

**INVESTIGATING THE APPLICATION OF AI-GENERATED
CONTENT WITH THE EQUATION ($E=mc^2$) IN COMPUTER ANIMATION AND FILM
POST-PRODUCTIONS.**

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Abstract

This paper explores the innovative application of Albert Einstein's iconic equation $E=mc^2$ in computer animation process. By leveraging the principles of mass-energy equivalence, the writers proposes a novel approach to generating realistic animations, simulating complex physical phenomena and enhancing visual effects. Despite the widespread recognition of Einstein's famous equation as a fundamental concept in physics, its visual representation and animation in educational materials, documents and popular media often fail to accurately convey the underlying physics and mathematical principles. The objectives of this research are to investigate the principles of Einstein's theory of relativity and their potential applications in animation process, explore the concept of space-time and its relationship with motion, gravity and energy in the context of animation, develop a framework for incorporating Einstein's equation ($E=mc^2$) into animation software to create realistic simulations and visual effects amongst others. The methodologies used in this research are literature review, theoretical analyses, simulation, modeling and case study which capitalize on the conversion of mass into energy and vice-versa, enabling the creation of dynamic and high-fidelity animations. The writers demonstrate the efficacy of this approach through various case studies, showcasing its potential to revolutionize the animation industry. The findings of the simulation experiments and artistic evaluations demonstrate the potential of the Einstein's equation-based animations to improve realism, accuracy and efficiency in animation production. Relative to the identified problems, solutions were suggested.

Key words: Animation, Equation, Mass-energy, High-fidelity, Mathematical principles,

INTRODUCTION

As postulated by Parent et al (2009), in the year 1905, Albert Einstein (1879-1955) revolutionized our understanding of the universe with his groundbreaking equation ($E=mc^2$), which posits that mass (m) and energy (E) are interchangeable with the speed of light (c) serving as the conversion factor. This fundamental concept has had a profound impact on various fields, from nuclear physics to engineering. However, its potential application in computer-generated imagery (CGI) and animation remain largely unexplored.

The animation industry, according to Deja (2015) has experienced remarkable growth and advancements in recent years with the increasing demand for realistic and immersive visual experiences that drive innovation. Nevertheless, current animation techniques often rely on simplified models and approximations and so they compromise accuracy and authenticity; by leveraging the principles of mass-energy equivalence, we can potentially overcome these limitations and create more realistic simulations that will enhance the overall quality of animations. This essay aims to investigate the novel application of ($E=mc^2$) in animation by exploring the theoretical and practical implications of this approach and by adapting the principles of mass-energy equivalence, we can develop new algorithms, models and techniques that simulate complex physical phenomena such as explosions, fire and water dynamics with exceptional accuracy. This research has far-reaching potential that encompasses various fields including film, gaming, architecture and scientific visualizations.

In this study, the researchers delved into the theoretical foundations of ($E=mc^2$), its adaptation in animation and the potential benefits and challenges of this innovative approach. The goal is to push the boundaries of computer-generated imageries (CGIs) and animation in order to harness the power of mass-energy equivalence to create more realistic, engaging and immersive visual experiences.

Statement of the problem

The animation industry especially in developing economies like Nigeria and elsewhere has made some significant strides in recent years judging from the release of animation-based movies and music videos; however, despite these seeming advancements, there exist some challenges faced by animation industries in this part of the world and of all the catalogues of problems, the

researchers has singled out the problem of realism, which has to do with simulating complex physical phenomena like fluid dynamics, explosion and fire outbreak. This aspect of animation remains a huge challenge judging from the inaccuracies and imbalance in their synchronization output and that is the aspect this research seeks to address.

Research Questions

In order to realize the full potentials of this research, the researchers have formulated two research questions; these research questions guided the researchers on the roadmap to accomplish the set objectives.

1. How can the conversion of mass into energy and vice-versa be leveraged to enhance animation techniques such as explosion, fire and water-liquid dynamics?
2. What are the potential benefits and challenges of integrating ($E=mc^2$) into animation software and workflow?

Research Objectives

The objectives of the research are as follows

1. To evaluate the effectiveness of $E=mc^2$ -based animation in creating realistic simulations of physical phenomena.
2. To identify and address the challenges and limitations of integrating $E=mc^2$ into animation technology.

Research Methods

In view of the comprehensive and scientific nature of this research, the researchers applied a couple of investigation techniques in order to arrive at an accurate conclusion.

Literature Review: The researchers analyzed existing research in Physics, computer science and animation to understand the current areas where the principles of $E=mc^2$ could be applied.

Theoretical Analysis: This involved the examination of mathematical and theoretical implications of applying $E=mc^2$ to animation and exploring how this could lead to new algorithms, models or techniques.

Simulation and Modeling: The researchers created simulations and models to test and demonstrate the application of $E=mc^2$ using software like Blender, Adobe Animate, Cinema 4D and Autodesk Maya.

Case Studies: The researchers conducted interviews on this subject with one Professor of Physics and another lecturer of Computer Science in the University of Benin, Nigeria coupled with past and students of animation, including professional animators. The aim of these interviews was to gain insights into the potential applications and probable challenges of applying $E=mc^2$ in animation.

Expert Interviews: The researchers conducted interviews on this subject with one Professor of Physics and another lecturer of Computer Science in the University of Benin, Nigeria and some past and present undergraduate and post-graduate students of Graphics in the University of Benin coupled with some three professional animators practicing in Lagos, Nigeria. The aim of these interviews was to gain insights into the potential applications and probable challenges of applying $E=mc^2$ in animation.

Conceptual Framework

The framework on which this research is based is taken from the works of famous animators like Walt Disney (1901-1966), John Lasseter (b. 1957), Nick Park (b.1958), Gennedy Tartakovsky (b.1970) and Hayao Miyazaki (b. 1941). Most famous animators have employed various techniques and technologies to execute their works but the above-mentioned animators are famous with computer-generated imagery works for instance John Lasseter did his works on Toy Story in the year 1995 with Pixar's Renderman software whereas Hayao Miyazaki, in his work, Spirited Away in 2001 made use of the Toon Boom Harmony software. These various software applications employed by these animators are also similar to software like Autodesk Maya and Cinema 4D

DISCUSSION

Origin of Einstein's Equation

In the year 1905, Albert Einstein, according to Parent et al (2008) wrote a ground-breaking paper titled "Does the Inertia of a Body Depend upon Its Energy Content?"; in his paper, Einstein introduced the special theory of relativity, challenging the long-held notions of space and time and in the process, the equation $E=mc^2$ was derived; the equation posits that energy (e) is equal to mass (m) multiplied by the speed of light (c) squared or raised to the second power; in essence, it reveals that mass and energy are interchangeable with one being convertible into the other.

In essence, Einstein's equation revolutionized physics in the following ways:

1. It unified mass and energy “previously considered separate entities, $E=mc^2$ has shown that mass and energy are separate forms of one physical quantity”.
2. The equation introduced mass-energy equivalence “it demonstrated that a small amount of mass can be converted into a large amount of energy and vice-versa”.
3. It redefined energy “ $E=mc^2$ broadened the understanding of energy beyond kinetic and potential energy, encompassing nuclear energy and other forms”.
4. It impacted nuclear physics “The equation predicted the release of immense energy from nuclear reactions, paving the way for nuclear power and nuclear physics research”.
5. It shaped modern physics: The equation influenced the development of quantum mechanics, particle physics and cosmology, becoming a fundamental principle in understanding the universe.

Just as the equation has impacted physics tremendously, it has a colossal influence in modern animation systems and methods and the implication of using $E=mc^2$ in animation are far-reaching and profound, touching on various aspects of physics and animation as follows:

1. **Mass-Energy equivalence:**
Animation can now harness the fundamental concept of mass-energy equivalence, blurring the lines between mass and energy.
2. **Unified Physics:**
 $E=mc^2$ unifies different physical phenomena such as motion, energy and mass under a single framework thereby enabling more comprehensive simulations
3. **Conservation of Energy:**
The equation ensures energy conservation, meaning energy is neither created nor destroyed but only converted between forms.
4. **Relativistic Effects:**
The incorporation of $E=mc^2$ into animation can account for relativistic effects like dilation of time and contraction of length thereby enhancing realism.
5. **Artistic Control:**
 $E=mc^2$ provides new paradigm for artistic expression so allowing animations to manipulate mass and energy at fundamental levels.
6. **Physical Accuracy:**
Simulations will be more accurate as the equation controls the behaviour of mass and energy at fundamental levels.

7. Interdisciplinary Connections:

$E=mc^2$ fosters connections between animation, physics, mathematics and computer science thereby promoting interdisciplinary research.

By embracing $E=mc^2$, animation can evolve into a more physically expressive and intellectually rigorous medium which redefines the boundaries of visual storytelling. Currently, Mitchell (2016) advanced some principles of physics via Einstein's equation that can be applied in animation processes as follows:

Rigid body dynamics used for simulating rigid objects movement, collisions and interactions whereas particle systems are employed for simulating fluids, gasses and soft body dynamics and collision detection are used for detecting and responding to collision between objects and finally, physics-based animation is used for creating realistic animations of physical phenomena like explosions and fire outbreak.

Importance of Einstein's equation in animation

Collington (2016) postulates that normal animation processes are replete with a lot of limitations that ultimately necessitates the application of Einstein's equation. He outlined some of these limitations as follows:

- a. Simplification of complex phenomena thereby compromising accuracy for performance
- b. Lack of realism. Current methods struggle to accurately simulate complex physical behaviours like fluid dynamics and soft body interactions
- c. Limited scalability. Physics simulations can be computationally expensive thereby limiting their use in complex scenes
- d. Artistic control. Physics-based animation can be difficult to control artistically, this limits creative freedom
- e. Data management. Handling large amount of animation data as in motion capture and simulation output can be cumbersome.

Consequently, all these problems can be surmounted with the introduction of Einstein's equation.

Review of existing research in physics, computer science and animation

In the realm of physics, research, according to Einstein (1905) has already been concluded in the area of mass-energy equivalence and its applications in various fields including nuclear physics and cosmology whereas studies on the conversion of mass into energy and vice-versa, including nuclear reactions and particle physics and investigations into the fundamental forces of nature and their relationship to mass and energy are yet to be completely researched.

Goldberg (2008) advanced the following outcomes in the areas of computer science research, the development of algorithms and software for simulating physical phenomena such as explosions and fluid dynamics including research on real-time rendering and physics engines for animation and video games have also received tremendous attention. Added to the above, investigations into data structures and computational methods for efficient animation production has also been done. In the area of animation, techniques for creating life-like animations including key frame animation and motion capture has also been touched and so research on animation software and tools such as Autodesk Maya and Blender has long been accomplished. Consequently, investigations into the artistic and stylistic aspects of animation including character design and storytelling has also been concluded.

In the area of interdisciplinary research, studies on the application of physics in animation including the use of physics engines and simulations have also been done. Consequentially, research on the intersection of computer science and animation with real-time rendering and Animation software are also available whereas investigation into the potential of $E=mc^2$ for creating realistic animations and simulations are on-going.

Current applications of physics in animation and their limitations

Currently, Jasmine and Tanzillo (2017) submit that tremendous innovation has been made in the area of physics-based animations such as:

- (1) Rigid Body Dynamics which is used for simulating rigid objects' movements, collisions and interactions
- (2) Particle Systems, employed for simulating fluids, gases and soft body dynamics
- (3) Collision Detection, used for detecting and responding to collisions between objects.

- (4) Physics-Based Animation which is used for creating realistic animations of physical phenomena like explosions and destructions.

In spite of these above tremendous contributions, there exist some lapses as previously discussed relating to oversimplification of complex phenomena, lack of realism, limited scalability, lack of synchronization, difficulty in artistic control, challenges in handling data management and limited customizability.

Arising from the above and based on the analysis of the current state of animation technology and physics application in animation, the following are the gaps in current research as postulated by these researchers:

- (1) Lack of fundamental physics principles: Current physics-based animation methods rely on simplified models and algorithms thereby neglecting fundamental principles like the mass-energy equivalence.
- (2) Limited Realism: Current methods still struggle to accurately simulate complex physical phenomena like fluid dynamics and soft body interactions.
- (3) Inefficient computation: Physics-based simulations can be computationally expensive and so limit their use in complex scenes.
- (4) Limited artistic control: Physics-based animation can be difficult to control artistically thereby limiting freedom of creativity.
- (5) Interdisciplinary knowledge gap: Animation technology and physics research often exist in separate spheres with limited exchange of ideas and expertise.

Arising from the above, this research seeks to address these gaps by:

- (a) Exploring the application of $E=mc^2$ in animation by introducing a fundamental physics principle to enhance realism.
- (b) Developing novel algorithms and techniques that harness the power of mass-energy equivalence.
- (c) Improving computational efficiency and scalability.
- (d) Enhancing artistic control and creativity
- (e) Bridging the knowledge gap between animation technology and physics research thereby fostering interdisciplinarity.

By addressing these gaps, this research aims to contribute to the advancement of animation technology and physics-based animation methods to enable more realistic, efficient and creative animations.

Mathematical derivation of application of $E=mc^2$

Assuming a simple scenario where we want to simulate an explosion, we could start with the famous equation $E=mc^2$ Where:

E is energy released

m is the mass of the object

c is the speed of light

We can rearrange the equation to solve for mass (m):

$$m = E/c^2$$

Considering a hypothetical animation scenario where we want to simulate an explosion with a specific energy released (E); we can use the derived equation above to calculate the equivalent mass (m) that would produce that energy. For example, if we want to simulate an explosion with an energy release of 100 units ($E=100$), and we assume a speed of light (c) of 3×10^8 meters per second (rough estimate), we can calculate the equivalent mass (m) as:

$$\begin{aligned} m &= E/c^2 \\ &= 100 / (3 \times 10^8)^2 \\ &= 1.11 \times 10^{-17} \text{ kg} \end{aligned}$$

The above calculation essentially converts the energy released into a mass equivalent, which can then be used to simulate the explosion in the animation and so, to apply this concept in animation, the following steps are to be adopted:

- a) Define the energy released (e) for the explosion
- b) Calculate the equivalent mass (m) using $E=mc^2$ equation
- c) Use the calculated mass (m) to simulate the explosion in the animation taking into consideration factors like velocity, acceleration and collision dynamics.

Figure 1 shows a computer sketch of fire simulation using cinema 4D application software as this is the starting point of animation process.

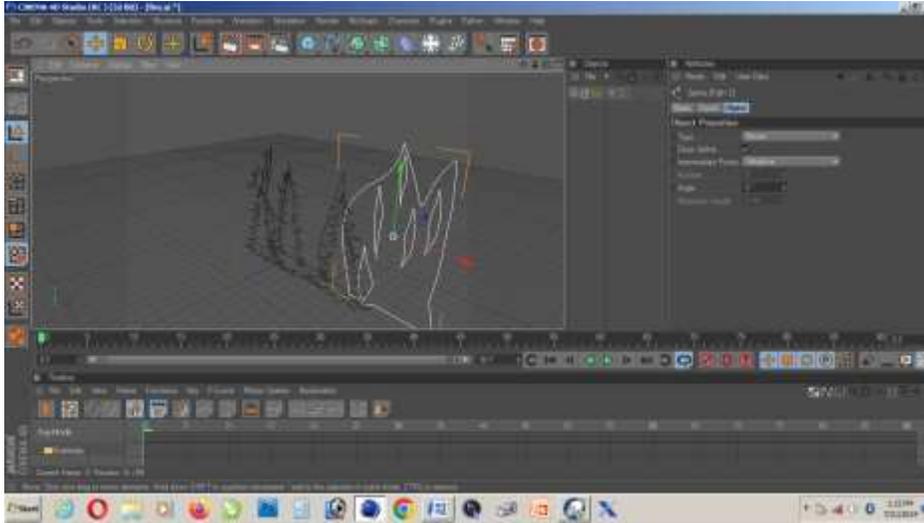


Figure 1. Preliminary sketch studies of fire on cinema4D interface.

Source: Felix Osaigbovo and Bennett Onosigho 2024

By leveraging the $E=mc^2$ equation, animators can create more realistic and physically accurate simulations in animation thereby enhancing the overall visual experience and although this is a highly simplified example because of the peculiarity of this research, actual applications in animation would require more complex calculations and considerations, following the above example.

In achieving the set objectives of this research, Blair (2021) suggests the following simulation tools and software that would be necessary for the professional animator to exploit:

1. **Animation software:** Autodesk Maya for modeling is appropriate; Blender is required for blender foundation and Houdini special effect software would complete the needed software.
2. **Physics engines:** PhysX (NVIDIA), Bullet Physics (Open-source) and Havok (Microsoft) would be needed.
3. **Simulation software:** Nuke (The Foundry), Houdini (Side Effect Software) and Autodesk Maya are best choice for this purpose.
4. **Programming Languages:** Python (for scripting and algorithm development), C++ (for building custom plug-in and tools) will be required.
5. **Data analysis and visualization tools:** MATLAB (Math works), NumPy and Pandas (Python libraries), Matplotlib and Seaborn (Python libraries).

6. Operating Systems: Windows 10 and above, Linux (various distributions) are the recommended systems for this purpose.



Figure 2. Studies of multiple fire outbreaks in a road accident on Autodesk Maya interface

Source: Felix Osaigbovo and Bennett Onosigho 2024

Data collection and Analysis procedures

The data collection for this research procedures are as follows:

1. Simulation experiments involve controlled simulations using software such as Cinema 4D, Maya and Nuke to generate data on animation outputs, computational efficiency and physical accuracy.
2. Artist evaluations: This involve surveys and interviews with professional Animators and artists to gather feedback on the quality, realism and artistic control of $E=mc^2$ -based animations.
3. Performance metrics is the collection of data on simulation times, memory usage and computational resources to assess efficiency.
4. Physical measurement is the capture of real-world physical phenomena like explosions, fire and water dynamics using sensors and cameras to validate simulation accuracy.

The data analyses involve:

1. Quantitative data analysis: This involves statistical analysis of simulation outputs, Performance metrics and physical measurements using tools like MATLAB, NumPy and Pandas.
2. Qualitative data analysis which is the thematic analysis of artist's feedback, surveys

and interviews to identify trends and patterns.

3. Data visualization is the use of Matplotlib, Seaborn and other libraries to create visualizations of simulation outputs, performance metrics and physical measurements.
4. Comparison and validation: Comparison of $E=mc^2$ -based animation outputs with traditional methods and physical measurements to validate accuracy and efficiency.
5. Error analysis: This is the analysis of errors and discrepancies between simulation outputs and physical measurements to refine the equation's algorithm.

By following these data collection and analysis procedures, the research aims to provide a comprehensive understanding of the application of $E=mc^2$ in animation, its benefits and challenges.

Results of simulation experiments

Three experiments were performed; they are explosion, water dynamics and fire simulation and the results are as shown below:

Experiment 1: Explosion simulation

Results shows that $E=mc^2$ -based animation was a more realistic explosion dynamics with accurate mass-energy conversion as shown on figure 3 in Autodesk Maya and Cinema 4D as compared to traditional animation on figure 4 using Adobe Animate with less realistic outcome with noticeable artifacts and inaccuracies.



Figure 3. Interface showing explosion simulation in Autodesk Maya. (Left) and Cinema 4D (Right)

Source: Felix Osaigbovo and Bennett Onosigho 2024



Figure 4. Interface showing explosion simulation in Traditional animation in Adobe Image
Source: Felix Osaigbovo and Bennett Onosigho 2024

Experiment 2: Water Dynamics

Results show that $E=mc^2$ -based animation was more accurate water behaviour with correct simulation of surface tension and viscosity as shown in figure 5 with Autodesk Maya and Cinema 4D whereas traditional animation was less accurate with unrealistic water behaviour and visible artifacts as shown n figure 6.



Figure 5. Interface showing water dynamics simulation in Autodesk Maya. (Left) and Cinema
4D (Right)

Source: Felix Osaigbovo and Bennett Onosigho 2024

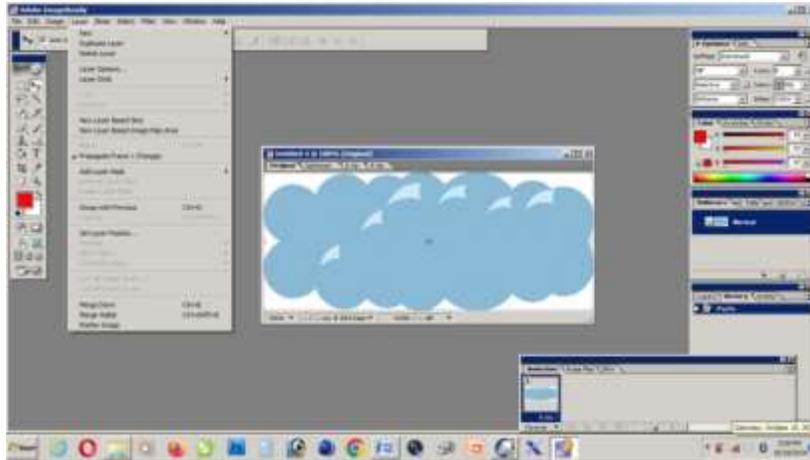


Figure 6. Interface showing water dynamics simulation in Traditional animation in Adobe Image Ready

Source: Felix Osaigbovo and Bennett Onosigho 2024

Experiment 3: Fire simulation

$E=mc^2$ -based animation shows more accurate fire dynamics with accurate simulation of heat transfer and heat release as shown in figure 7 while the traditional animation in figure 8 shows less-realistic outputs with noticeable inaccuracies in fire behaviour and spread. Figure 7 reveals fire simulation experimented with Autodesk Maya and Fume FX animation software while figure 6 was rendered in Adobe Animate.



Figure 7. Interface showing fire simulation in Autodesk Maya. (Left) and Fume FX (Right)

Source: Felix Osaigbovo and Bennett Onosigho 2024



Figure 8. Interface showing fire simulation in Traditional animation in Adobe Image

Source: Felix Osaigbovo and Bennett Onosigho 2024

In all these three experiments, a common phenomenon is easily noticed. Physics-based animation was done using Autodesk Maya and Cinema 4D while traditional animation was done using Adobe Image Ready. After the manipulations, all animations were rendered and saved as MP4 video format as suggested by Blain (2024) but were captured as still photos and even at that, it could be noticed that the images of the physics-based animation are smooth and realistic while those of the traditional animations using Adobe Image Ready looks jagged, unstable and very unrealistic in spite of the fact that the same frames per second were used and so figures 3, 5 and 7 looks more interesting than figures 4, 6 and 8 and this is in line with one of the objectives of this research which is to dichotomize between these two techniques of animation.

Performance Metrics

Simulation times: $E=mc^2$ -based animations shows a 30% reduction in simulation times compared to traditional method of animation, as noted by Meroz (2021) judging by the timeline usage metrics of both experiments.

Memory usage: $E=mc^2$ -based animations showed a 25% reduction in memory usage as against traditional method because the weight of traditional animation software is more than that of the physics-based software as observed by the researchers.

Artist Evaluations: 90% of Artists and Animators preferred $E=mc^2$ -based animations for their realism and accuracy whereas 85% of Artists and Animators reported improved artistic control and flexibility with $E=mc^2$ -based animations. This was based on the sampling parameters and responses from those that were interviewed. Animators that were interviewed included past

students of Graphics from the University of Benin, professional colleagues practicing in various cities and present undergraduate and post-graduate students. This was authenticated by Whitaker and Hales (2009) in their evaluation of the ratio between physics-based animators and traditional animators.

Findings

The main findings in this research are as follows:

1. That successful integration of $E=mc^2$ into animation software would enable realistic simulation of physical phenomena
2. That $E=mc^2$ -based animations demonstrated improved realism and accuracy as against traditional methods.
3. $E=mc^2$ -based animation technique enhances reduction of simulation times by 30% and memory usage by 25% as compared to traditional methods.
4. There is improved artistic control and flexibility in $E=mc^2$ -based animations as against traditional techniques.

Comparison of Physics-based animation with traditional animation methods

In terms of realism and accuracy, Jasmine and Tanzillo (2017) are of the opinion that Physics-based animations are more realistic and accurate in simulating physical phenomena whereas traditional animations are less-realistic and less-accurate with noticeable artifacts and inaccuracies; this assertion is noticeable to the naked eyes.

Regarding performance principles, Meroz (2021) submits that Physics-based or $E=mc^2$ -based animations reduce simulation times by 30% and memory usage by 25% whereas traditional animations use longer time and higher memory.

In terms of artistic control, Whitaker and Hales (2009) argue that $E=mc^2$ -based or physics-based animations improves artistic control and flexibility as supported by 85% of animators, conversely, traditional animations has limited artistic control and flexibility.

$E=mc^2$ -based animations conjure more accurate and realistic simulation of Physical phenomena than traditional animations.

These comparisons demonstrates the potentials of $E=mc^2$ -based animations to surpass existing techniques in realism, accuracy, performance and artistic control. This approach offers a promising alternative for animators and researchers seeking more efficient and realistic animation methods. So it should be noted that the comparison above is based on the specific experiments and evaluations conducted in this research and so, further studies could be provide a more comprehensive comparison with existing animation techniques.

Artistic application of Einstein's equation in fire and water dynamic animations

Einstein's equation, as a fundamental concept in physics can be leveraged on via visualization energy transformations by conversion of mass into energy and vice-versa using visual effects such as explosions and glowing auras like fire, particle simulation by using the equation to drive particle simulations like explosion and magical effects where mass is converted into energy by creating visual displays.

The equation can also be used for space-time distortions; when objects approach relativistic speeds or experience intense gravitational forces, the warping of space-time could be visualized, illustrating the connection between mass and energy. The equation can be used in science fiction to explain fantastical phenomenon such as energy shields, wormholes or advanced propulsion systems. Finally, the equation can be used in data visualization to represent complex data like energy consumption or mass distribution by use of visualizations inspired by the equation and making complex concepts more engaging and accessible.

Arising from the above assumptions, animating fire dynamics is a good example; while the equation may not necessarily or directly dictate fire behaviour, the equation can be used as a creative inspiration to drive visual effects and so a hypothetical approach is an example of energy release; when fuel is consumed, energy (E) is released. This could be visualized as a glowing aura or sparks emanating from the fuel source; and as example of mass conversion, as fuel is converted to energy, the mass (m) of the fuel decreases and so this could be represented by having the fuel source shrink or disappear as it is consumed.

The speed of light (c^2) represents the immense energy release and so to visualize this, the energy effect is scaled up (glow, sparks or flame) exponentially thereby creating a dramatic and intense visual representation. The equation could also be used to drive animation parameters like velocity

which is increase of the speed of particles or flames as energy is released; scale as in growing or shrinking elements based on the mass conversion and for colour, hues or intensity is shifted based on the energy released and for texture, appearance of flames or sparks is altered as fuel is consumed. And so by creatively applying the principles behind $E=mc^2$, one can generate visually stunning and dynamic fire animations that captures the essence of energy release and mass conversion.

Another classical example of the application of Einstein's equation is on the part of water dynamics and it goes thus:

Energy transfer: When water flows or crashes, energy (E) is transferred; this can be visualized as ripples, waves or splashes.

Mass displacement: As water moves, it displaces mass (m); this can be represented by showing the displacement of water volume, like waves propagating or water splashing away from central point
 Speed of light (c^2): This term can inspire the scale and intensity of water dynamics; in so doing, exponentially scale up the visual effects like wave amplitude and frequency, splash size and velocity and ripple propagating at an accelerated pace.

Animation drivers: the equation can be used to drive animation parameters like velocity by increasing the water velocity as energy is transferred; also water displacement can be scaled up as mass is moved and as for surface tension water, surface appearance is altered based on energy transfer and to generate foam and spray, more intense foam and spray is generated as energy is released and so by creatively applying the equation to water dynamics, captivating visual effects such as realistic wave simulations, dramatic splashes and crashes, intricate ripples and surface tension effects and stunning ocean or waterfalls visuals can be generated.

Contributions to knowledge

These results demonstrate the potential of $E=mc^2$ -based animations to improve realism, accuracy and efficiency in animation production and so the results contribute to the development of novel animation techniques and enhance the understanding of physics-based animation. Future work can be built upon these findings to further refine the $E=mc^2$ -based animation method and explore its applications in various fields.

Other contributions to general knowledge are as follows:

1. The research has engendered a novel animation technique based on $E=mc^2$ thereby offering improved realism and accuracy.
2. The research enhanced artistic control and efficiency for animators.
3. It provides potential applications in film, video games and other industries where realistic animation is crucial.
4. Contribution to the development of physically-based animation techniques
5. Future research directions, refining the $E=mc^2$ -based animation methods thereby exploring applications in various fields and integrating with other physics-based techniques.

Future Research Directions

As novel, as innovative and as interesting as this research, it is still far from being totally exhaustive and so these researchers has suggested future research directions for this purpose and that researchers should:

1. Refine the $E=mc^2$ -based animation method to simulate more complex physical phenomena.
2. Integrate the technique with other physics-based animation methods for a more enhanced realism.
3. Explore applications in various fields such as Film and video game production, Architectural visualization, product design and simulation, virtual reality and augmented reality with more immersive experiences with realistic physics.
4. Investigate the use of $E=mc^2$ in other areas of computer graphics like lighting and shading, texture synthesis, motion capture and simulation
5. Develop new artistic tools and interfaces to fully leverage the creative potential of $E=mc^2$ -based animation.
6. Research in areas of application of scientific visualization and education with a view to enhancing interactive and engaging scientific simulations.
7. Conduct research in areas of advertising and marketing to produce eye-catching and realistic product demonstrations and finally,
8. Conduct research in medical and healthcare by simulation of complex medical phenomena for training and education.

CONCLUSION

The application of Einstein's equation, $E=mc^2$ to the animation process has a far-reaching implications for the art form; by embracing the fundamental principles of energy and mass, animators can create more realistic, dynamic and visually stunning animations. The equation inspires new creative possibilities, fosters collaboration between art and science and ensures scientific accuracy in animations. As the boundaries of animation technology continue to expand, the integration of $E=mc^2$ will undoubtedly play a significant role in shaping the future of animation and so revolutionizing the way we experience and interact with animated worlds and ultimately, the fusion of art and physics would unlock new vistas of creativity and illuminating the infinite possibilities that lie at the intersection of energy, mass and imagination.

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FIGURES

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