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Simulation Design and Research of Flame Generation in Virtual Fire Scene Based on Unity3D

Lixiao Dong*

Yanshan University, Qinhuangdao, China

*Corresponding author: 295199530@qq.com

Abstract. Since the 21st century, with the continuous development and progress of science and technology, the possibility of fire danger is also rising, the requirements of public fire safety management have also been improved accordingly, and the problems in its fire safety management work make it difficult to meet the management requirements. The selection of firefighters has also become the top priority of management, good psychological quality of firefighters can keep calm in the face of fire explosions and various emergencies, and can make the most correct choice to complete the rescue and fire fighting work. In this paper, a building in a certain location is selected as the location to simulate the scene of fire. Through human-computer interaction to judge the psychological quality of firefighters. First use major modeling software such as 3ds Max, Adobe Fusecc, or find material in the Unity3D store to create models of fire scenes and people and import them into Unity3D. Using Unity3D's own particle system component to build flame models, adding collision body components to all models to detect their collision detection mechanism and the mechanism of flame spreading combustion. A Scenario-based Communication Ability Evaluation System Based on Traditional Cognitive Behavior Measurement and Advanced Eye Movement, EEG and NIR Acquisition Techniques.

Keywords: Unity3D, Particle systems, Human-computer interaction.

1. Introduction

The virtual weapon countermeasure simulation system for virtual weapon training and military exercises has been applied and developed abroad. And such systems based on VR technology, the fidelity of the virtual simulation scene is an important factor affecting the use of the system, the more realistic the system, the better the training simulation effect will be, because in the real fire scene, there will usually be a large number of unpredictable combustion and explosion processes. Therefore, it is an important aspect to improve the verisimilitude of the scene in the process of constructing the virtual scene, so as to make people immerse themselves in the scene and achieve the purpose of testing. The simulation of a series of irregular phenomena, such as flame and explosion, has always been a hot and difficult point in computer graphics. In this field, Fournier's classification algorithm and Reeves's particle system theory require large computational costs, so it is inappropriate to use virtual reality systems. The particle system was proposed in 1983 by William.

And Communication ability involves two aspects: "information transmission" and "interpersonal interaction." "information transmission" is the most basic way of communication between people. Through the communication and transmission of information, human beings can share experience and perception with each other and form a specific social division of labor. "Interpersonal interaction" refers to the speaker's subjective emotion, attitude and intention to the listener, and the listener needs to extract the speaker's emotional attitude and intention based on objective experience information, to respond and give feedback. Nowadays, with the rapid development of artificial intelligence technology, human-computer communication has given a new connotation to the social function of language. In the face of the computer, people can be either the "speaker," giving speech instructions to the computer to complete a series of tasks, or the "receiver," receiving speech feedback from the computer. Therefore, communication ability, that is, the ability to use language for information

transmission and social interaction, reflects the most important social attribute of language, and is a necessary ability for human survival and development.

In the face of crisis situations, it is often necessary to make the most accurate judgments in a very short time, and it is under great psychological pressure to react, in the performance of firefighters, the sound of buildings collapsing, the sound of explosions, and sirens, These factors require firefighters to integrate information quickly, share information with teammates, communicate the scene information with teammates concisely and make quick decisions, so language communication skills in crisis situations are put forward very high requirements. adoptA Scenario-based Communication Assessment System Combining Traditional Cognitive-Behavioral Measurement with Cutting-edge Eye Movement, EEG and Near-Infrared Acquisition Techniquesand simulated real fire scenes to test and select the psychological quality of firefighters.

2. Related Work

Before the 1990s, the basic idea of the flat particle system by vacuum tube computer was to use a large number of tiny particles with certain life and properties as basic elements to describe irregular fuzzy objects. In the example system, each particle has properties such as shape, size, color, transparency, speed and direction of motion, and lifetime, all of which are functions of time t. With the passage of time in the virtual world, each particle has to experience "generation" and "activity" in the virtual world.”And the three stages of "extinction."

The scene or animation effects of the game are relatively simple, in this era, the quality of the players is low, the game concept is unclear, a large number of manufacturers fish in troubled waters is a typical feature of this era.

Until the 1990s, the Quake engine was the first true 3D engine to fully support polygonal models, animations, and particle effects. Until the 21st century, home games formed a three-legged situation, the game industry unprecedented development, and then the game engine has also been unprecedented development. With the advent of Direct9 in 2002, EPIC launched the unreal3 engine that supports 64-bit HDRR high-precision dynamic rendering, multiple lighting and advanced dynamic shadow effects, and provides powerful editing tools. At this time, joachion from Denmark and Nicholas Francis from Germany were very fond of making games, so they invited David from Iceland to form a team to develop the first version of unity.

The particle system in Unity is a tool that most scholars use to do virtual simulations of fire explosions and a series of special effects. Master Wang Gang of Qingdao University of Science and Technology in the L-CHG gas station accident simulation system development through the particle system to simulate the spray flame fireball and use this module to define the duration of particle initialization, cycle mode, emission speed, size and a series of basic parameters. The Flame Explosion needs a scene for its effect to be fully realized. Flames burning buildings collapsing and exploding are bound to produce some smoke, and Dr Liu mentioned using particles to simulate the effect of black smoke. The acceleration and deceleration process of particles can be achieved by setting the value of the Z axis of velocity over lifetime, so that particles can produce different velocities in different life cycles. Particles in the deceleration process, the smoke will spread, become thin, very quickly dissipated in the air, we can set the color transparency of the particles in different life cycle in the color overlifetime module, so that you can achieve the effect of smoke fades. During the combustion process, the smoke particles will be launched upward at a fairly high speed, but will cool down quickly when they come into contact with the atmosphere. For this situation, we also used Peng Zeng of Anhui University to quickly create the basic body of the human model in Adobe Fusecc. Upload it to the online character animation website Mixamo and put on the main actions of the escapers in the fire evacuation, such as running and standing, and then freeze each frame of the character model with the evacuation model of the third chapter in 3ds Max at the origin, and finally import it into the Unity 3D simulation software.

The fire in the fire scene will be more and more big, at home and abroad proposed to use the coupling Rothermel model and particle system forest fire spread simulation method to achieve the simulation of forest fire spread process expression, physics engine by controlling the simulation time and particle cycle simulation entity real movement process, Then the particle system feeds back the geometric position, motion property and energy of the particle at the next moment, and calculates the corresponding range according to the physical model, thus achieving a more realistic simulation. And this kind of calculation I think can be applied anywhere -- buildings, ships, cars, a whole range of scenarios[1].

3. Proposed Method

3.1. Particle systems

In the particle system, each particle represents an image effect, and the unity system simulates the image effects of each image combined to produce a complete effect. When you need to create dynamic objects such as flames, smoke, liquids, it is difficult to depict such objects in 3D or 2D, so particle systems are very useful. 3D and 2D are more suitable for depicting physical objects such as houses and cars.

The basic idea of particle system is to use a large number of tiny particles with certain life and properties as basic elements to describe irregular fuzzy objects. In the example system, each particle has properties such as shape, size, color, transparency, speed and direction of motion, and lifetime, all of which are functions of time t. With the passage of time in the virtual world, each particle has to experience "generation" and "activity" in the virtual world."And the three stages of "extinction."[2]

Mathematical concepts and formulas commonly used in the Unity3D particle system:

Location Update:

$$\text{Position new} = \text{Position old} + \text{Velocity} \times \Delta t \tag{1}$$

Acceleration:Velocity

$$\text{Position New} = \text{Velocity old} + \text{Acceleration} \times \Delta t\text{Random number} \tag{2}$$

generation:Position

$$\text{random} = \text{InitialPosition} + \text{RandomVector} \times \text{RandomRange} \tag{3}$$

$$\text{Velocity random} = \text{InitialVelocity} + \text{RandomVector} \times \text{RandomSpeedVelocity random} = \text{InitialVelocity} + \text{RandomVector} \times \text{RandomSpeed} \tag{4}$$

Interpolation:

$$\text{Linear interpolation (Lerp): } \text{Lerp}(a, b, t) = a + (b - a) \times t \tag{5}$$

Smooth interpolation (Slerp): Used for smooth interpolation between two vectors, typically used with quaternions or unit vectors.

Noise function:

Perlin noise or Simplex noise: Used to simulate natural phenomena such as flame flickering or smoke diffusion. These are continuous, random, and often multi-scale.

$$\text{Life cycle Lifetime}=\text{CurrentTime}-\text{StartTime} \tag{6}$$

$$\text{Size} =\text{InitialSize}+\text{SizeOverLifetime}\times\left(1-\frac{Lifetime}{\text{MaxLifetime}}\right) \tag{7}$$

$$\text{Colormixing:Color}=\text{Color} = \text{InitialColor} + \text{ColorOverLifetime} \times \frac{\text{Lifetime}}{\text{MaxLifetime}} \tag{8}$$

These formulas are very useful in particle systems to create various dynamic effects such as particle emission, movement, transformation, and decay. In programming implementations, these formulas are often iteratively calculated to simulate continuous processes.

Particle system theory is one of the most mature theories for describing irregular objects. Compared with other methods of describing irregular objects, it has the following three remarkable characteristics:

(1) An object is described not by a set of primitive patches with boundaries, such as polygons, but by a set of primitive particles defined in space.

(2) A particle system is not a static entity, and the properties of each particle are functions over time.

(3) The object described by the particle system is not pre-defined, and its shape and position are described by random processes. In general, particle system theory can be used to describe objects as follows (Figure 1):

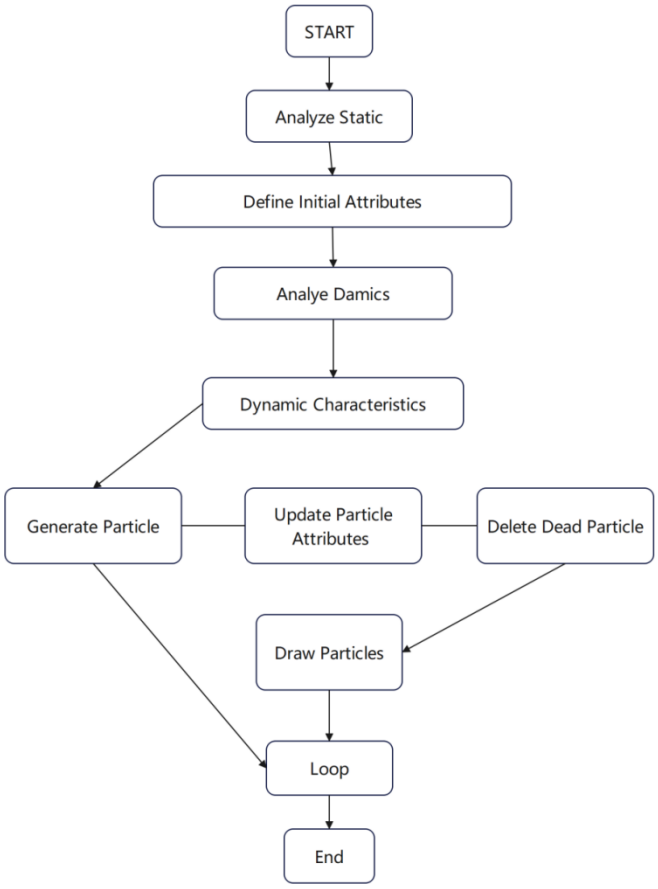

Figure 1. (3-10)Flow chart of the particle system generation

Particles as Groups [3] In different fields, the number of particles is different, and its range is usually between dozens, hundreds or even thousands. However, there are still similarities between particle systems. In this paper, the need to use the particle system are: flame, fire hydrant jets of water. Taking flame as an example, the life cycle, shape, ejection speed, duration and other related properties of the particles are expounded. [4] Duration is set to cycle mode, lifetime is 3 units, and launch speed is 2 units. The shape of the particle emission is conical, which is more in line with the normal.

The number of particles in the center point is the largest, and the number of particles decreases with the distance between the center point and the center point increasing.

For convenience, the particle system may be abstracted with a simple mathematical model [5]. The expression corresponding to this model is:

$$P_{\square}^{n} = \left\{a_{1}^{\square}, a_{2}^{\square}, \cdots, a_{n}^{\square} | n \geq 3, n \in I\right\} \tag{9}$$

Of which a_nRepresents the individual properties corresponding to each particle. In addition, each particle has a corresponding enantiomeric relationship, set to $I_t^{\square}$reach $P_n^{\square}$ Mapping of:

$$\mathrm{Q(t)} = \{\mathrm{P_t}: \mathrm{I_t} \rightarrow \mathrm{P_n} | \mathrm{I_t} \epsilon \mathrm{J}, \mathrm{n} \geq 3, \mathrm{n} \epsilon \mathrm{I}, \mathrm{t} \epsilon \mathrm{R}\} \tag{10}$$

Finally, will Q(t)Is defined as a particle system with the formula [6]:

$$\mathrm{S(t)} = \{\mathrm{Q(t)} | \mathrm{t} \epsilon \{\mathrm{t_0}, \mathrm{t_1}, \ldots, t_m\}\} \tag{11}$$

3.2. Control parameters for making flame effects

3.2.1. Shortening the life span of particles

(1)Reduce the duration of the particle system: In Unity's particle system component, you can shorten the life cycle of a particle by reducing the duration of the particle system. By reducing the duration, the particle system can play all particle effects faster, reducing the overall lifetime.

(2)Reduce the lifetime of individual particles: Another approach is to reduce the lifetime of individual particles. In a particle system, each particle has its own lifetime, controlling how long it exists. By reducing the lifetime of each particle, it is possible to make them disappear more quickly, thus shortening the lifetime of the entire particle system.

(3)Adjust transmission speed and frequency: By increasing the speed and frequency of particle emission, the particles can be emitted faster, thus shortening the life cycle of the entire particle system. This makes the particle effect more dense and short-lived.

(4)Use scripts to control lifecycles: In addition to adjusting parameters directly in the Unity compiler, you can dynamically control the life cycle of a particle system by writing scripts. Through scripting, you can achieve more flexible and complex particle effects, including dynamic adjustment of particle lifetime and emission frequency.

By combining or applying the above methods alone, you can achieve the effect of shortening the life cycle of a particle system in Unity, making the particle effect more transient and dynamic.

3.2.2. The setting of the world space

In Unity, setting an object to World Space means that the object's position, rotation, and scaling are relative to the world coordinate system, not relative to the parent or local coordinate system. This

setup can be useful in situations such as keeping objects in a fixed position throughout the scene or making them independent of other object transformations.

In theory, setting an object to world space can be achieved by following these steps:

(1)Select the object: First, select the object you want to set as world space in the Unity Compiler.

(2)Adjustment transformation component: In the object's Transform component, set the coordinate space to "World." The position, rotation, and scaling of the object will be calculated based on the world coordinate system, independent of the parent object.

(3)Application transformation: Adjust the position, rotation, and scaling of the object as needed. These transformations will directly affect how the object behaves in world space.

(4)Dealing with paternity: If the object previously existed as a child of another object, setting it to World Space will be removed from the parent object's transformation. This means that even if the parent moves or rotates, the object remains in its fixed position in the world coordinate system.

By setting an object to world space, certain effects can be achieved, such as creating movement independent of the parent object or ensuring that the object remains in a fixed position throughout the scene. This setup is useful for some specific needs and effects, but it is important to note that it may cause changes in the relative positions and relationships between objects and other objects.

3.2.3. Speed of flame spread at fire scene

In the process of the spread of the site, it is necessary to calculate the fire boundary in real time in order to record the characteristics of the fire at each moment. The main characteristics include the characteristics of site spread such as height or speed of fire and the characteristics of fire conditions such as fire area, fire perimeter and length breadth ratio.

The calculation of the characteristic quantity of fire spread. The calculation of flame spread characteristic quantity is to calculate the spread speed and fire height by inputting the fire disaster factor and nested formula. The corresponding input items are dry combustible $\frac{I\mu(1+\varphi 1+\varphi 2)}{\rho\delta\theta}$, dry particle density, surface volume ratio and so on. The calculation formula is, In the equation, v is the flame spread speed (m / min); I_v Intensity of reaction in the fire zone $(KJ/(min\cdot m^2))$; μ is the rate of flame spread (dimensionless); φ1Wind speed correction factor;φ2Is the slope correction factor; The density of the fuel(KJ/m^3); Σ is the effective thermal coefficient (dimensionless)θ_{ig}; The amount of heat (kJ / kg) required to ignite a unit mass of combustible material.

3.2.4. Setting the emission shape and rate of particles

Adjust the launch shape: In the Inspector panel of the particle system component, find the "Shape" option. Here, you can choose different launch shapes such as spheres, boxes, cones, etc. Choose the right launch shape for your needs.

Adjusting shape parameters: Depending on the selected launch shape, you can adjust shape parameters such as radius, size, height, etc. These parameters will affect the position and direction in which the particles are emitted from the emitter.

3.2.5. Setting the Particle Emission Rate

Adjust the emission rate: In the Inspector panel of the particle system component, find the "Emission" option. Here, you can adjust parameters related to emission rate, such as "Rate over Time" (number of particles emitted per second) or "Burst" (number of particles emitted at one time).

Adjustment rate curve: You can also use the rate curve to customize the particle's emission rate. In the "Emission" option, you can find the curve icon below "Rate over Time" and click on it to open the Rate Curve Editor to adjust the particle emission rate change based on time.

Other launch parameters: In addition to the emission rate, you can also adjust other emission-related parameters such as emission angle, velocity, lifetime, etc., to further customize the behavior of the particle.

3.3. Control of life parameter cycles

3.3.1. Life Cycle Curve (Lifetime Curve):

In the life cycle module of a particle system, curves can be used to control the life cycle of a particle. The life cycle changes of the particle can be adjusted by the slope and shape of the curve.

3.3.2. Life Cycle Constant (Lifetime Constant):

In addition to using curves, it is possible to set a constant value to control the lifetime of all particles. All particles will have the same lifetime.

3.3.3. Lifetime Randomness:

A random range can be set in the lifecycle module so that the lifetime of each particle fluctuates within a random range. This increases the variety and naturalness of the particle effect.

3.3.4. Life Cycle Curve Mode (Lifetime Mode):

Different life cycle patterns can be selected, such as constants, curves, random values between two constants, and so on. Choose the appropriate life cycle mode as needed.

3.3.5. Inherit Lifetime property:

You can set whether a particle inherits from its parent object's lifetime. If this option is enabled, the particle lifetime will be affected by the parent object lifetime.

4.angleset upReduce the radius to 0.

5.Modify the curve to make the transition of particles from large to small

6. SetSet upFlame Gradient

R:246G:235 B:1

(With unit Time-generated Increased number of particles)

4. Experimentation and Validation

4.1. Experimental Settings and Implementation Details

4.1.1. Experimental Configuration

Version: Unity2023. 2.3f1c1

Processor: AMD Ryzen 9 6900HX with Radeon Graphics

Through the above mentioned experimental process began to test. After creating a particle system in unity, material is set. Then proceed to render the module.[7]

Change Material to Fire as shown in (Figure 2).

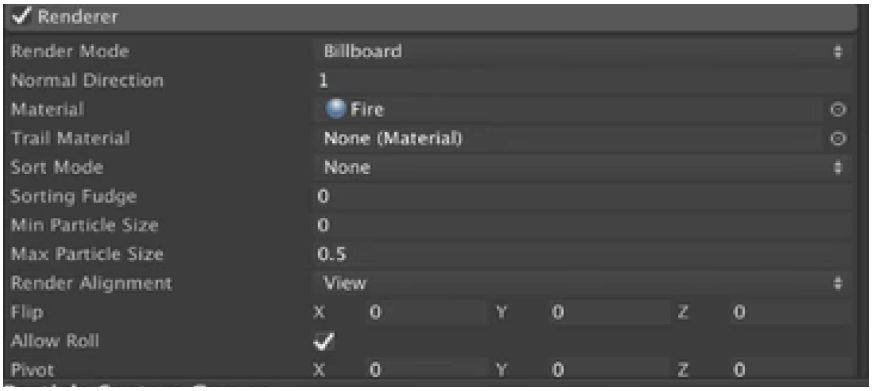

Figure 2. Changes in Material

Then set the basic properties of the particle (Figure 3):

These are some common ways to set the basic properties of a particle system, which can be adjusted to create different particle effects. In Unity, you can further customize particle effects with more advanced properties and modules, such as speed, rotation, zoom, and other properties, as well as external force fields, collision detection and other modules. It is suggested that the properties of the particle system should be flexibly adjusted according to the specific needs and effect requirements to achieve the desired visual effect.

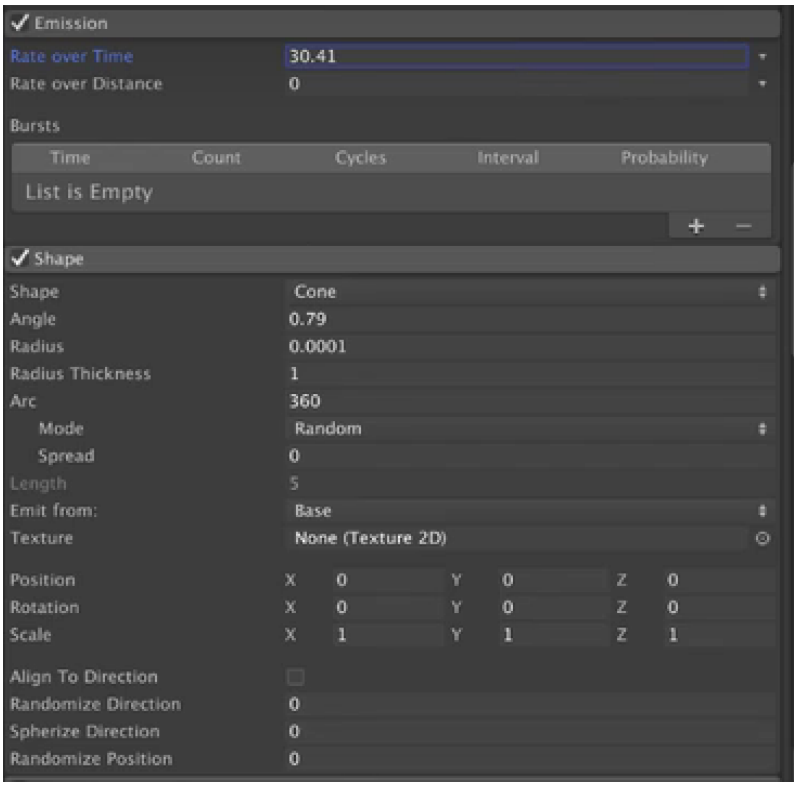

Figure 3. Setting the Particle Emission Shape and Rate

Then set the basic properties of the particle (Figure 4-5):

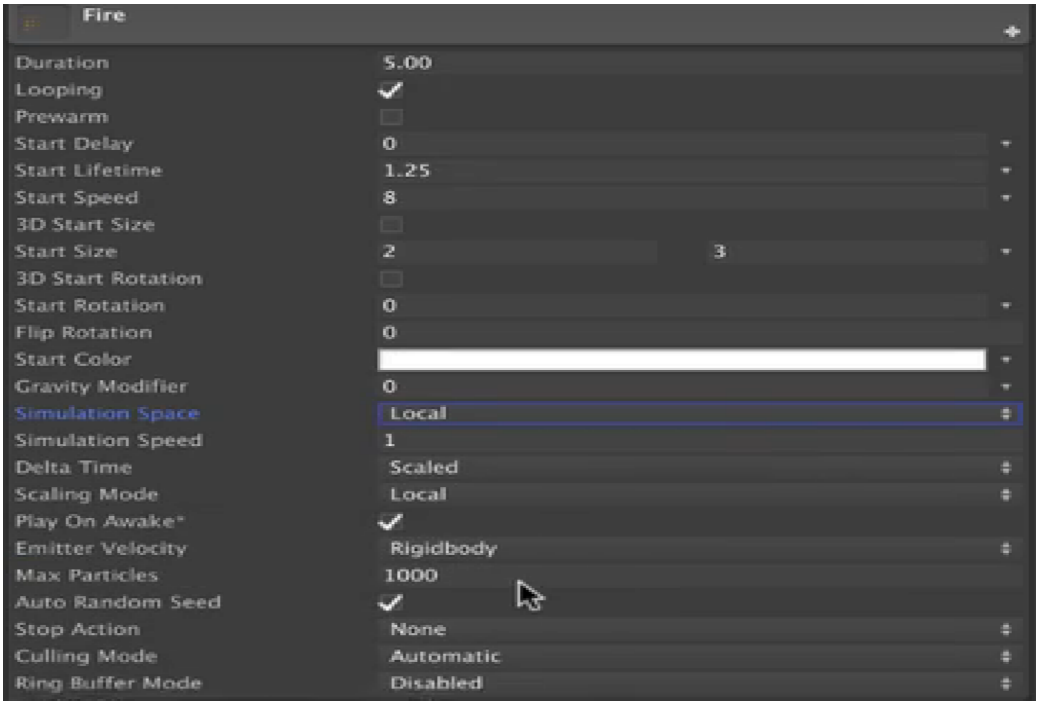

Figure 4. basic properties of the particle

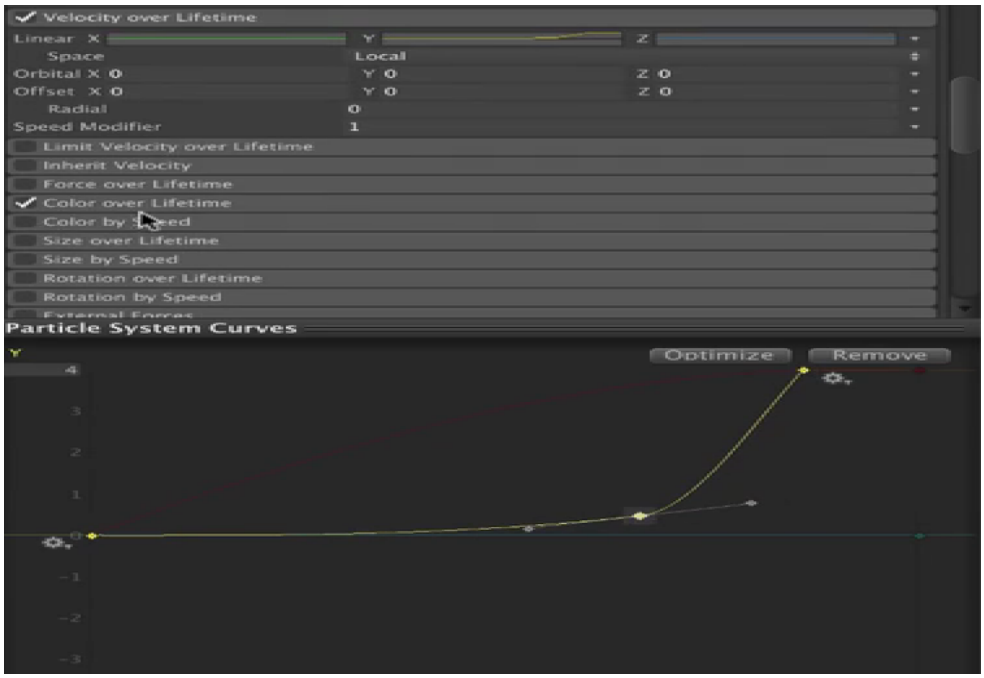

Figure 5. Setting Basic Properties of Particles

If you want the flame to float upwards, you can set the particle life cycle parameter control.

By adjusting these life cycle parameters, the life cycle of the particles can be controlled, making the particle effects more vivid and diverse.

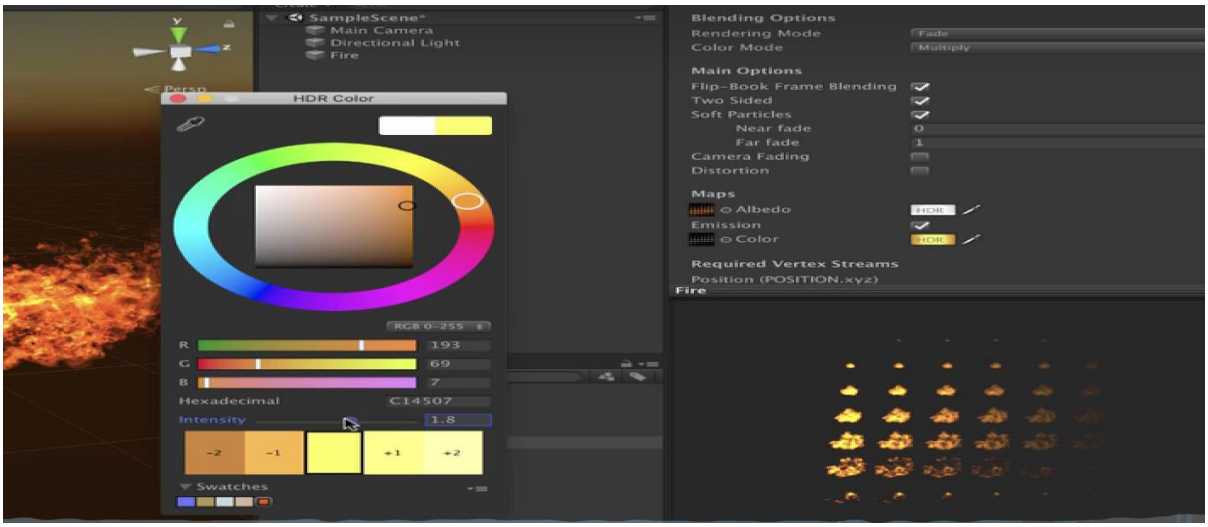

Figure 6. color

Last modified color (Figure 6).

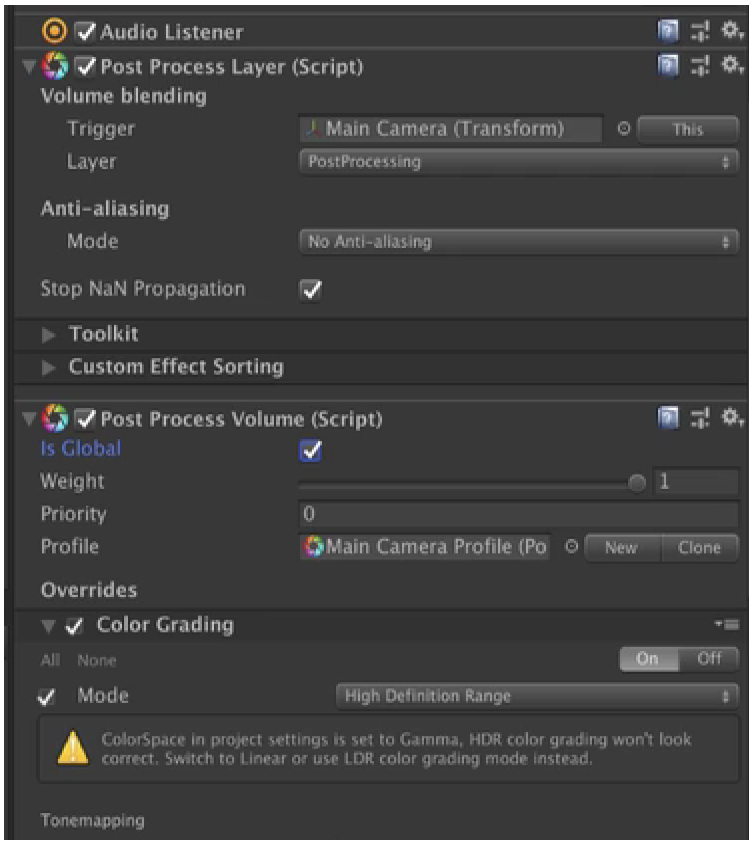

Figure 7. post-processing effect

This alone is not enough, you need to achieve the effect of firelight, you need to post-processing effect (Figure 7).

Comparison of resolution with different number of particles, Three different frame rates were selected as shown in Table 1, The different flame effects produced are shown in Figure 8.

Table 1. Comparison of resolution with different number of particles

	frame rate
100,000 particles	87
1 million particles	52
2 million particles	36

Figure 8. Three particle flame renderings corresponding to the number of three particles

5. Conclusion and Future Works

In this paper, we combine the fire scene simulation and disaster effects, with the help of unity's own particle system module, developed a set of Unity3D based virtual fire scene of the fire generation, to achieve the simulation of the accident and can let users immersive, do not feel the gap with the reality. Reference and assistance for the selection of firefighters in the fire department.

First of all, we know that the flame in unity3d is made by particle system, know the principle of particle system, theoretical analysis and calculation, and make the special effects of flame through unity. The system mainly uses 3dxMax as the main modeling tool and Unity3D as the development tool. Using the powerful virtual reality technology, particle system and graphical user interface technology of Unity3D, the main interface and four functional modules of the system are designed.

In the future work, the combination of "smart eye" system and virtual reality technology, what is "smart eye" that is The Eye system provides contextualized tasks that dynamically measure a subject's ability to communicate in real-time interactions. Compared with the traditional static paper and pencil or computer test, the scene task fits the dynamic interaction of communication ability and can more accurately capture the differences of individual communication ability level. Secondly, the comprehensive indicators of communication ability in the "Eye" system are extracted from multi-modal data. Through the multi-modal synchronous acquisition technology, the multi-dimensional data of the same psychological process of the subjects in the same scene and the same event can be collected, which can describe the communication ability of the subjects more comprehensively and accurately. Finally, "Eye Eye" system is a new generation of communication assessment tool that integrates cutting-edge technologies including psychology, cognitive neuroscience, psychometrics and artificial intelligence.The scene is set up to let firefighters wear VR helmets to simulate the fire scene, through a variety of explosive flames and emergencies, to detect the psychological quality of firefighters, whether the various physical indicators are uncomfortable, to determine whether they can make the most accurate judgment in difficult circumstances.

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