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Application and Optimization of 3D Model Building Technology in Film and Television Special Effects

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ABSTRACT
The combination of technology and art in film and television special effects can greatly enhance the visual impact of film and television animation, and improve its commercial and artistic value. The study elaborates on the generation of special effects in 3D modeling technology in film and television production, and based on the application of rigid body special effects, it proposes a highly efficient rigid body crushing mode for optimization in response to the problems such as low real-time performance in rigid body crushing simulation. The model is a particle-based real-time simulation method of object crushing under the impact of external forces, using the discrete unit method to represent the inter-particle force, and proposes an inverse crushing mechanism, which realizes the particle-based DEM simulation on the GPU. Experimental results show that the simulation method of rigid body crushing constructed in this paper can meet the simulation requirements in different scene scales, and the rendering rate in small-scale and large-scale scenes is 90~155FPS and 40~50FPS, respectively, which is not only realistic but also real-time, and can meet the requirements of film and television production.

Keywords: three-dimensional model, discrete unit method, inverse crushing mechanism, rigid body crushing simulation, film and television special effects

1. Introduction

With the improvement of people's living standard, after satisfying the basic material life, people start the pursuit of spiritual level, which makes the movie belonging to satisfy people's spiritual level get the opportunity of development, and gradually form the movie industry. Three-dimensional film and television special effects technology is an important technology to promote the development of the field of film and television, which makes the production of the movie more sophisticated, and can bring the audience an immersive feeling, so that the audience can get a better sense of experience [1-4]. Three-dimensional film and television special effects refers to the use of computer systems and

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related software to create a three-dimensional, virtual special effects. Generally speaking, three-dimensional special effects include sound special effects and visual special effects in two dimensions [5-6].

Currently three-dimensional special effects technology is most widely used in movies, through the establishment of models and effects in computer software, with film and television post-production editing software, to create three-dimensional film and television, not only that, with the development and maturity of three-dimensional technology, as well as three-dimensional technology shows the advantages of three-dimensional technology, nowadays three-dimensional film and television technology has also begun to be used in the field of medical care, military, games and so on [7-9].

Three-dimensional film and television technology in the beginning stage as early as the 1950s, Europe and the United States in the film industry began to appear in the 3D film, expected to create an immersive feeling for the audience, bringing the audience a better sense of experience, but when the use of two-color color printing method, although subverted the traditional two-dimensional technology, however, there are still certain problems in technology, so the 3D film at that time did not have a large area of the spread of the opening [10-11] ...In the 1980s, after many years of development, three-dimensional film and television technology has made great progress, and is more often used in film shooting and editing, however, at that time, the use of three-dimensional film and television technology film producers are too much to pursue the three-dimensional film and television technology of the three-dimensional effect, coupled with a number of works similar to such a work appeared on the market, the audience appeared to be aesthetically fatigued, and the market response of such films did not achieve the desired effect. Therefore, the number of movies using three-dimensional stereoscopic technology in this period is also relatively limited [12-13]. The use of three-dimensional film and television technology to achieve good visual effects, not only need three-dimensional film and television technology has a certain level, can create a three-dimensional viewing effect for the people, but also on the movie screen and picture quality have certain requirements, otherwise it will affect the effect of viewing. Now with the emergence of high-definition picture quality and the further development of three-dimensional film and television technology, now the use of three-dimensional film and television technology of the film can really bring the audience from the visual and auditory aspects of the immersive experience, there are a number of similar to the "Avatar", Disney series of excellent three-dimensional film animation works, and has obtained the affirmation of the film market, which three-dimensional film and television technology has been more widely used in the film and television industry[14-16].

With the rapid progress of computer technology, China's three-dimensional film and television technology industry has ushered in the spring of development, and its application scope is very wide, involving architectural planning, product design, advertising animation, film and television special effects, virtual world and many other fields. Among them, the progress of 3D animation technology in film and television special effects is particularly rapid [17-18]. Although China's three-dimensional film and television technology is gradually developing, there is still a small gap compared with the same industry in other parts of the world. Therefore, we should correctly recognize the constraints on the development of three-dimensional film and television technology in the art of film and television special effects, fully utilize the existing means of production of film and television special effects, and combine the Chinese film and television three-dimensional modeling technology with the production of film and television special effects, so as to continue to promote the development of China's film and television industry [19-21].

With the development of information technology, film and television special effects production is more and more sophisticated and shocking, around the film and television special effects production technology, production methods and special effects on the development of special effects production in the film and television industry for in-depth research. Literature [22] describes the rapid development of the movie from the traditional mode to the multi-special effects and high budget, points out that the new media technology plays a great influence in it, and finally looks forward to the future development of the movie industry. Literature [23], the main aspects of the disruptive changes in the film industry are high-definition and advanced special effects, and discusses the trend of the film industry combined with the development of cloud computing in the world, which helps to improve people's understanding of the digital development of the film industry and the development of special effects. Literature [24] aims to improve the visual quality and sound impact of film and television special effects, and explores the VFX technology used in film and television special effects production, including its current cutting-edge research, classification and applicable scenes, etc. The study helps to improve the special effects personnel's understanding of the VFX technology and related skills, and to produce more artistic and ornamental special effects for film and television. Literature [25] examines how key images, especially special effects, affect the image of the movie in the film and television production of Morning Star, so combining the historical and theoretical perspectives, it examines the themes and influences of the movies related to the journey to Venus before and after World War II for the reference of special effects production.

The application of 3D film technology is becoming more and more popular at the present time, and researchers in this field have made certain contributions to the further application and research of 3D film technology by continuously digging deeper into the potential application of 3D film technology, as well as the direction of technological optimization and development, based on the underlying logic of 3D film technology. Literature [26] mentions digital restoration technology, the underlying principle of which is to utilize 3D computer models to recreate historical buildings in visual dynamics through relevant documents and existing structural themes, and combining with cinematic technology with the lowest cost production budget. Literature [27] discusses the development of 3D movie technology, especially the introduction of 3D movies in China at the beginning of the audience's perception of serious discomfort, but with the development of technology, such as the 3-D camera platform technology of the on-board computers, the digital projector to accurately locate the two three-dimensional objects in the silver screen, the polarized silver screen, etc. are effective in enhancing the stereoscopic film production of the fine and comfortable viewing, and finally look forward to the 3D movie technology production and post broadcasting development trend. Literature [28] elucidates the current cutting-edge research and practice areas of 3D imaging technology such as 3D cinema, biomedical 3D imaging, etc., and tries to focus on the theoretical tools of geometrical optics and wave theory in order to teach the principles and processes of 3D capture and 3D imaging systems. Literature [29] discussed the motion capture technology used for 3D film and television production, the technology through the real motion data input to the film and television character model to achieve a natural flow field, continuous action, restore the realistic character dynamic action, and finally the depth of the analysis of the obstacles that exist in the 3D motion capture technology and the practical application of the 3D motion capture technology, looking forward to the development of China's film and television animation. Literature [30] introduces the role played by digital media technology in 3D film production and presentation, and tries to analyze its advantages and logic in 3D animation film production based on the concepts and theories of digital media technology, which makes a positive contribution to the promotion of digital media technology and 3D animation film production.

Based on the 3D model construction technology, the article describes the production techniques of movie and television special effects such as rigid body, particle, fabric, fluid, hair, brush and so on. Based on the enhancement of the realism and interactivity of film and TV screen by the broken special effects, a real-time simulation method of rigid body breaking based on DEM is proposed. First, the object is discretized into a series of particles in space, and the discrete unit method is used to calculate the interaction force between particles. Different from the previous traditional crushing methods, a crushing model called inverse crushing mechanism is proposed. Considering the acceleration of particle property calculation by utilizing the parallel computing capability of GPU, the algorithm is implemented on GPU using CUDA. Through the experimental analysis of particles with different particle sizes at different impact velocities, the effects of impact velocity and particle size on the crushing strength of rigid bodies are explored. Afterwards, the algorithm proposed in this paper is applied to the simulation of rigid body model crushing in small-scale and large-scale scenarios, and comparative experiments of rigid body crushing simulation methods are carried out to explore the real-time and simulation effect of the proposed rigid body crushing simulation algorithm.

2. Application of 3D modeling technology in film and television special effects

With the development of the times three-dimensional modeling technology has developed into a new digital technology era, and has been in the field of various digital media art has an irreplaceable position, but also for the visual arts contributed to the immeasurable commercial value. Three-dimensional modeling technology used in film and television production can make the film and television works through a series of visual effects so that the audience can see things and phenomena, has a very high artistic value of film and television. The application of 3D modeling technology in film and television special effects is as follows.

2.1. Rigid Body Effects

Rigid body effects that rigid body dynamics in order to simulate the reality of things made of special effects, generally including a variety of solid force objects in the role of external forces produced by the subsequent effects, such as building demolition, car explosion and so on. Rigid body dynamics of special effects production can be said to be the most commonly used and the most extensive kind of special effects, can simulate most of the real scene of the real collision, explosion, collapse and other images.

2.2. Particle Effects

Particle special effects is the use of computer software programs or other expressions to control points in space to produce continuous animation, together with a variety of rendering effects, will produce simulation of special effects. The application of particle special effects and rigid body special effects are often complementary to each other, complementary to each other. Smoke and dust, light and electric sparks, blasting debris flying and other scenes can use particle effects to simulate.

2.3. Fabric effects

Fabric effects, on the other hand, are designed to simulate realistic fabrics, making certain fabrics in purely virtual movies look softer and more natural. In addition, fabric effects can also simulate the surface of various soft objects, such as large balloons, fluttering soccer nets and so on. Moreover, fabric effects are often used in conjunction with rigid body effects to make soft objects break up.

2.4. Fluid Effects

Fluid effects simulate the movement of constantly flowing objects by calculating the flow of viscous fluids over time. Although this effect is also very widely used in major films, it is the most complex and slowest rendering speed in various special effects software, usually used to simulate smoke, fire, ocean, waterfalls and other realistic effects.

2.5. Hair effects

Hair effects is the use of computers to create a series of nodes to control the object skin with a small area of the hair curve, to achieve the control of the appearance or action of the hair. Hair effects mainly simulate the film all the virtual hair, animal fur or grass, rope, etc., these hair in the role of external forces will also produce the corresponding effect of fluttering or collision.

2.6. Brush Effects

Brush FX mainly simulates the vegetation cover and grassland in the movie, the main thing is that Brush FX can add dynamics effects to the vegetation and grassland it creates, making its movements very realistic and natural.

3. DEM-based rigid body crushing modeling

With the rapid development of graphics hardware, people have put forward higher and higher requirements for visual effects in film and television works, and the simulation results of crushing and explosion directly affect people's perception of realism. Based on the application of 3D modeling technology in rigid body special effects in film and television works, a particle-based real-time simulation method of object crushing under the impact of external forces is proposed.

3.1. Numerical model of discrete unit method

The basic idea of Discrete Element Method (DEM) simulation is to start from the microscopic particles/grains of a material, or to hypothesize these materials as an aggregate consisting of a series of particles (the size of the particles does not necessarily correspond to the actual microscopic particle size), and subsequently to set up a solid bond between the particles based on a certain rule that binds the discrete particles together to form a macroscopic continuum. The force on the particles is obtained by calculating the deformation of the solid bonds between the particles, and subsequently, based on Newton's law, the acceleration, velocity and position information of each particle at each moment is obtained, which in turn gives the macroscopic mechanical evolution of the whole system. The core of the numerical simulation of the discrete unit method is the calculation of the forces between the basic units of the system-particles, and its basic strategy is to abstract the mechanical action between particles as a combination of springs, sliding friction devices and dampers.

In the discrete unit method, it is known that there are a variety of contact models on the force between discrete units, the most common contact model is based on the theory of solid mechanics developed by the Hertz contact action model. Hertz contact action model in the discussion of the elastic contact problem, the general assumptions are as follows: mutual contact between the two discrete units is uniform, isotropic, neighboring discrete units of the contact The deformation conforms to the deformation continuity condition, and the change law of the stress on the contact surface between the discrete units in contact with each other is linearly related to the strain between the contacting objects. Based on the Hertz contact action model, the contact action of neighboring particles in the normal direction is:

$$F_n = \frac{4}{3}\frac{E}{1-v^2}\frac{a^3}{2R^*} \tag{1}$$

where E is the Young's modulus of the material, v is the Poisson's ratio of the material, a is the contact radius between particles, and $R^*\left(R^* = \frac{R_1 R_2}{R_1 + R_2}\right)$ is the equivalent radius of the two particles in contact. For the position where the discrete cell and the edge wall are in contact, it is set to R^* approximated as R.

In the tangential direction, the tangential contact action between particles is calculated as:

$$F_s = \min\left(2\frac{Ea}{(2-v)(1+v)}u_t, \mu|F_n|\right) \tag{2}$$

where μ is the coefficient of friction and u_t is the tangential displacement.

The above equations are obtained based on the interaction of two bodies, but for actual granular materials, they are usually in multiple contacts. Under the condition of multi-body contact, the classical Hertz contact action model must be modified in order to accurately calculate the force at the contact surface. In view of this, the Hertz contact action model was modified.

In DEM simulations of the mechanical behavior of materials, there may be a total of three different forms of interaction between particles: pairs of particles that are not bound together at the initial moment, but form geometrical contact as loading proceeds. Pairs of particles that are initially bound together and where the solid bonds are not yet broken at the current time. Pairs of particles that are initially bound together, but whose solid bonds break at a later time and geometrical contact occurs again as loading proceeds.

For the first type of interparticle contact interaction, the particles are subjected to normal N_e and tangential T_e interactions:

$$N_e = \frac{4}{3}\frac{E}{1-v^2}\frac{a^3}{2R^*} - 2\pi wR^* \tag{3}$$

$$T_c = \min\left(2\frac{Ea}{(2-v)(1+v)}u_t, \mu|F_n|\right) \tag{4}$$

where w is the adsorption energy, the value of which is set in this thesis to approximate two times the surface free energy $(2\gamma_s)$. In Eq. (3) $\frac{4}{3}\frac{E}{1-v^2}\frac{a^3}{2R}$ is the classical Hertz contact interaction model (i.e., for Eq. (1)), and the second term $2\pi wR^*$ is the inter-particle adhesion interaction. Since the grain size of partially sintered ceramic materials is generally in for the second type of interparticle contact interaction (i.e., for the Bonded contact model), the normal and tangential forces are obtained based on the deformation of the solid bonds in the normal and tangential directions (u_N, u_T). In this thesis work, it is calculated by the following equation:

$$N_b = \frac{E}{1-v^2} f_N a_b u_N \tag{5}$$

$$T_b = \frac{2E}{(2-v)(1+v)} f_T a_b u_T \tag{6}$$

where u_N is the normal relative displacement and u_T is the tangential relative displacement. a_b is the radius of the solid bond between the bonded particles $(a_b = a^* R^*)$. f_N and f_T are the correction factors for the forces in the normal and tangential directions, respectively, and when their values are equal to 1 Eq. (5) and Eq. (6) are the classical Hertz contact model. The correction factors f_N and f_T are obtained from the following equations, respectively:

$$f_N = \frac{1+a^*\left[\frac{\pi}{6}(1-v^2)(1+2a^*)-a^*\right]}{\sqrt{1-a^{*2}} - \bar{\psi}\left\{a^* + a^{*2}\left[\frac{\pi}{6}(1-v^2)(1+2a^*)-a^*\right]\right\}} \tag{7}$$

$$f_T = \frac{1+a^*\left[\frac{\pi}{6}(1-v^2)(1+2a^*)-a^*\right]}{\sqrt{1-a^{*2}}} \tag{8}$$

where a^* is the factorless radius $\left(a^* = \frac{a_b}{R^*}\right)$, and $\bar{\psi}$ is the geometrical action factor reflecting the effect of mechanical coupling between the solid bonds. For a given particle, the value of ψ is related to the configuration of the spatial arrangement between the solid bonds involved in that particle as well as the Poisson's ratio of the material itself.

Obviously, the tangential action leads to a relative rotation between the particles. However, due to the presence of solid bonds, the mutual rotational interaction of particles bound together will be significantly limited. Based on the above considerations, in this model, normal rotation resistance moment M_N and tangential rotation resistance moment M_T are introduced in the normal and tangential directions, respectively, to reflect the finite rotation of the particles:

$$M_N = -\frac{8ER^{*3}}{(2-v)(1+v)} f_T^{a^3} \theta^N \tag{9}$$

$$M_T = -\frac{2ER^{*3}}{1-v^2} f_N a^{*3} \theta^T \tag{10}$$

where θ^N and θ^T denote the relative rotation angles in the normal and tangential directions, respectively.

When the stress on the solid bond between particles is greater than a certain critical stress, the solid bond will fracture. In this study, the crystal penetration damage is not considered, only the solid bond damage caused by stretching and shearing is considered, and the fracture criterion is as follows:

$$\sigma_{tersion} = -\frac{N_b}{\pi a^2 R^2} + 4\frac{\left|M_b^T\right|}{\pi a^{-3} R^3} > \sigma_{c,s} \tag{11}$$

$$\sigma_{shar} = \frac{T_b}{\pi a^2 R^2} + 2\frac{\left|M_b^V\right|}{\pi a^{-3} R^3} > \sigma_{c,s} \tag{12}$$

In this paper, the critical tensile breaking strength $\sigma_{c,t}$ and the critical shear breaking strength $\sigma_{c,s}$ of a solid bond are set to be the same, i.e. $\sigma_{c,t} = \sigma_{c,s}$.

The critical tensile/shear fracture strength is calculated as:

$$\sigma_{c,t} = \sigma_{c,s} = \sqrt{\frac{E}{1-v^2}\frac{\Gamma}{\pi a_b}} \tag{13}$$

For the third type of contact action, the normal force N_{bb} and tangential force T_{bb} between the two particles are:

$$N_{bb} = N_b - 2\pi w R^* \tag{14}$$

$$T_{bb} = \min\left(T_b, \mu N_{bb}\right) \tag{15}$$

The $2\pi w R^*$ in Eq. (14) represents the adhesion between the newly formed free surfaces following the breaking of a solid bond between two particles bonded by a solid bond. After the breakage of the solid bond, the particles may rotate freely in the normal direction $(M_N = 0)$. In the tangential direction, the geometrical effect due to the surface contact still inhibits the rotation of the particles (M_T), which is calculated by the same formula as Eq. (10).

3.2. Reverse crushing mechanism

Contrary to this self-macroscopic to microscopic research method, this chapter proposes an inverse fragmentation mechanism from microscopic to macroscopic. The method is based on the idea of fuzzy clustering, i.e., the whole object object is firstly discretized into tiny particles, and these particles are calculated to get the properties of force, acceleration, velocity and position of each particle after completing the DEM simulation process, and then the connection relationship between the particles is evaluated, and certain particles are reassembled to form fragments macroscopically through the clustering analysis. The properties of the particles belonging to the same fragment are integrated over the problem domain to obtain the law of motion of the whole fragment.

3.2.1. Particle Unit Clustering. So far, the simulation process has yielded the particle units constituting the object and their corresponding physical properties such as velocity, position, etc. In the following, certain particle units in space are clustered to reconstruct the object itself and the debris produced during the collision process.

It may be assumed that neighboring particle units are connected by a connecting spring, and two states between neighboring units are defined:

State1: Normal state. The equilibrium length of the connecting spring between the units is set to r_0. According to the physical properties of the material itself, the maximum length of the spring that can be stretched or compressed is set to Δr. When the length of the spring (i.e., the relative displacement between the unit particles) is in the range of $r_0 + \Delta r$, the connecting spring between the unit particles works normally, and at this time, it is considered that the connecting relationship between the neighboring particles units is the normal state.

State2: Discrete state. When the relative displacement between neighboring particles is greater than $r_0 + \Delta r$, the spring no longer works, and with the increase of the relative distance, the force between neighboring particles gradually decreases to 0. At this time, it is considered that the neighboring unit particles are in the discrete state.

The clustering method used is to be subjected to external forces are still in the normal state of the particle group combined as a new unit to deal with, in the discrete state of a single particle or a combination of multiple particles are also used as a new unit.

3.2.2. Debris and its motion. According to the clustering method proposed in the previous section, the new units formed are the fragments generated during the simulation process, and these newly generated fragments are mapped out in the mapping stage after the collision detection and collision processing are completed in the following simulation process.

Considering the object before the fragmentation as the parent, the connection relationship between the particle units of the fragment and the parent in the discrete state becomes non-connected due to the breakage of the connection spring between the newly generated fragment and the parent. Of course, the particle units inside the fragments are still in normal state with connection relationship between them. The particle units inside the parent fragment that has not been separated from the parent also maintain the original topological and geometric relationships. If there is n particle unit inside the fragment, and its center of mass position is $p_1, p_2, \cdots, p_n$ respectively, then the velocity of the particle unit is:

$$u_i = v_i + \omega_i \times p_i \tag{16}$$

In equation (16), v_i is the linear velocity of the particle unit and ω_i is the angular velocity of the particle unit. Then the velocity of the fragment is:

$$\begin{bmatrix} I & -P_1 \\ \cdots & \cdots \\ I & -P_n \end{bmatrix} \begin{bmatrix} V \\ \omega \end{bmatrix} = \begin{bmatrix} u_1 \\ \cdots \\ u_n \end{bmatrix} \tag{17}$$

In Eq. (17), V and ω are the linear and angular velocities of the debris, respectively, I is the third-order unit matrix, and P is the dyadic matrix, i.e:

$$P = \begin{bmatrix} 0 & -p_z & p_y \\ p_z & o & -p_x \\ -p_y & p_x & 0 \end{bmatrix} \tag{18}$$

With the velocity of the debris obtained, a dynamic fragmentation simulation that conforms to the physical laws of motion can be performed.

3.3. Data Structures and Algorithm Implementation

A particle-based DEM simulation framework is implemented on GPUs using a unified grid data structure.

3.3.1. Data structure. The key to the design of the data structure is the efficiency of the search for a given particle field. In this chapter, a “loose” grid mechanism is used, where each particle cell is assigned to a specific grid node based on the location of its center of mass. In this way, each particle can be assigned to a grid cell by sorting it by its grid index.

Unified grids can be constructed using atomic operations supported by the GPU hardware, which are implemented using two arrays: gridCounters and gridCells. gridCounters stores the number of particles in each node cell, with an initial value of 0. gridCells stores the particle index of each cell, with a maximum value of 4.

The kernel function “updateGrid” updates the grid attributes and allocates a thread to each particle at runtime. Each particle calculates which gridCell it belongs to, and then adds itself to the cellCounter according to its location using the “atom add” function. Once this is done, the index is written to the correct position in the grid array.

3.3.2. GPU implementation. In the computational process based on DEM models, the properties and states of each particle have to be recalculated when the particles constituting the object are displaced. Due to the large number of particles to be computed, the computational effort is still considerable, even with the relevant optimizations. However, the computational model is the same for each particle, which is very suitable for GPU-accelerated applications, so GPUs are very suitable for accelerating particle operations in DEMs.

CUDA is utilized to perform high-density computation on GPUs, thus effectively accelerating the DEM computation process and improving the efficiency of the computation. In this chapter, GPU-based DEM accelerated computation is implemented using CUDA.

4. System realization effect and analysis

This chapter demonstrates the feasibility of the proposed algorithm by applying it to a real environment. This chapter shows the simulation effect of rigid body crushing in small-scale and large-scale scenarios, and compares the results with the experimental results of other methods.

4.1. Crushing analysis

Under different impact velocities, the crushing behavior of particles with the same macroscopic properties, such as crushing strength and crushing morphology, may also differ. In order to study the effects of particle size and impact velocity on the probability of material crushing, a spherical specimen is selected as the simulation object, 2 groups of particles with different particle sizes are constructed, and the total number of particles in each group is 30, and different impact velocities are applied to them respectively. At the end of the impact simulation, each particle was examined one by one, and if the meridional crack ran through the whole specimen, then the particle was defined as broken.

Figure 1 shows the fragmentation of particles of different sizes at different impact velocities. Where the fragmentation probability of the particles is the ratio of the number of specimens fragmented to the total number of specimens at different fractions. When the particle size is 24μm and the impact velocity is about 35m/s, there is no penetrating meridional crack inside the specimen, all the specimens are basically intact, and the probability of fragmentation at this time is 0. However, with the increase of the impact velocity, the number of fragmentation of the specimen rises gradually, which causes the probability of fragmentation to rise gradually. Finally, when the impact velocity is about 45m/s, all the specimens are formed through the meridional crack, and the probability of fragmentation is 1. Meanwhile, when the particle size is 36μm, the minimum velocity of the specimen fragmentation is lower than that of the specimen with a particle size of 24μm, and it is easier for the specimen with large particle size to be fragmented. Moreover, in order to obtain the same crushing probability, the impact velocity required for small-sized specimens is significantly higher than that for large-sized specimens. This shows that under the same impact velocity, large-size specimens tend to break more easily than small-size specimens.

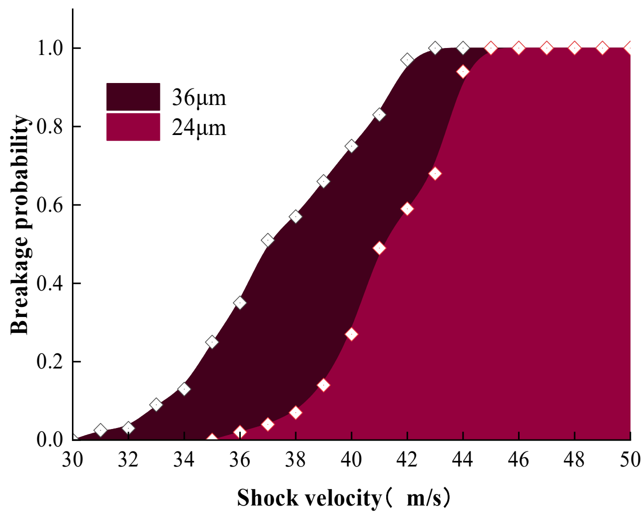
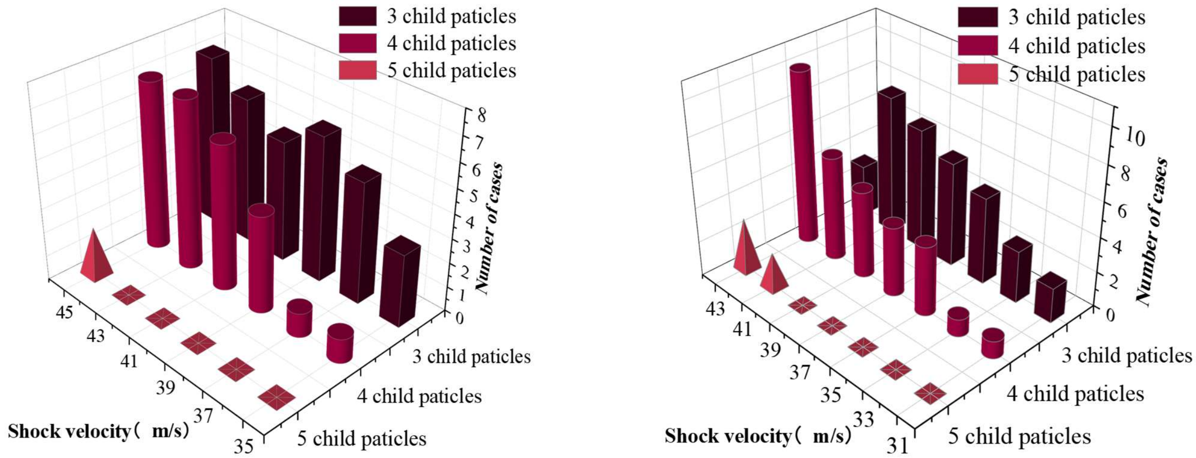


Fig. 1. The crushing of different particle size particles under different impact velocity

Particles of different sizes have different probabilities of fragmentation at different loading velocities; some particles may fracture, some do not, and for particles that have fractured, they likewise fragment into different numbers of flaps, usually into several large fragments and a large number of small fragments. For the single-particle impact fragmentation results in this section, fragments with a volume less than 3% of the particle as a whole are ignored for ease of analysis and processing. The above simulation results for different speeds and different particle sizes were compiled to count and analyze the number of broken flaps of the particles after impact.

The number of broken flaps of particles at different impact speeds is shown in Fig. 2, and (a) and (b) are the changes in the number of broken flaps of particles at 24 μm and 36 μm particle sizes, respectively. The number of broken flaps of the specimen is between 3 and 5. In addition, at the same particle size, the total number of broken specimens and the number of broken flaps increased with the increase of impact velocity. Meanwhile, at the same impact velocity, the larger the particle size, the more likely the specimen is to be broken into more flaps, and the total number of broken particles with particle sizes of 24 μm and 36 μm was 13 and 16, respectively, at an impact velocity of 43 m/s. The larger the impact velocity, the larger the input energy, and the larger the probability of specimen breakage and the number of cracks.



(a)size=24μm (b)size=36μm

Fig. 2. Numbers of Child particle for particles under different impact velocities

4.2. Small-scale scenarios

In the simple scene, a rabbit model and a wolf model were used to simulate the rigid body crushing effect, respectively. In both tests, there was only one model in the scene except the skybox and the floor. The test results of the small-scale scene are shown in Figure 3. The rabbit model contains a total of 322 vertices and 591 triangular facets, and the model is fragmented into 35 pieces in the preprocessing stage. The rendering rate was 280 FPS when the model was not fragmented, and the frame rate was 155 FPS when the model fragments were separated from the object after the model was violently hit by an external force.

The wolf model contains 9583 vertices, 18725 triangular facets, and the model contains a total of 50 fragments. The rendering rate is 180 frames per second when the object is not hit by an external force. When the object is slightly impacted by an external force and the object is not large enough to break, only cracks are drawn on the surface of the model, at which point the frame rate is around 120 FPS. When the model is hit by a large enough external force, a large amount of debris splits off from the model, and the fragmentation simulation rate is around 90 frames per second. Although the frame rate drops dramatically compared to before fragmentation, the efficiency still meets the real-time requirements and the rendering is still relatively smooth.

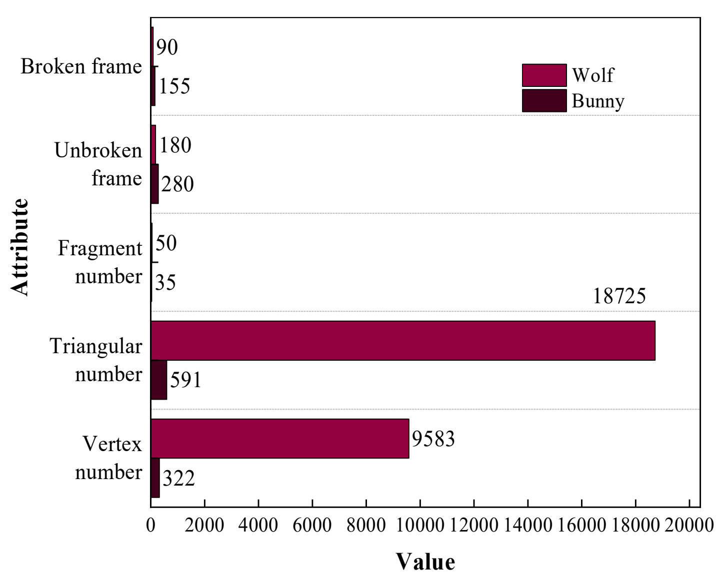


Fig. 3. Test results for small-scale scenarios

4.3. Large-scale scenarios

In the large-scale scene, a sky-surrounded box, floor and 20 breakable rigid bodies are included. Extremely fragile vase models and stone column models were chosen as the breakable objects. Each vase model contains 1529 vertices, 3000 triangle meshes, and 300 pieces of debris in the scene. Each stone column model contains 285 vertices, 674 triangles, and 100 fragments in the scene. At the same time, 20 objects are simulated to be broken, and 500 pieces of debris are dynamically simulated at the same time, which can fully satisfy most of the scenes in the film and TV special effects scenes.

The test results of the large-scale scene are shown in Figure 4. At the beginning of the simulation, i.e., when the objects are not collided by external forces, the rendering rates of the vase model and the stone pillar model are 180 frames per second and 200 frames per second. When a few objects in the scene are broken, the rendering rates of the vase model and the stone column model are around 155 frames per second and 170 frames per second. When the objects in the scene continue to be subjected to external forces and all the objects in the scene are completely broken, and all the fragments are separated from the objects to be simulated individually for dynamics, the rendering rate decreases significantly, and the rendering rates for the vase model and the stone column model are around 40 frames per second and 50 frames per second.

For movies and videos, a minimum of 24 frames per second is required so that the human eye does not feel the picture stuttering. For the game for a minimum of 30FPS gamers will not feel the screen stutter. So at the same time to meet the film and television production and game scenes in the broken simulation, the rendering speed of at least 30 frames per second. Therefore, this algorithm can basically meet the real-time simulation requirements of the game and film production in the broken rigid body scene.

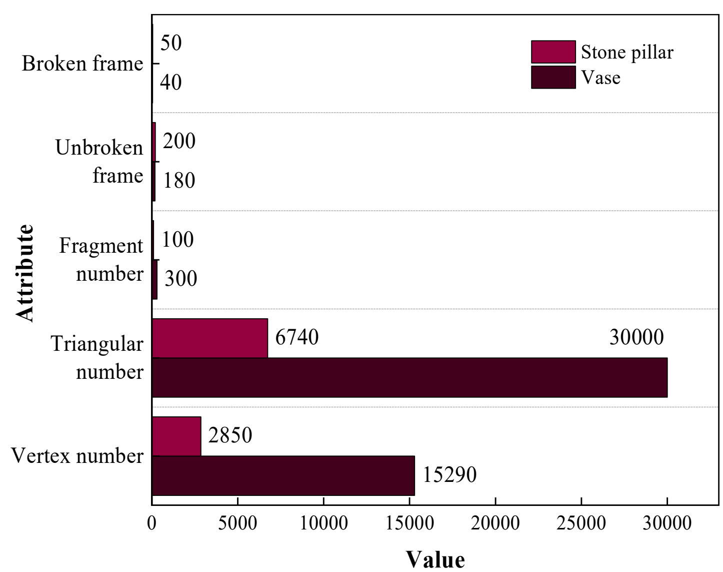


Fig. 4. Test results for large-scale scenarios

4.4. Comparative analysis of models

The previous two subsections show the simulation results and rendering frame rates of the rigid-body fragmentation model of this paper in both small-scale and large-scale scenes. In order to further prove the effectiveness of this algorithm, this section compares the experimental results with the current widely used rigid body fragmentation simulation methods (Method 1 ~ Method 4).

The comparison of the experimental results of each method is shown in Fig. 5.Method 1 uses the method based on geometric segmentation to simulate the crushing effect, which produces the crushing effect according to the predefined crushing pattern, and the algorithm also adds the collision point information to the crushing simulation stage, and the simulation efficiency reaches 130 FPS, which gives the paper satisfactory results in terms of real-time and realism.Method 2 simulates the object crushing process by means of A large number of physical calculations to simulate the object breaking process, the simulation results are more realistic, but the fracture surface will produce jagged, which affects the simulation effect. The frame rate of the simulation is low, only 20FPS, so the algorithm is not practical for real-time simulation of large-scale scenes of rigid body crushing.

Method 3 adopts a geometry-based method, and the fragmentation result is obtained according to the predefined pattern when the object is fragmented, the result obtained by this simulation method is relatively single, and the simulation efficiency is 35FPS, which has a low sense of realism.Method 4 has a real simulation effect, and it adopts a multi-core CPU to accelerate the calculation, and real-time performance can also be guaranteed.

This thesis is based on the discrete unit method to establish a numerical model, and put forward the inverse fragmentation mechanism, not only to get a more realistic effect, and the simulation speed reaches 60FPS, can also meet the real-time requirements. The method of this thesis achieves the expected goal.

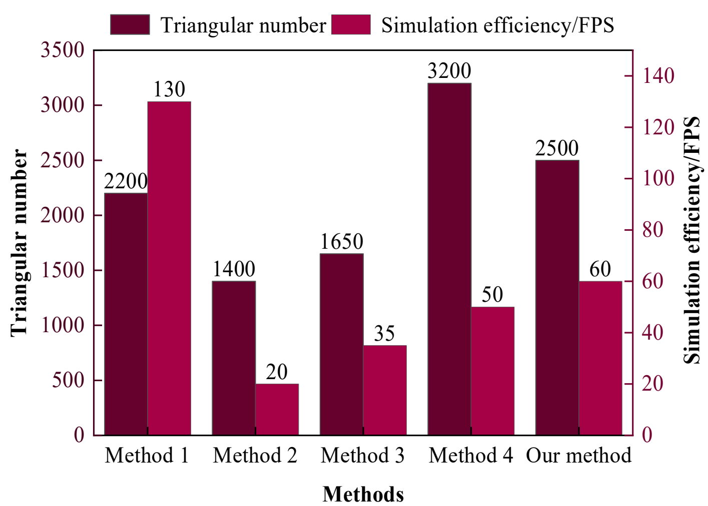


Fig. 5. Comparison of experimental results of different methods

5. Conclusion

With the rapid increase in computer speed, the application of film and television special effects technology in movie production plays an increasingly important role. The article discusses the application of 3D model building technology in film and television special effects. With the help of 3D model building technology, creators can add more action effects and visual effects in the process of film and television production, including rigid body effects, particle effects, fabric effects, fluid effects, hair effects and brush effects, etc., and the use of 3D special effects can show a more realistic and shocking effect. Then, take the rigid body crushing effect as an example, construct the rigid body crushing simulation method based on the discrete unit method, and analyze it experimentally, and find that the impact velocity and particle size are the key factors affecting the rigid body crushing mode and mechanical response. The impact velocity has a greater influence on the damage mode of rigid body particles, while the particle size has a greater influence on the crushing strength of rigid body particles. With the increase of impact velocity and grain size, the degree of particle crushing and crushing probability increase. Meanwhile, the crushing simulation rate of the rabbit model and wolf model in the small-scale scene is 155FPS and 90FPS, and the rendering rate of the vase model and the stone pillar model in the large-scale scene reaches 40FPS and 50FPS, and the simulation rate of rigid-body crushing of the present paper's method is higher than that of most of the methods in the model comparison. Therefore, the simulation algorithm proposed in this thesis achieves the goal of the research in terms of realism and simulation efficiency, and is suitable for simulating the effect of rigid body crushing in film and television production. With the development of information network technology, higher level modeling software and methods will be gradually applied to the production of film and television special effects. The modeling of film and television special effects production not only requires the staff to have the knowledge of computer graphics, but also has an inseparable and close connection with virtual reality, artificial intelligence and other fields. Therefore, industry workers should adhere to the modeling innovation, scientific integration of 3D modeling technology, and further enhance the efficiency of 3D modeling technology applied to film and television special effects production.

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