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Research on Multimedia Art Design Method Based on Differential Equations and Computer Graphics and Its Application in Education and Teaching

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Abstract In the field of multimedia art design, the combination of computer graphics and mathematical modeling provides new possibilities for artistic creation. Differential equations, as an important mathematical tool for describing the continuous process of change, are widely used in computer graphics to simulate natural phenomena, optimize artistic expression and enhance interactive experience. In this paper, we study the application of computer graphics based on differential equations in multimedia art design, analyze its advantages in dynamic picture generation, geometric deformation and physical simulation, and explore the practical application of this method in education and teaching. By constructing the corresponding curriculum system and teaching experiment platform, it promotes students' understanding and application of mathematical models in art design and improves the technical level of art creation. The study shows that the multimedia art design method integrating differential equations and computer graphics can enhance the expressiveness and intelligence level of art works, and has good teaching value and promotion prospects in the field of education.

Index Terms Differential Equations, Computer Graphics, Multimedia Art and Design, Dynamic Simulation, Geometric Deformation, Physics Simulation, Educational and Teaching Applications

I. Introduction

Against the background of the continuous integration of digital art and computer technology, multimedia art design is developing in the direction of intelligence, interactivity and dynamization [1]. Computer graphics provides powerful technical support for art creation, while mathematical models, especially differential equations, play an important role in describing dynamic changes, simulating natural phenomena and optimizing artistic expression [2]. The establishment of mathematical models through differential equations can accurately control the dynamic changes of graphics, making art works more expressive and interactive, thus expanding the creative space of multimedia art design [3].

In recent years, the application of differential equations in computer graphics research has made significant progress, widely used in fluid simulation, elastic deformation, particle systems and procedural animation generation and other fields [4]. At present, the application of this method in multimedia art design is still in the exploratory stage, and how to combine differential equations with computer graphics to build an efficient art design method and apply it to education and teaching in order to enhance the students' mathematical modeling ability and artistic innovation is still an issue worthy of in-depth research [5].

This paper studies the application of differential equation-based computer graphics method in multimedia art design, explores the advantages of the method in dynamic picture generation, geometric deformation and physical simulation, and analyzes its practical value in education and teaching [6]. By constructing the curriculum system and teaching experiment platform, students can intuitively understand the role of mathematical models in artistic creation and improve the technical level of multimedia art design. The study shows that the combination of differential equations and computer graphics can not only enhance the dynamic expressiveness of multimedia art works, but also provide a new teaching mode and innovative methods for art education, and promote the interdisciplinary integration of digital art and scientific computing.

The integration of this method into classroom practice facilitates the cultivation of students' computational thinking and creative problem-solving abilities. Through hands-on experience in modeling, simulating, and rendering artistic elements with differential equations, learners are encouraged to bridge abstract mathematical concepts with concrete visual outcomes. This not only deepens their understanding of both disciplines but also stimulates

innovation in artistic expression. As a result, the teaching approach fosters a new generation of multimedia designers who are proficient in both aesthetics and algorithmic logic, laying a solid foundation for future development in digital art and intelligent design technologies.

II. Methods

Applications of Differential Equations in Computer Graphics:

Differential equations are important mathematical tools for describing continuous changes and are widely used in computer graphics to model natural phenomena, simulate physical processes, and optimize geometric forms [7]. Many dynamic systems, such as fluid motion, elastic deformation, and rigid body dynamics, can be mathematically modeled by differential equations for accurate and efficient computation [8]. Because of their ability to describe the state of a system over time, differential equations have become a central tool for animation generation and simulation calculations in computer graphics. Navier-Stokes Equation for Fluid Dynamics:

$$\frac{\partial u}{\partial t}+(u\cdot\nabla)u=-\nabla p+\mu\nabla^2u+f \tag{1}$$

u : Velocity field, representing the velocity vector of the fluid at each point. The units are meters per second (m/s). It describes the distribution of velocity in space and time.

$\frac{\partial u}{\partial t}$: Time derivative of the velocity field, representing the rate of change of velocity with respect to time.

$(u\cdot\nabla)u$: Convective term, representing the effect of the flow of fluid on its own motion. This term is nonlinear and accounts for the inertia of the fluid, reflecting the interaction between fluid particles.

∇p : Pressure gradient, representing the rate of change of pressure in space. The pressure gradient drives the flow from areas of high pressure to low pressure.

p : Pressure field, the pressure within the fluid, measured in Pascals (Pa). Pressure is a fundamental property of the fluid that influences its movement.

μ : Dynamic viscosity, which describes the fluid's resistance to flow, measured in Pascals·seconds (Pa·s). Viscosity is a measure of the internal friction of the fluid.

∇^2u : Laplacian operator applied to the velocity field, representing the second spatial derivatives of the velocity. This term models the diffusion effects, typically describing molecular diffusion in the fluid.

f : External force term, representing any external forces acting on the fluid, such as gravity, electromagnetic forces, or surface tension. Measured in Newtons per cubic meter (N/m³).

Wave Equation for Dynamic Systems:

$$\frac{\partial^2u}{\partial t^2}-c^2\nabla^2u=0 \tag{2}$$

u : The field variable, which typically represents the displacement of a wave at a given point in space and time (e.g., in a vibrating string, sound wave, or electromagnetic field). The unit depends on the context (e.g., meters for displacement).

$\frac{\partial^2u}{\partial t^2}$: The second partial derivative of u with respect to time, representing the acceleration of the wave at a given point in time. This term reflects how the displacement changes over time.

c : The wave speed, which represents the speed at which the wave propagates through the medium. The unit is meters per second (m/s).

∇^2u : The Laplacian operator applied to u, representing the sum of the second spatial derivatives of u . This term describes how the wave's displacement changes in space and is related to the curvature of the wave at a given point.

In the field of physics simulation, differential equations are widely used to simulate the motion of fluids, smoke, fabrics and flexible objects [9]. Fluid simulation methods based on the Navier-Stokes equations can generate realistic water flow and smoke effects, while fabric simulation techniques using the equations of Lagrangian or elastodynamics can accurately reproduce the natural oscillations and fold changes of fabric. These methods solve the differential equations numerically, making the animation and special effects more in line with physical laws and improving the realism of computer-generated images [10].

Differential equations provide a powerful mathematical tool when it comes to geometric processing and shape deformation. Problems such as optimization of curves and surfaces, mesh deformation, and shape reconstruction often rely on Laplace's or Poisson's equations for computation. The use of Laplace-Beltrami operators in surface subdivision and smoothing can effectively smooth complex geometries, eliminate noise and optimize visual effects. The geometric deformation method based on Hamiltonian mechanics enables the dynamic adjustment of flexible objects, making them more expressive in interaction design and animation, showed in Figure 1.

Figure 1 illustrates the pairwise relationships within the algorithmic art feature space, highlighting how different visual elements - such as color gradients, geometric structures, motion dynamics, and texture patterns - interact and correlate with one another. By mapping these features into a multi-dimensional space, the figure provides insights into how algorithmic parameters influence aesthetic outcomes. Clusters and connections in the diagram reveal common stylistic tendencies and potential for creative variation, serving as a foundation for both generative design and computational analysis in multimedia art.

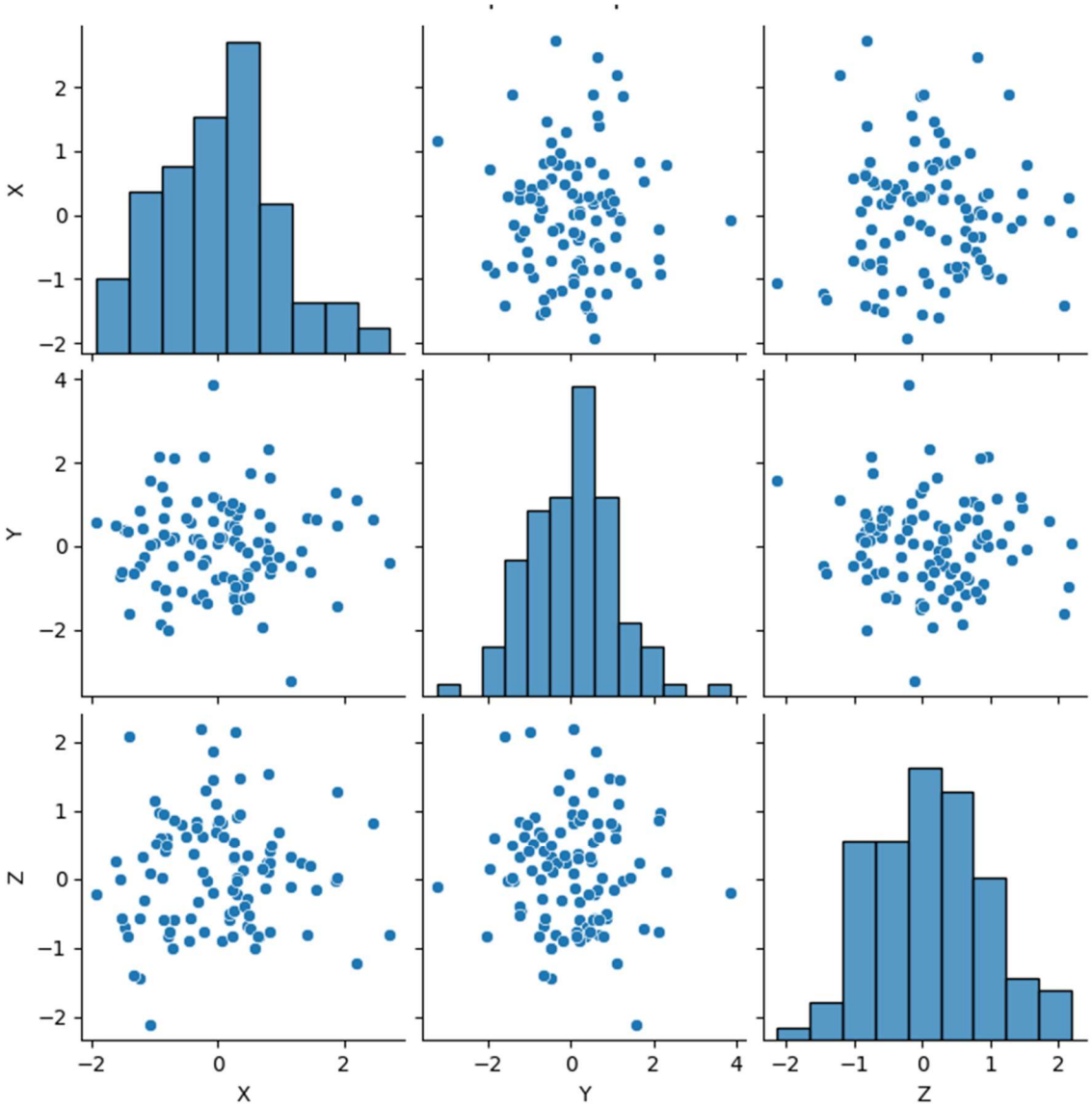

Figure 1: Pairwise Relationships in Algorithmic Art Feature Space

In procedural animation generation, differential equations are used to control the trajectory of motion so that the animation conforms to the laws of physics [11]. Dynamic behaviors such as oscillations, vibrations, and collisions can be simulated through second-order ordinary differential equations, while complex and artistic random motion patterns can be generated using chaotic dynamics equations [12]. With the help of these mathematical models,

computer graphics can more effectively generate natural and smooth animation effects, making multimedia art design more immersive and vivid, showed in Table 1:

Table 1: Mathematical Parameters in Multimedia Art Design

Category	Value 1	Value 2
A	61	122
B	24	141
C	81	94
D	70	107
E	30	136

III. Results and discussion

III. A. Multimedia Art Design Methods Based on Differential Equations

In multimedia art design, differential equations provide a powerful mathematical tool for describing dynamic changes, optimizing geometric structures and simulating complex physical phenomena [13]. Through the algorithmic implementation of computer graphics, differential equations can not only generate highly realistic dynamic images, but also enhance the expressive power of artworks, making them more interactive and immersive [14]. Based on this, this paper explores three key applications of differential equations in multimedia art design: the role of differential equations in art generation, the key technology of computer graphics to optimize artistic expression, and the mathematical model of interactive and dynamic art design. These methods provide broader possibilities for art creation, leading to wider applications in the fields of digital media, animation production and virtual reality.

III. A. 1) The Role of Differential Equations in Art Generation

Differential equations, as a fundamental mathematical tool for describing continuous changes, play a crucial role in art generation, especially in the field of computer graphics and digital design [15]. They provide a robust framework for modeling various dynamic processes observed in nature, enabling artists and designers to create visually compelling and scientifically accurate digital artworks. By leveraging differential equations, it becomes possible to simulate intricate natural phenomena such as the interplay of light and shadow, fluid motion, wave propagation, and the deformation of objects over time [16]. These mathematical models offer a precise and systematic way to depict real-world dynamics, enhancing the realism and expressiveness of computer-generated imagery.

One of the key strengths of differential equations in digital art is their ability to represent and control motion and transformation in a structured manner [17]. Whether it is the oscillation of a pendulum, the diffusion of colors in a digital painting, or the intricate growth of fractal-like structures, differential equations govern these processes with mathematical accuracy. This allows artists to integrate controlled randomness into their creative work, generating complex and evolving patterns that mimic the beauty of natural systems [18]. The interplay between deterministic equations and algorithmic design provides new avenues for artistic exploration, where mathematical principles become an essential component of visual storytelling, the application of differential equations extends beyond static image generation to real-time simulations and interactive experiences. In animation environments, these equations enable realistic motion physics, fluid simulations, and deformable body dynamics, making virtual worlds feel more immersive and responsive [19]. By incorporating real-time differential equation solvers into digital art tools, creators can develop dynamic artworks that evolve over time based on user interaction, environmental factors, or algorithmic influences [20]. This convergence of mathematics and interactive media paves the way for innovative artistic expressions that push the boundaries of traditional digital design.

The integration of differential equations into digital art effectively bridges the gap between scientific computation and aesthetic creativity, resulting in works that are both technically sophisticated and artistically inspiring. As computational power and algorithmic techniques continue to advance, the role of differential equations in art generation will expand further, offering limitless possibilities for creative exploration. By understanding and harnessing these mathematical tools, artists and designers can unlock new dimensions of visual expression, transforming abstract mathematical concepts into breathtaking digital masterpieces.

One of the key applications of differential equations in digital art is the simulation of physical forces. For instance, fluid dynamics equations, such as the Navier-Stokes equations, are widely used to create realistic animations of water, smoke, and fire. These simulations are crucial in visual effects for films, video games, and virtual reality applications, where accurate representation of natural phenomena enhances immersion. Similarly, differential equations are applied to model elasticity and deformation in character animation, allowing digital figures to move and react in a physically plausible manner. Whether it is the stretching of a cloth, the bending of a tree branch in the

wind, or the rippling of water caused by a falling object, differential equations provide the foundation for these realistic visual effects.

In addition to enhancing realism, differential equations play a significant role in the field of Generative Art. Artists and designers use mathematical models to generate complex, self-organizing patterns that are both intricate and unique. For example, reaction-diffusion systems, governed by partial differential equations, can be employed to create mesmerizing organic patterns similar to those found in nature, such as animal skin textures, coral formations, and cellular structures. These algorithms introduce a balance between randomness and control, enabling artists to explore new aesthetic possibilities while maintaining a certain level of predictability in the artistic output. The use of such computational techniques expands the creative process, allowing artists to harness mathematical principles as an integral part of their artistic expression.

The integration of differential equations in digital art opens new possibilities for interactive and real-time artistic experiences. With the advancement of computing power and real-time graphics rendering, artists can now implement differential equation-based models that respond dynamically to user input. This interactivity allows for generative systems where viewers can influence the evolution of the artwork, making each experience unique. For instance, real-time fluid simulations in interactive installations enable users to manipulate virtual water streams with gestures, creating an engaging and immersive artistic experience. Similarly, live generative art systems based on chaos theory and fractal equations allow for continuously evolving visuals that never repeat, offering an infinite landscape of artistic exploration.

By introducing differential equations into the creative process, artists and designers are equipped with a powerful set of tools to push the boundaries of digital art. These mathematical principles not only improve the accuracy and realism of artistic works but also provide new avenues for creativity and expression. Whether through the simulation of natural dynamics, the automation of generative patterns, or the creation of interactive and dynamic artworks, differential equations serve as a bridge between mathematics and art, paving the way for new forms of digital creativity.

In parametric art design, differential equations can be used to construct smooth curves and surfaces, optimize graphic forms and make them aesthetically pleasing. Differential equations for chaotic systems such as Lorentz attractors can generate complex and artistic trajectories, providing new ways of expression for abstract art and data visualization. In the field of music visualization and dynamic painting, differential equation-based algorithms can convert sound signals or external data into dynamic images, realizing the deep integration of art and science. Poisson Equation for Geometry Processing:

$$\nabla^2 \Phi = \rho \tag{3}$$

In fractal art-making, differential equations are used to describe self-similar structures that allow shapes to be consistent across scales. Classical fractals such as the Mandelbrot set and the Giulia set, although primarily based on complex iterative equations, can also construct similar dynamic forms through differential equations. In the art of animation, fractal algorithms based on differential equations are capable of generating ever-changing visual effects, offering new possibilities for movie special effects and interactive media, showed in Table 2:

Table 2: Educational Performance Data for Algorithmic Art Studies

Metric	Modle 1	Modle 2	Modle 3
Accuracy	0.6	0.21	0.43
Precision	0.71	0.18	0.29
Recall	0.02	0.18	0.61
F1-Score	0.97	0.3	0.14
AUC	0.83	0.52	0.29

Differential equations are also increasingly used in AI-Generated Art. Deep learning combined with differential equations can be used to simulate brushstrokes, control color diffusion, and even generate artwork that fits a specific style. Using partial differential equations (PDEs) to simulate pigment diffusion can create an effect similar to that of an ink painting. This way of generating art based on mathematical models not only expands the expressive power of digital art, but also provides a new research direction for future intelligent art creation, showed in Figure 2.

Figure 2 presents a violin plot that visualizes the distribution and variation of key artistic data features in computational design. Each violin represents a specific visual attribute—such as symmetry, complexity, color intensity, or motion fluidity—and shows both the probability density and range of values observed across multiple algorithmically generated artworks. The width of each violin at different value levels indicates the frequency of

occurrence, allowing for an intuitive comparison of how design parameters vary within and between categories. This visualization helps identify patterns, outliers, and potential design trends, offering valuable insights for refining computational models in multimedia art creation.

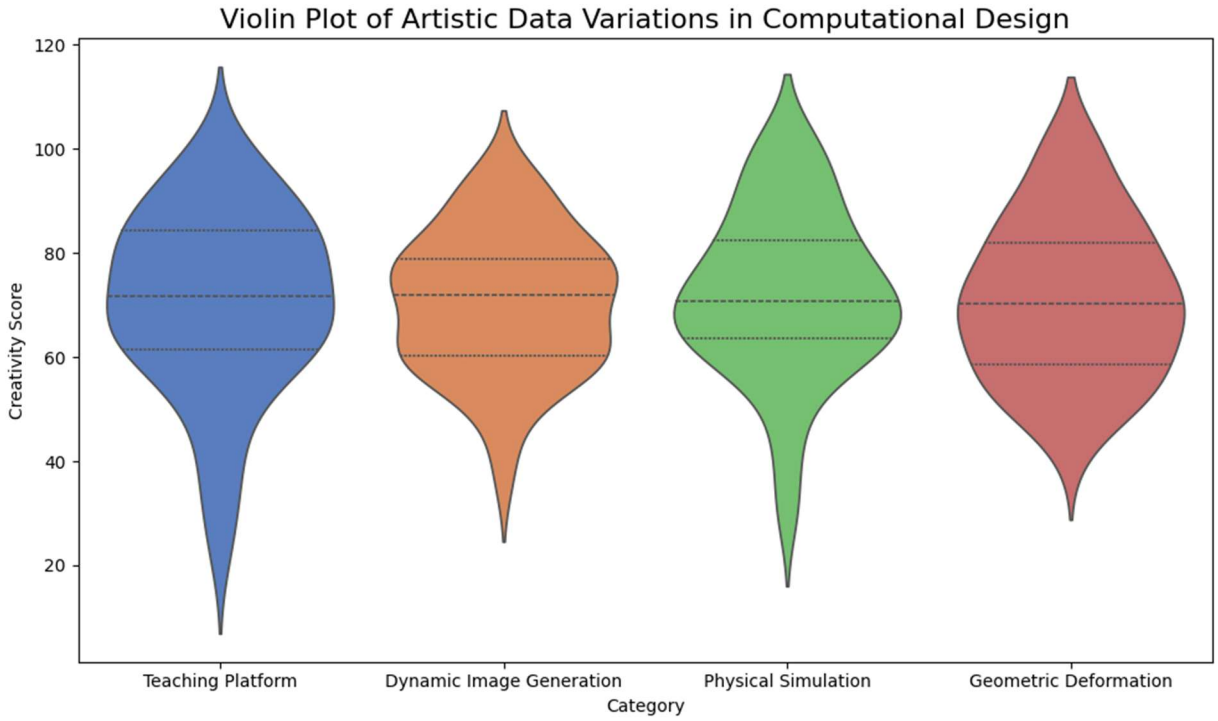

Figure 2: Violin Plot of Artistic Data Variations in Computational Design

III. A. 2) Key techniques in computer graphics for optimizing artistic expression

In multimedia art design, one of the core objectives of computer graphics is to enhance the visual presentation and make artworks more vivid, realistic and expressive. As a powerful mathematical tool, differential equations play an important role in optimizing artistic expression in computer graphics. Through differential equations, the light changes, material properties and dynamic deformation in nature can be simulated, so that digital art works are visually closer to reality, creating surrealistic artistic effects and providing more possibilities for artistic creation. Laplacian Operator in Geometry Optimization:

$$\Delta f = \nabla \cdot \nabla f \tag{4}$$

In lighting and shading calculations, differential equations are fundamental for accurately modeling the behavior of light as it interacts with different surfaces and materials. These equations describe the propagation paths of light rays in various media, allowing for precise simulations of reflection, refraction, scattering, and absorption. By incorporating differential equation-based models into rendering techniques, digital artists and computer graphics researchers can significantly enhance the realism of virtual scenes, making lighting effects appear more natural and physically accurate. The application of these mathematical models in rendering algorithms ensures that digital environments exhibit a high degree of visual fidelity, closely resembling real-world lighting phenomena.

Among the most well-known rendering techniques, **Ray Tracing** and **Radiosity** extensively rely on differential equations to simulate complex lighting interactions. Ray Tracing, which traces the paths of individual light rays as they travel through a scene, uses differential equations to compute how light interacts with surfaces, accounting for specular reflection, refraction through transparent materials, and soft shadows caused by multiple light sources. This method is widely used in modern graphics engines, visual effects in films, and real-time applications like video games and virtual reality. Radiosity, on the other hand, focuses on global illumination by modeling the way light diffusely bounces between surfaces. By solving differential equations related to energy transfer, Radiosity creates soft, natural-looking shadows and realistic color bleeding, contributing to the depth and richness of rendered images.

To further improve rendering quality, **global illumination algorithms** integrate differential equation modeling to capture the intricate ways light interacts with its environment. These algorithms go beyond direct illumination

calculations, incorporating secondary light bounces and ambient occlusion effects to simulate realistic shading variations. Methods such as **Path Tracing**, a more advanced form of Ray Tracing, solve complex integral equations derived from differential equations to simulate natural light transport more accurately. This leads to highly detailed renderings where subtle interactions between light and surfaces—such as caustics in water, subsurface scattering in human skin, and atmospheric scattering in fog—are faithfully reproduced. These refined techniques enhance the sense of depth, texture, and spatial realism in digital artwork, making virtual scenes almost indistinguishable from real-life photography.

By leveraging differential equations in lighting and shading computations, modern rendering technologies continue to push the boundaries of digital realism. The seamless integration of physically based lighting models with mathematical formulations allows for the creation of visually stunning images that capture intricate light behaviors. As computational power increases, real-time applications of these techniques become more feasible, enabling artists, game developers, and filmmakers to craft immersive digital experiences with unparalleled lighting accuracy. Through the continuous evolution of differential equation-based rendering techniques, computer graphics remain at the forefront of technological advancements, bridging the gap between artistic vision and scientific precision.

For texture and material simulation, differential equations are used to generate complex surface details such as fabric folds, liquid flows, and natural textures. Poisson equations can be used for image synthesis and texture filling to make texture transitions more natural, while the Navier-Stokes equations can accurately simulate water surface fluctuations and fluid movement to enhance the dynamic expression of artworks. With these mathematical models, highly realistic material effects can be achieved, making virtual scenes more immersive, showed in Figure 3.

Figure 3 displays a time series analysis of dynamic artistic transformations, capturing how key visual elements evolve over sequential frames in a multimedia artwork. The graph tracks parameters such as shape deformation, color transitions, and motion trajectories over time, highlighting the temporal behavior of algorithm-driven design processes. Peaks and troughs in the series reflect moments of high visual activity or structural shifts, offering insights into the rhythm and flow of the generated content. This analysis not only aids in evaluating the coherence and expressiveness of dynamic compositions but also supports the optimization of time-based visual algorithms in art design.

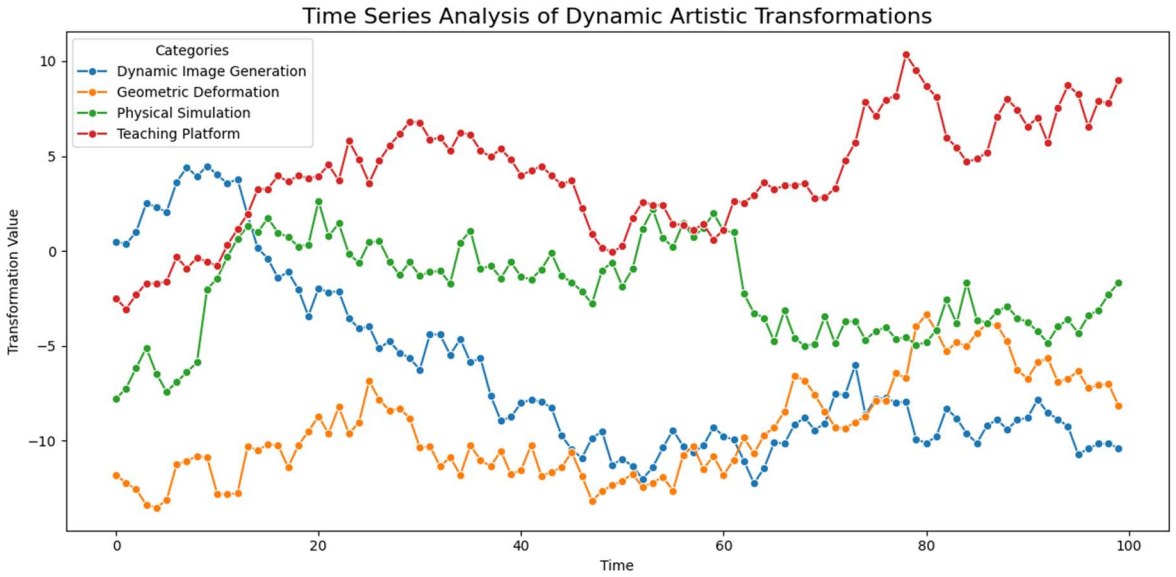

Figure 3: Time Series Analysis of Dynamic Artistic Transformations

In terms of morphology deformation and dynamic effect optimization, differential equations can provide smooth and natural deformation process, which is widely used in character animation, special effect design and interactive art. The deformation of skin, fabric and flexible objects can be simulated by using elastic mechanics equations to make animated characters more vivid; the dynamics modeling using Hamiltonian and Lagrange equations can optimize the motion trajectory to make the motion more smooth and natural. With the help of these techniques, computer graphics not only enhances the visual quality of art works, but also provides a wider range of creative means for multimedia art design.

III. A. 3) Mathematical modeling of interactive and dynamic art design

In multimedia art design, interactivity and dynamic performance are key factors to enhance user experience. Differential equations, as an important mathematical tool for describing system changes over time, play a central role in interactive and dynamic art design. By constructing appropriate mathematical models, artworks can be made to respond to user inputs in real time, realizing complex animation effects and immersive interactive experiences. This approach is widely used in digital art installations, real-time generative art, virtual reality (VR) and augmented reality (AR), making art design more intelligent and diverse. Lorenz Attractor Equation for Generative Art:

$$\frac{dx}{dt} = \sigma(y - x) \tag{5}$$

$$\frac{dy}{dt} = x(\rho - z) - y \tag{6}$$

$$\frac{dz}{dt} = xy - \beta z \tag{7}$$

In user interaction modeling, differential equations are used to describe how input signals affect the movement and change of visual elements. In touchscreen art applications or somatosensory interactive devices, kinetic equations (e.g., Lagrange's equations) can be used to calculate the effects of gesture, pressure, or speed on image morphology, allowing the artwork to adjust its shape, color, or motion trajectory in real time based on user input. This approach not only enhances the interactivity of the artwork, but also provides the viewer with a personalized art experience, showed in Figure 4.

Figure 4 presents a regression analysis illustrating the influence of key algorithmic parameters on various aspects of artistic output. By plotting the relationships between input variables - such as differential equation coefficients, iteration depth, and geometric modifiers - and output metrics like visual complexity, aesthetic appeal scores, and user engagement levels, the figure reveals the degree to which computational factors shape artistic results. The regression lines and confidence intervals provide a quantitative understanding of trends and dependencies, supporting data-driven adjustments in algorithmic design. This analysis helps refine generative models and informs the development of more controllable and expressive multimedia art systems.

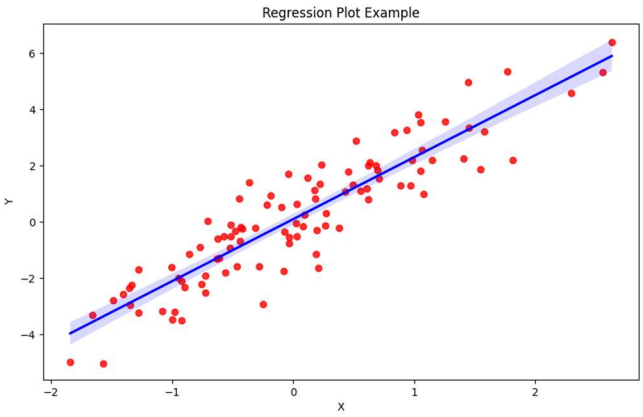

Figure 4: Regression Analysis of Algorithmic Influences on Artistic Output

In real-time animation generation, differential equations are used to model the behavior of objects in a dynamic environment. Using second-order ordinary differential equations allows for the calculation of bouncing, swinging, and inertial motions, making the animation of digital characters more physically correct. Utilizing differential equations for chaotic systems can generate unique and unpredictable dynamics, giving artwork a naturally occurring aesthetic. With these mathematical models, complex and expressive real-time animations can be created to provide richer visual representations for games, digital media, and interactive installations.

In immersive environments and virtual world building, differential equations play a crucial role in optimizing spatial interactions and physical simulations, enabling digital spaces to behave in a natural and realistic manner. By incorporating these mathematical models, developers can create highly interactive and dynamic virtual experiences

that respond to user inputs in real-time. Whether it is the fluid motion of water, the swirling patterns of smoke, or the smooth transition of camera perspectives, differential equations provide the computational foundation for enhancing both the technical realism and artistic expression of VR-based digital art. The ability to accurately simulate real-world physics within a virtual space not only deepens immersion but also expands creative possibilities in interactive art design.

One of the most significant applications of differential equations in VR art design is **fluid simulation**, which is essential for creating realistic water flows, smoke, and other dynamic natural elements. The **Navier-Stokes equations**, which govern the motion of fluids, allow for the simulation of complex behaviors such as turbulence, viscosity, and dynamic interactions with objects in the scene. In a virtual environment, integrating these equations enables water to ripple and flow naturally in response to a user's movements, while smoke and mist can swirl around characters or objects in a physically plausible manner. Such effects greatly enhance the sense of presence and realism in VR experiences, making interactive artworks feel more lifelike and engaging.

Beyond fluid dynamics, dynamics modeling based on the **Hamiltonian system** plays a crucial role in optimizing camera movement and viewpoint transitions, ensuring a smooth and intuitive navigation experience within virtual environments. In VR applications, abrupt or unnatural camera shifts can lead to discomfort or motion sickness, significantly reducing user immersion. By employing **Hamiltonian mechanics**, developers can design camera systems that respond fluidly to user inputs, dynamically adjusting movement speed, acceleration, and direction based on the scene’s physical constraints. These models help simulate inertia, momentum, and damping effects, making camera transitions feel natural and visually cohesive. Additionally, Hamiltonian-based optimization techniques enable predictive motion adjustments, allowing the system to anticipate user intent and modify viewpoints accordingly. This approach not only enhances realism but also improves the narrative flow by ensuring seamless transitions between different perspectives. Whether used in **VR storytelling, gaming, or interactive simulations**, the application of differential equations in camera control transforms virtual experiences into more engaging, immersive, and comfortable environments, effectively bridging the gap between mathematical precision and artistic vision.

The application of differential equations in immersive digital art extends beyond physics-based realism; it also fosters new forms of artistic creativity. Interactive artworks that respond dynamically to user actions, such as generative visual effects, real-time soundscapes, or evolving virtual sculptures, can be driven by differential equation models. For example, a VR installation might use reaction-diffusion equations to generate constantly shifting patterns on virtual canvases based on audience movement, creating a unique blend of algorithmic precision and artistic spontaneity. These advancements make interactive and dynamic art design not only more technically refined but also richer in creative expression, paving the way for new artistic paradigms in the digital age.

III. A. 4) An investigation of the realization mechanism and teaching application path of differential equation technology

In multimedia art design, the introduction of differential equations is mainly used for modeling dynamic systems, describing geometric deformation processes and realizing realistic simulation of natural physical phenomena. The realization mechanism usually relies on numerical computation methods, such as Euler's method, Lunger-Kutta method, etc., together with graphic rendering frameworks (e.g., OpenGL, Unity, or WebGL) to complete image generation and real-time interaction. By modeling differential equations for particle systems, rigid body dynamics or fluid motion, etc., the logic and naturalness of the work in terms of motion representation and visual changes can be enhanced.

Specifically for the optimization of geometric structures, differential equations provide mathematical tools for fine control in modeling curves and surface changes. By solving partial differential equations it is possible to realize the gradual change of complex shapes, the evolution of fractal structures or the simulation of natural weathering effects. These effects, which are difficult to achieve in traditional manual design, can be generated efficiently by algorithmic means, and personalized artistic expression can be achieved through parameter adjustment, greatly expanding the boundaries of artistic creation.

In terms of teaching application, building a visualized teaching experiment platform is the key path for the technology to land. The platform should integrate modeling, calculation and visualization functions, allowing students to observe the dynamic process of image change in real time by modifying the parameters of differential equations. Teachers can set tasks to guide students to carry out simulation experiments, simulate a dynamic picture that changes over time, or design a geometric figure that deforms based on physical rules, to help students understand the way of integration of mathematics and art, so as to enhance their comprehensive application ability. The design of the course system also needs to keep pace with the times, and should be centered on the three phases of “theoretical teaching-practical training-project creation”, which gradually introduces differential equations into the course modules of graphic science, animation design, interactive media, etc. Through interdisciplinary

teaching strategies, students can not only understand the integration of mathematics and art, but also learn how to design a geometric figure based on the deformation of physical rules. Through interdisciplinary teaching strategies, not only can we enhance students' mathematical and scientific foundation, but also stimulate their interest in the technical logic behind digital art, and promote the transformation of talent cultivation mode to the direction of “technology + art” integration, Analysis of Students' Comprehension Across Modules on Differential Equation Applications showed in Figure 5.

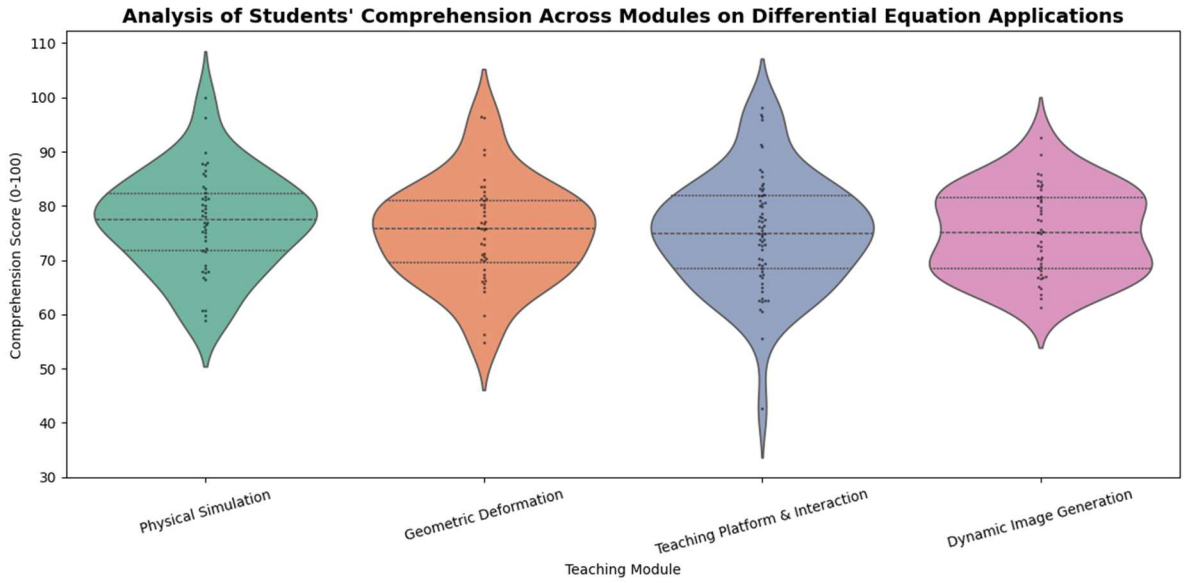

Figure 5: Analysis of Students' Comprehension Across Modules on Differential Equation Applications

III. B. Application and Practice of Differential Methods in Education and Teaching

The application of differential methods in education and teaching can not only help students understand the practical significance of mathematical theories, but also stimulate their creative thinking by combining them with practical problems. In subjects such as computer graphics and multimedia art design, differential equations provide many practical application cases, and students are able to understand how mathematical models can play a role in artistic creation by studying these cases. By introducing differential equations and related computer technology, educators can help students develop a mindset that integrates math and art, broadening their learning horizons and improving their problem-solving skills. Hamiltonian Equation for Physical Simulations:

$$\frac{dq}{dt}=\frac{\partial H}{\partial p},\frac{dp}{dt}=-\frac{\partial H}{\partial q} \tag{8}$$

In classroom teaching, differential equations are often introduced through hands-on experiments and case studies, particularly in multimedia art design. By designing interactive projects, educators allow students to experience firsthand how mathematical models shape artistic creation. Programming animations using differential equations enables students to visualize complex natural phenomena, such as fluid motion and dynamic transformations, deepening their understanding of mathematical applications. This practice-oriented approach fosters engagement, enhances problem-solving skills, and strengthens the connection between theory and real-world applications. By integrating art and computation, students not only improve their technical proficiency but also develop a creative mindset for interdisciplinary innovation.

The application of differential methods in interdisciplinary courses also has important teaching significance. In the cross-curricular courses in computer science, mathematics, art and other fields, differential equations are widely used as a basic tool. In courses that integrate art and technology, students need to learn not only the basic concepts of computer graphics, but also the methods of mathematical modeling and algorithm optimization. Through these interdisciplinary studies, students can understand how to apply mathematical methods to multimedia art creation, and can independently design and realize related art works, and this interdisciplinary knowledge integration helps to cultivate students' comprehensive innovation ability. Another important application of differential equations in education and teaching is in self-learning and research-based learning. With the development of online learning platforms, students can learn and explore independently through online courses and simulation experiments. In this

process, application cases of differential equations can be used as a basis for guiding students to deeper research. Through the use of numerical solution methods, students can gain a deeper understanding of the application of differential equations in practical calculations and can independently complete art-related mathematical modeling tasks. This not only enhances students' independent learning ability, but also encourages them to conduct exploratory research, which in turn promotes academic innovation and cross-disciplinary collaborative research.

IV. Conclusion

This paper discusses the application of differential equations in computer graphics and multimedia art design, and analyzes its practical significance in education and teaching. The study shows that differential equations, as the core tool of mathematical modeling, have an irreplaceable role in artistic creation. By simulating natural phenomena, optimizing geometric forms and generating dynamic effects, differential equations not only enhance the expressiveness and authenticity of digital art works, but also provide more innovative possibilities for art creation. Especially in many fields of computer graphics, such as physical simulation, light calculation and morphological deformation, the application of differential equations greatly enriches the means of artistic expression and promotes the interdisciplinary integration of art and science.

In education and teaching, the application of differential equations not only deepens students' understanding of mathematical theories, but also helps them to combine mathematical models with artistic design, and enhances their comprehensive innovation ability. Through practical and interdisciplinary course design, students are able to master the practical application of differential equations in art design through specific cases and experiments, and develop their ability to solve practical problems. The application of differential methods in education and teaching provides a new teaching mode for the combination of art design and mathematical theory, and promotes the integration of knowledge and innovation between disciplines. The multimedia art design method based on differential equations provides a new technical means for art creation and opens up a new research direction for the development of computer graphics. In the future, with the further development of computing technology and mathematical methods, the application of differential equations in art design will be more extensive and in-depth, which will not only promote the innovation of art creation, but also provide more practical opportunities and research space for education and teaching.

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