Research on Natural Scene and Meteorological Environment in Virtual Rebuilding of the Prehistoric Settlement Sites

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***Abstract*—Based on the data of Jiangzhai one-stage settlement sites archaeological excavation data, this paper applies three-dimensional visualization technology of virtual reality to scenario building. In order to enhance the fidelity of prehistoric settlement sites to reproduce the virtual system simulation results in the system design and implementation process, it essential to build plenty of the natural environment and weather environment scene. Time and user input as the driving source to realize the sky and the surface changing with the time of seasons and weather changes in the environment. The texture mapping technology, Billboard, LOD and Particle Systems are also used in the reconstruction of trees, mountains, and meteorological elements, such as snow sleet. To generate a vivid model of the scene of the prehistoric settlement site, and the life of the primitive settlement has been reproduced.**

***Index Terms*—prehistoric settlement,Jiangzhai site, natural environment, meteorological environment**

I. INTRODUCTION

Since the birth of mankind, there has been a variety of world civilization and cultural sites. China is one of the ancient civilizations in the world, the culture of prehistoric settlement is an important part of the spiritual wealth of China, to lay a solid foundation for the later development of civilization. The Jiangzhai prehistoric settlement site, which locates in the middle or lower reaches of the Yellow River, is a matriarchal clan society with large excavation area and a vast agricultural establishment during this period. In addition to the formation of maternal system and paternal system in Neolithic society, the institution of clan marriage and economic system are also produced. They have a distinctive character in stone grinding, pottery producing, the invention of agriculture, prehistoric art and other aspects.

The Jiangzhai prehistoric settlement site dating back over 6500 years, is located in the north of Xi'an, with Mount Li in its south and the Wei River in its north. Since its discovery in 1972, a total of 11 scientific excavation have been performed, the exposed area of about 17084 square metres and, the total site area of approximately 50000 square meters. The site includes four periods of sequential development whose relationship is Principle of Stratigraphic Succession [1], and creates a measurement for the study of different periods of Yangshao culture in the Guanzhong area. Among them, the first period of settlement site preserved almost all the distribution of primitive settlements and various kinds of facilities inside it. This settlement site provides valuable materials for the study of social organization and social development stage of the residents in the early phrase of Yangshao culture and it has precious scientific research value because it is the most intact settlement site in the Neolithic Age. This paper is significant because Jiangzhai settlement site and the real life of the primitive settlement have been reproduced virtually.

Researching on the prehistoric settlement history of civilization is mainly based on the studies of settlement archeology. Generally, the study of prehistoric settlement sites experienced exploration, mining, research,

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demonstration, and some problems existed in these processes. In the process of exploration and mining, it will cause damage to the original remains and relics inevitably; In the process of research, the inherent relationship between layout of remains need to be revealed; In the process of demonstration, how to reflect the true face of ancient settlement and let visitors experience the immersive feel.

Non-contact measurement technology and three-dimensional imaging technique are used in the terms of monuments and relics recovery. There are many research and applications for virtual restoration of ancient settlement sites in domestic and foreign: October 2004, the first "International Conference on Remote Sensing Archaeology" held in Beijing, hundreds of delegates from 15 countries discussed the methodology and technical specifications of the combination of remote sensing technique and archaeological research; August 2011, scholars from several countries, who engaged in cultural heritage and digital technology research, gathered together to discuss cultural heritage digitization in Mo Kao Grotto at Dunhuang; Professor Zhao Haiying from Xinjiang University, realized the modeling of Xinjiang ethnic fabric patterns based on physical model and theoretical model; Professor Pan Zhigeng from Zhejiang University realized the virtual experience and interactive driving experience in the Grand Canal from Beijing to Hangzhou by building a roaming experience module; scholars in Italian scan the architectural and sculptural of Pompeii with 3D laser scanner, realized the virtual simulation based on the three-dimensional data.

The paper realized the virtual reproduction of Jiangzhai settlement site. Focusing on specific archaeological sites and excavation regions, and manage the three-dimensional data with the software of GIS. In the process of reproducing the Jiangzhai settlement sites, in order to show a better immersion effect of the system, the sun, the moon and other natural scenes are implemented in the reproduced environment and these scenes change as the time flies. Simultaneously, we introduce scenes effect of weather environment to realize the rain, snow, fog and other scenes. By building the natural and weather environment in the process of reproducing the settlement sites, the virtual fidelity can be enhanced and provides a preference for the virtual reproduction of other primitive settlements.

II. Constructing The Natural Scene

A. Sun Building.

The natural scenes include the scenes that we can see in daily life, like the sun, the moon, clouds, daytime, night and others. The sun and the moon are implemented through OpenGL. The sun modeling of the system in this paper is created by drawing a clockwise rectangle according to the four vertices by using GL_QUADS pel (the four angles of the rectangle are in the same plane) [2]. Besides, the modeling is also implemented by using coordinate converting, rectangle converting, color blending, texture mapping, fog effecting, depth testing and other processes. The method used to construct the moon is similar to constructing the sun. The only difference is that the shape of the entity object of the moon changes as seasons and time change. In this paper, the sun, will be expounded.

The position of the sun changes as the time passes and so does the rotational motion around the central point O [3]. As shown in the Fig. 1. We set the rotating time to 12 hours. In the coordinates, we assume that the height H and the diameter R. The speed (V) can be calculated according to the time. The details are shown in the following: first, according to the season that is set by the system, taking the summer as an example, then, the daytime is set from 5 am to 19 pm, otherwise, the rotating time is set as from 7 am to 17 pm. Secondly, initialize the height and orientation of the sun, and calculate the coordinates in the space according to the changing of the time.

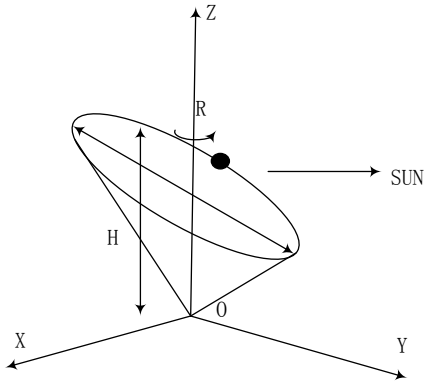

Figure1. Schematic diagram of the movement of the sun

The sun moves in a certain speed and orientation during the time that is set by the system. It must be removed when it excess the limit of the time and set according to the meteorological conditions, such as substituted by the moon, changing from the daytime to the night. The process can be described as shown in the Fig. 2.

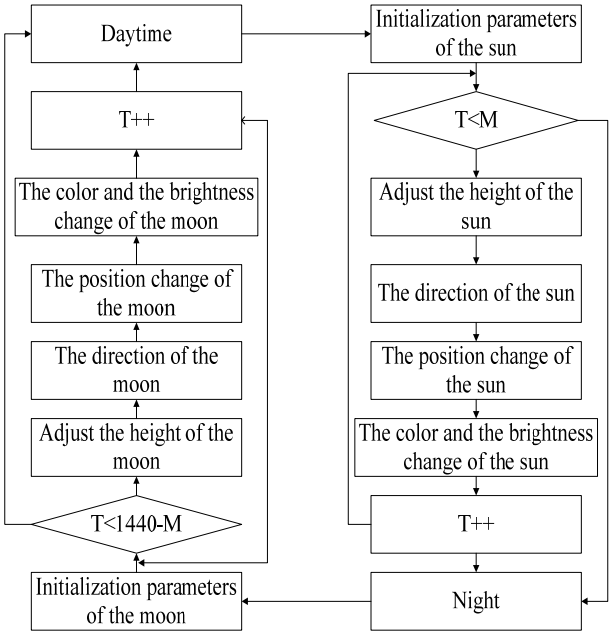

Figure2. The flowchart of the change from day to night

In the process of rendering the sun and the moon, apart from the entities of the sun and the moon, additional solar light effect should also be covered. For example, in the effect of solar light, the halo and color effect produced by the solar light should also be included. Therefore, the following texture shouldbe covered in the system. As shown in the Fig. 3, all the essential textures to generate the sun are covered in this figure. For instance, the one on the top left is used to generate the sun light and the top right one can generate the body of the sun. By using these textures, the movement of sun can be generated vividly. For example, when the sun light irradiated on the surface of ground through the cloud, the solar light effect (the top half of Fig. 4) and the effect of the sun body (the bottom half of Fig. 4) can be shown in the Fig. 4.

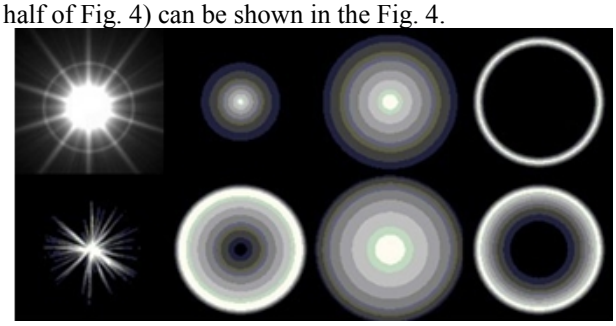

Figure3. The texture mapping of the sun and the halo effect

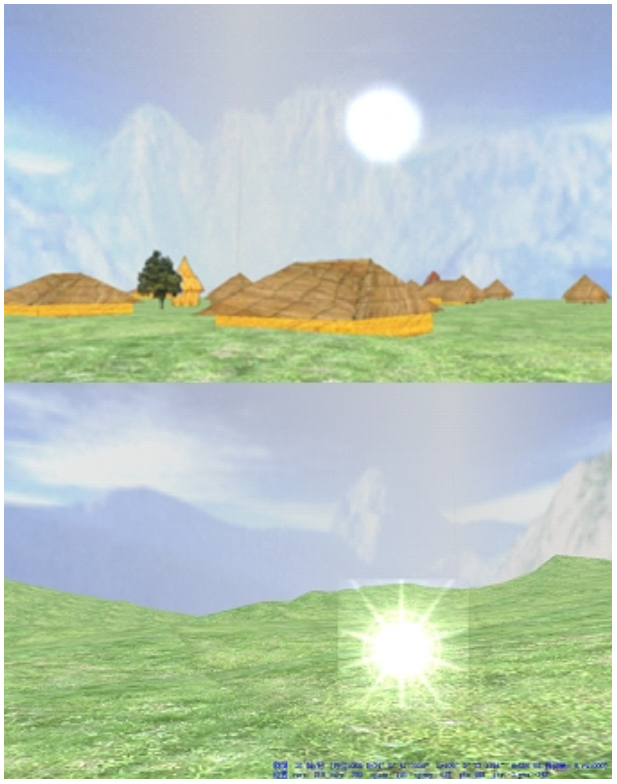

Figure4. The effect of the sun and the halo

B. Night

During the changing of the time, the parameters can be set according to the season set by the system. For instance, if the season is set as summer, then the period of night is from 19 pm to 5 am. The night is realized by atomization effect provided by OpenGL. The code as follows and the effect is shown in the Fig. 5.

```
m_fFogColor [0] = 0.001f;
m_fFogColor [1] = 0.001f;
m_fFogColor [2] = 0.001f;
m_fFogColor [3] = 0.9f;
m_fFogDensity=0.0013f;
glFogfv (GL_FOG_COLOR, m_fFogColor);
glFogf (GL_FOG_DENSITY, m_fFogDensity);
glFogf (GL_FOG_START, m_fFogStart);
glFogf (GL_FOG_END, m_fFogEnd);
glHint (GL_FOG_HINT, GL_DONT_CARE);
```

Figure5. Night scene effect

C. Tree Building

Twenty-nine kinds of animals, including black bear, tiger, cat, macaque and others, are found in the Jiangzhai settlement site: revealing that the settlement contained a certain area of forest. Despite the Jiangzhai settlement has been there for thousands of years and changed as time flies, the trees still share the common features with the modern ones. In order to show the life of primitive settlement vividly, plants are introduced in the production of settlement. Shrub is the main part consist the vegetation, and several kinds of shrub are shown in Fig. 6.

Figure6. The textures of trees

In the process of tree building, "Billboard" is the technique used in the process and contains texture mapping [4]: by building a polygon, taking square as an example, this square is always oriented towards the point of sight. Meanwhile, texture is "pasted" on the square and the data of texture is from the texture data of tree sample in the first step. In the process of "pasting texture", the main techniques applied are transparent texture mapping and isotropic technology. In real life, the scene behind the tree can be observed through the gaps. In order to realize this phenomenon realistically, transparent texture is necessary. Specific method is to fuse the data of the texture and the color values of the target scene so that house site can be seen through the trees. Furthermore, a certain thickness is the feature of the trees. Therefore, different angles should be covered as the point of sight moves. Hence, the tress should be observed as cylinders and isotropy is necessary.

Double vertical plan texture mapping and Billboard polygon texture mapping are the two methods to realize the isotropy of trees. The first method is to build two perpendicular planes and "paste" specific texture. Since the two planes are perpendicular to each other, the interval between each other is 90 degrees; the observations from different orientations are the same. A shortcoming of this method is that when applying the light, part of the two planes will shelter from each other. Shadow can be produced because of the inconsistence of transmissivity of the light and the effect of observation can be alternately bright and dim. As a result, this method is not used in the systems generally.In the process of realization, build the single object using the Billboard polygon and map the texture map data of the trees to the plane. In order to reach the requirements of isotropic, the orientation of the trees ought to change as the point of sight is moving. The main focus here is to rotate the orientation of the trees to ensure the direction of the normal vector is always toward the point of sight and this can be seen in Fig. 7. The shortcoming of this method is that the constant operations of rotating the trees increase the computing quantity in the movement of point of sight. Therefore, a limited number is necessary for the trees, otherwise, the efficiency of the system will be reduces when applying this method.

Figure7. The effect of trees

D. Mountain Building

In order to apply the realistic of the system, the realization of Lishan Mountain near Jiangzhai settlement site is necessary. Since the lack of detail data of mountain such as range, height, shape and others, incomplete simulation can be applied [5]. In this case, a concise method to realize the mountain by applying the height, gradient and ridge is to adjust the terrain elevation data. In the process of adjusting, two adjustment including circular region and square are the main adjustment according to the adjusting requirement. Meanwhile, adjusting height, depth limit value, precision and range are all included.

First of all, acquire the position of the point of mouse click in the scene and the elevation. Weighted distance method is the method to acquire theelevation. The basic idea is create a function that variable is from discrete point to point of mouse click on the grid, then, choose the sample point from the multiple directions from the center point of the grid. The more the sample point close to the click point, the more effect the elevation H of the grid point of the click point will be. The following formula can be applied to calculate:

$$h = \frac{\sum_{k=1}^{m} w_k h_{lk}}{\sum_{k=1}^{m} w_k} = A^T H \tag{1}$$

With $A^T = \left[\frac{W_1}{\sum W_k} \frac{W_2}{\sum W_k} \ldots\ldots \frac{W_m}{\sum W_k} \right]$, $H = \left[h_{l1} h_{l2} \ldots . h_{\ln} \right]^T$

h_{li} is the elevation of the sample point, W_k is the weight function, h is the elevation acquired from the interpolation.

In the setting range of the click point, according to the chosen direction, if the elevation of the range of the mouse click point is less than the value of the measured, then, the direction should be set as the positive direction. The setting ought to increase according to the increasing value of elevation of the grid point. Meanwhile, according to whether the increased elevation exceeds the upper limit as set, if the elevation of the mouse click point is greater than the value measured, then the value of the elevation of grid point ought to be reduced and the corresponding step size ought to be reset. Meanwhile, compare whether the reduced elevation exceeds the lower limit. The specific algorithm calculating the elevation is shown as following:

- (a) Set the adjusting range as *L*, adjusting direction is *Flage*, adjusting precision is *step*, the upper limit is *Up*, lower limit is *Down*;
- (b) Acquire the coordinate *(X, Z)* of the click point *D*, according to the acquire elevation method, calculate the elevation *H*;
- (c) Do the scanning in the shape of square in the range of *L* around the click point *D*, and acquire the grid points in the adjusting range around *D*: *a, b, …, m*;
- (d) Calculate the distance from the grid points to the center point D:$(l_a,l_b…l_m)$; and set the corresponding weight as $1/l_i$, then the adjusting step size of corresponding point is $Step/l_i$;
- (e) *For* (*i*=1; *i*<*m*; *i*++)

```
{
  If (Flag is downward adjusting)
          {
             Hi=Hi-Step/li
             If (Hi<Down)
               Hi=Down;
     }
      Else
         {
            Hi=Hi+Step/li
             If (Hi>Down)
             Hi=Down;
     }
}
```

By adjusting the topographic data, realizing the adjustment of certain elevation of partial settlement site and make them match the measured data in the archaeological excavation. Meanwhile, by applying this method to realize the Lishan Mountain in the system, among them, Fig. 9 is the mountain effect picture based on Fig. 8 by adjusting the topography.

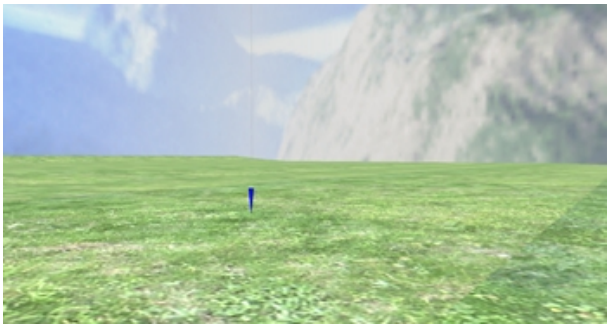

Figure8. The original ground map

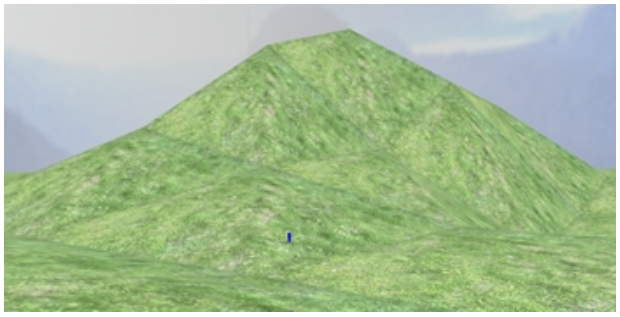

Figure9. The effect after adjusting the height of the mountain

III. METEOROLOGICAL ENVIRONMENT BUILDING

WillianmT.Reeves [6] promoted the particle system in 1983 and he applied this system to modeling some fuzzy sports. In realistic world, the moving entity objects like raindrop, cloud, snow, water flow, are typical natural meteorological environment.These objects can be seen as combination of multiple particles. By controlling the mode of motion, grid bearing, appearing and dismissing time of the particle consisting of the entities, meteorological environment can be simulated according to them. And applying the texture mapping techniques, the meteorological environment can be built more vividly.

This paper focuses on building the process of raindrop falling and snow falling in the meteorological environment, both of which are caused by the gravity. In the modeling system, the complexity of movement of particle is decided by the complexity of physical model. All the particle of each entity ought to apply the following characteristics: first of all is the grid bearing – the particle's showing process in the scene is always changing, so as the coordinates and orientation; the second one is speed – speed is a feature of moving particle and it affects the coordination of the particle in the next moment. Speed can be calculated according to the requirement of the system. The third one is the accelerating speed – the particle needs to do the moving related to the accelerated speed[7], taking a bullet as an example, a more realistic moving can be seen only if the accelerating speed applied. The fourth one is the particle is given the life in the process of rendering the scene, like the snow will be eliminate right before it comes to the ground.

Some other static attributes are included when rendering the rain and snow: one is the shape, rectangle and circle can be used to represent the drop and circle is the best choice for snow. Of course, a more realistic method can be applied here, which applies the 3-dimentional tetrahedron to represent the rectangle and sphere to represent the circle. The size of the drops is the same, but three types of size can be found for the snow. The color and transparency also have to be set in the scene.

The corresponding attributes of the snow and rain include motion properties and rendering properties, of which the motion properties focus on the particles' speed, accelerating speed and life time, the rendering properties includes the particle's size, texture characters and transparency[8]. Apart from that, group motion effect should be introduced here, which simulates the motion and density of the group. The rain and snow move according to the certain kinetic equation. It can produce a random controlling process to realize the group motion, which is to set the number of particles in the scene the same as the density of the group.

The rain motion is realized according to the motion equation, the process of rain dropping is the process of gravity drop. The flow chart is shown in Fig. 10. But the result by applying this method is not good enough. That's because the scene is small and the period of rain dropping is too short, so it's hard to see the process of rain dropping. So, we assume that the drops move in the uniform linear motion, so $particle-pos.y(n)$ is the Y coordinate in the nth frame, and then the Y coordinates of $(n+1)^{th}$ frame is $particle-pos.y(n+1)=particle-pos.y(n)-dy$, among that, dy is the speed parameter of the rain drop[9].

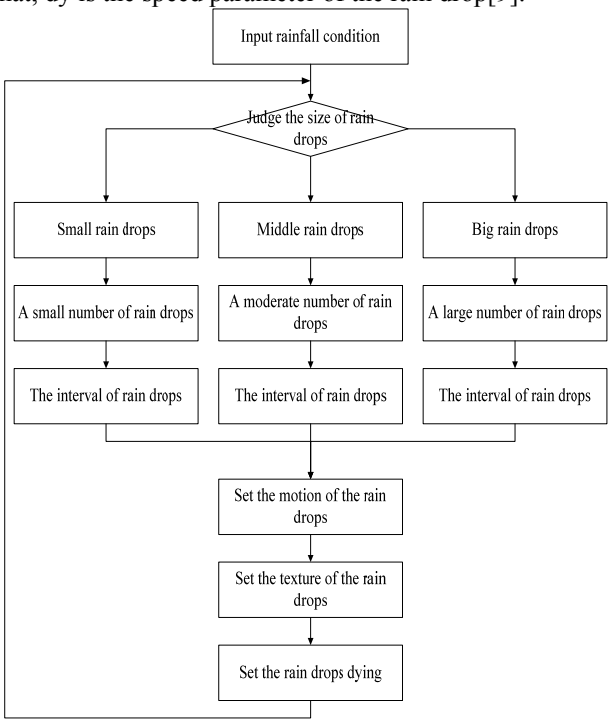

Figure10. The process of water droplets falling

First of all, set the area range of the rain drops to find out the number of drops, which is decided by the rain density. Secondly, set the data of the rain and the initialize the parameters, including the rain particles' initial speed, texture features[10]. The texture is shown as the first figure on the left of Fig. 11. The result of realizing the rain drops is shown in Fig. 12.

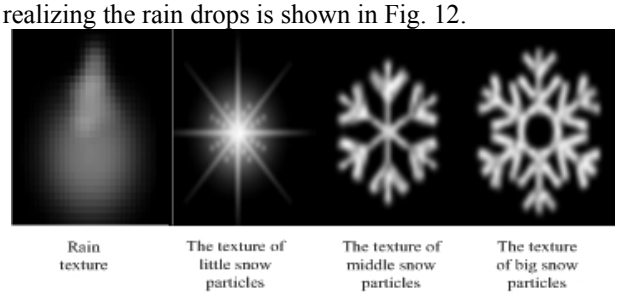

Figure11. Texture of rain drops and snow

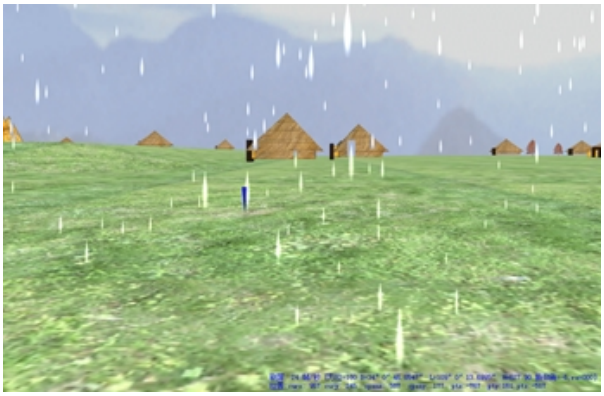

Figure12. The effect of rain drops

The motion equation of snow describes the moving process of the snow in the scene, but the snow falling is different from the water dropping. The flow chart is shown as Fig. 13, of which the snow falling can be realized by applying the sine curve. Assume the initial phase angle of a certain snow particle is $a(0)$, and assign the initial value is $a(0)=360.0*rand()$, the phase angle of each frame is $a(n)=a(n-1)+\triangle a$, among that, $\triangle a$ is the increment of the phase angle, then the coordinates of the snow particle in nth frame can be calculated [7]:

$$\begin{aligned} Particle\_pos.x(n) &= Particle\_pos.x(0)+K*\sin(a(n)) \\ Particle\_pos.z(n) &= Particle\_pos.z(0)+K*\cos(a(n)) \\ Particle\_pos.y(n) &= Particle\_pos.y(n-1)-dy \end{aligned} \quad (2)$$

The $Particle\_pos.x(0)$ and $Particle\_pos.z(0)$ here is the initialized distributed value, and K is the oscillation constant. Since the snow can only be found in the winter, the corresponding texture of rain drop in Fig. 14 should be transferred as the corresponding snow texture, and the certain terrain texture also needs to be switched.

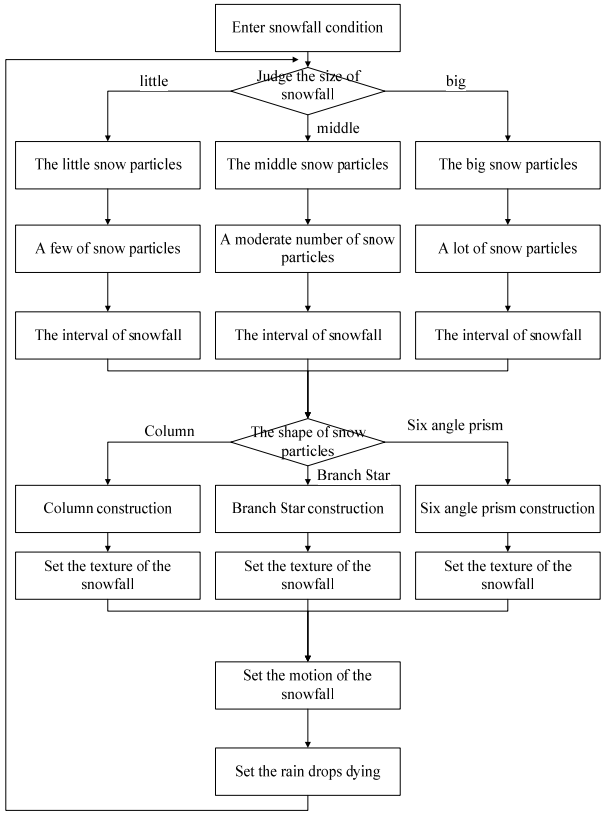

Figure13. The process of snow particles falling

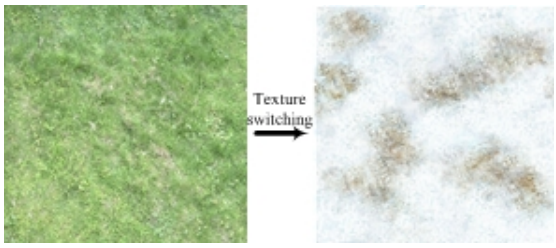

Figure14. Terrain texture switching from summer to winter

The process of rendering the snow fall first needs to determine the quantity of the snow, then the number and the size of the particle. Since the types of snow are various, multiple textures are needed in the system. Different from the rain drops, the snow falls in the curve motion, as the snow falling to the ground, it is different from people know in the real life. The flow chart is shown in Fig. 14. Based on this natural feature, three types of texture are applied in this system: large size snowflake, medium size snowflake and small size snowflake, shown as the three figures on the right of Fig. 7. The snowflake textures are applied according to the certain distance from the ground in the air and its particle rendering process is similar to the rain drops, the design sketch is shown in Fig. 15.

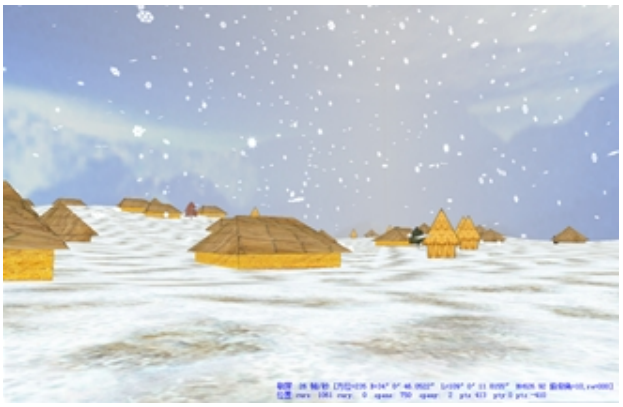

Figure15. The effect of snowfalls

IV. CONCLUSION

With the continuous development of graphics technology, the simulation of natural scenes has been received widespread attention and applied in many areas in recent years, such as After Effects, military simulation, landscape architectural design, virtual reality, flight simulation, and so on.

In this settlement sites reproducing system, the realization of the nature environment and the meteorological environment are achieved. The simulation of the nature scene is achieved according to the motion of the sun, realizing the sun entity and its radiation characteristics, brightness and space position change. Besides, we apply the corresponding technologies of particle system to realize the meteorological environment, the dynamic process of rain dropping and snow falling is reproduced. The nature environment and meteorological environment reproduction in the settlement site reproduction system can give the users a better visual feeling and enhance the reality and it has a significant effect to the study and realization of historic settlement sites.

The excavation report of Jiangzhai site contains a lot of legacy information, such as postholes, cellars, stones, bones and other relics. These relics have the characteristics of heavy workload and high difficulty, it will be the focus in the further work.

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