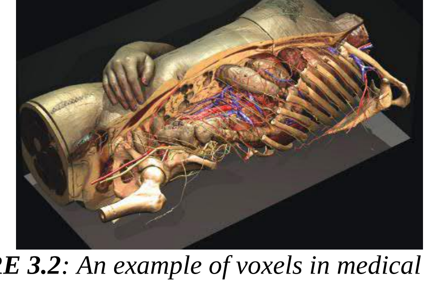

FIGURE 3.2*: An example of voxels in medical imaging. (Courtesy of Voxel-Man http://www.voxel-man.com.)*

Constructive Solid Geometry (CSG) represents 3D object volumes using Boolean operations on basic shapes (primitives). The CSG model is typically structured as a binary tree, with leaf nodes as primitives and branch nodes as Boolean operations (see Figure 4.1).

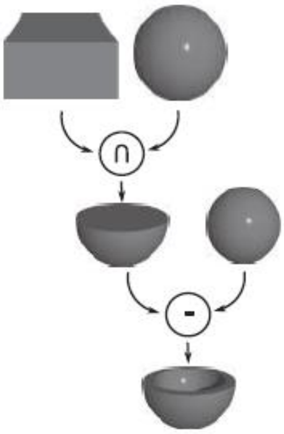

FIGURE 4.1: *Constructive solid geometry. An example of a CSG tree.*

Primitives in CSG can be defined using implicit equations, identifying the set of points that satisfy the inequality $f(x, y, z) < 0$, where $f(.) = 0$ serves as the implicit surface function. Points where $f(x, y, z) > 0$ are considered to be outside the volume bounded by the surface defined by $f(.)$ a convention typically assumed. Certain primitives, like a cube, may be defined by multiple implicit equations [4].

Results

Meshes are popular in video games, animation, and VR/AR for their detailed surfaces and ease of manipulation in animations. NURBS, however, offer advantages in accurately describing both simple and complex surfaces, making them ideal for CAD, automotive design, and high-precision modeling of smooth surfaces like car bodies.

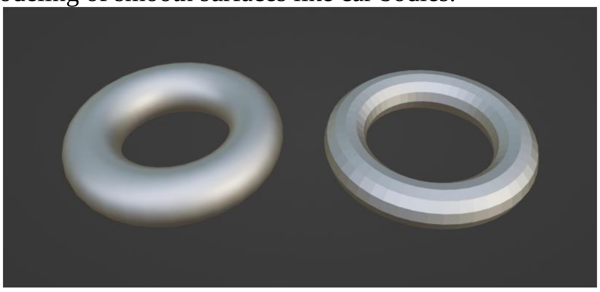

Figure 5.1: *A torus model with NURBS on the left side. Mesh on the right side.*

Figure 5.1 shows a torus model represented in two different ways - one as a NURBS model and the other as a mesh model. Their differences are illustrated in Figure 5.2, which shows that in NURBS modeling, the model is controlled through control points, where each point has its own weight and makes it easier to create smooth surfaces. In mesh modeling, however, the model consists of vertices (control nodes), and these nodes are used to directly control only that specific area, providing the ability to define the surface. This makes mesh modeling particularly suitable for creating complex organic forms and characters.

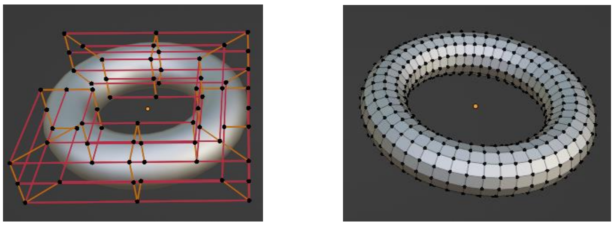

Figure 5.2: *Torus model with NURBS control points on the left and mesh model with control points on the right.*

Let's now look at voxels and constructive solid geometry, which describe volumetric data. Voxels can simultaneously represent both the surface and interior of an object, similar to how pixels represent a 2D image. Voxels are used in medical imaging and in game environments, such as in games with destructible environments like Minecraft. Voxels are good for representing internal structure details but have less detail in surface representation compared to meshes.

Now, regarding solid models, they represent the full volume of an object and often use geometric primitives: spheres, cylinders, cubes. Solid models are used in engineering, CAD, and manufacturing where precise volume and mass calculations are important. Their limitations include being very intensive for rendering and having limited flexibility in representing highly complex surfaces. Figure 5.3 shows a torus represented using different types of representation.

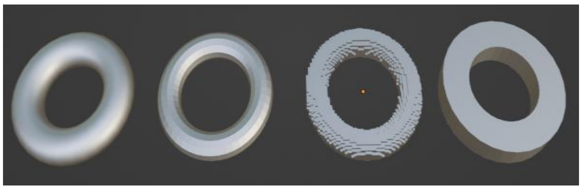

Figure 5.3: *from left 1. NURBS, 2. Mesh, 3.Voxel, 4.CSG representation of torus model.*

These four types of rendering have advantages and disadvantages related to specific fields. For example, meshes work well in the video game industry, film and animation because they are easy to modify since they are based on highly adaptable surfaces - we can take models in VR and AR as examples. NURBS, on the other hand, performs well in fields like CAD and automotive design because it's very easy to create smooth curved surfaces using mathematical expressions. As we mentioned before, voxels are convenient for visualizing volumetric data in medicine, for imaging tissues in physical space. Talking about constructive solid geometry, it is used in solid model engineering, based on its specific properties such as volume and mass.

Conclusion. Boundary-based and volume-based representations offer unique benefits in 3D graphics. Boundary methods, like meshes and NURBS, excel in surface-focused applications such as animation, gaming, and CAD. In contrast, volume methods, like voxels and CSG, are essential for internal analysis in medical imaging and engineering. While boundary methods offer flexibility in surface design, volume methods are crucial for structural data. Future advancements may integrate both approaches, enhancing 3D graphics across various domains.

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REZYUME. Maqolada 3D obyektlarni tasvirlashning yuzaga asoslangan va hajmga asoslangan usullari taqqoslanadi. Yuzaga asoslangan usullar, masalan, poligonal to‘rlar va NURBS, animatsiya va o‘yinlarda yuzani batafsil ifodalash uchun juda mos keladi. Hajmga asoslangan usullar, jumladan, voksel va CSG, tibbiyot va muhandislik sohalarida ichki tuzilmani tahlil qilish uchun ideal hisoblanadi. Tadqiqot ularning afzalliklari, cheklovlari va gibrid yondashuv imkoniyatlarini ko‘rib chiqadi.

РЕЗЮМЕ. Статья сравнивает поверхностные и объёмные методы представления 3D-объектов. Поверхностные методы, такие как полигональные сетки и NURBS, отлично подходят для детальной проработки поверхностей в анимации и играх, тогда как объёмные методы, например воксели и CSG, идеальны для анализа внутренней структуры в медицине и инженерии. Исследование рассматривает их преимущества, ограничения и возможности гибридного подхода.

SUMMARY. The article compares boundary-based and volume-based 3D representation methods. Boundary-based techniques, like meshes and NURBS, excel in surface detail for animation and gaming, while volume-based methods, such as voxels and CSG, are ideal for internal analysis in medical imaging and engineering. The study explores their strengths, limitations, and hybrid potential.

MATEMATIKA FANIDA RAQAMLI DIDAKTIK MATERIALLARNI YARATISH VA TATBIQ ETISHDAGI MUAMMOLAR

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Tayanch so‘zlar: raqamli didaktik materiallar, matematika ta’limi, muammolar, metodik tavsiyalar, texnologiyalar, ta’lim samaradorligi.

Ключевые слова: цифровые дидактические материалы, математическое образование, проблемы, методические рекомендации, технологии, эффективность обучения.

Key words: digital didactic materials, mathematics education, challenges, methodological recommendations, technologies, educational efficiency.

Kirish. Zamonaviy ta’lim tizimida raqamli texnologiyalarning ahamiyati tobora ortib bormoqda. Matematika kabi mantiqiy fikrlash va aniq bilimlarni talab qiluvchi fanlarda raqamli didaktik materiallar o‘quv jarayonini yanada samarali tashkil etishda muhim vosita hisoblanadi. Ushbu maqolada matematikada raqamli didaktik materiallarni yaratish va amaliyotga tatbiq etish jarayonida uchraydigan asosiy muammolar tahlil qilinadi.

Raqamli didaktik materiallarning ahamiyati. Raqamli didaktik materiallar (RDM) — zamonaviy ta’lim jarayonida pedagogik vazifalarni samarali hal qilishga yordam beradigan axborot texnologiyalari asosida yaratilgan vositalar. Ular ta’limni interaktiv, vizual va oson tushunarli shaklda tashkil qilish imkoniyatini beradi. Ayniqsa, matematika kabi murakkab va abstrakt fanlarda bunday materiallar o‘quvchilarning mavzuni chuqur tushunishlari, bilimlarni o‘zlashtirishlari va ularni amalda qo‘llashlari uchun qulay sharoit yaratadi [1:98].

1. O‘quv jarayonini interaktiv qilish. RDM yordamida o‘quvchilar faqatgina nazariy bilim olmay, balki o‘zlari bevosita ta’lim jarayonida faol ishtirok etadilar. Masalan:

- **Simulyatsiyalar va interaktiv grafikalar:** O‘quvchilar murakkab matematik jarayonlarni simulyatsiyalar orqali vizual tarzda kuzatishlari mumkin.
- **Interaktiv testlar va masalalar:** O‘quvchilarning darhol javob berib, xatolarini tahlil qilishlariga yordam beradi.

2. Mavzuni vizualizatsiya qilish. Matematika mavzulari ko‘pincha abstrakt bo‘lganligi sababli, tushunchalarni o‘zlashtirishda qiyinchiliklar tug‘iladi. Raqamli vositalar:

- Geometriyada fazoviy figuralarni uch o‘lchovli (3D) shaklda tasvirlab, ularni turli tomondan ko‘rish imkonini beradi.
- Algebra va analizda murakkab grafiklarni avtomatik chizib, ularning xatti-harakatlarini real vaqtda tahlil qilish imkonini beradi.

3. Individual yondashuvni ta’minlash. RDM o‘quvchilarni bilim darajasiga qarab turli xil mashqlar va topshiriqlarni taklif qilishga imkon beradi. Bu esa o‘quvchilarning:

- o‘z qobiliyatlariga mos ravishda bilim olishlariga;
- bilimlarini mustaqil rivojlantirishlariga yordam beradi.

4. Mustaqil ta’limni rivojlantirish. RDM yordamida o‘quvchilar mustaqil ravishda darslarni o‘rganishlari, o‘zlashtirishlarini baholashlari va murakkab masalalarni yechishda yangi usullarni o‘zlashtirishlari mumkin [2:113]. Masalan:

- Onlayn platformalar va mobil ilovalar yordamida mavzularni qayta ko‘rish va mustahkamlash.
- Virtual laboratoriyalar orqali matematik tajribalarni amalga oshirish.

5. Ta’lim samaradorligini oshirish. RDM o‘qituvchilarga:

- Dars vaqtini tejash va uni yanada mazmunli o‘tkazish imkonini beradi.
- Nazariy qismdan amaliyotga tez o‘tishni ta’minlaydi.
- Ko‘plab resurslarni bir joyda to‘plash va ulardan tezkor foydalanish imkonini yaratadi.

6. O‘quv motivatsiyasini oshirish. Raqamli materiallar: