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An Overview of Texture Mapping Technology

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Abstract: With the continuous development of computer technology, people have higher and higher requirements for the realism of graphics. Texture mapping technology is an important way to enhance the realism of images. This article briefly explains the concept of texture mapping, and focuses on mipmap texture, bump texture mapping and multiple texture technology, and analyzes their actual applications.
Keywords: Texture mapping, mipmap, multiple textures.

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1. INTRODUCTION

Texture mapping technology is an effective technology to realize the realism of graphics. In modern production, texture mapping technology is used more and more widely, especially in the fields of computer production, animation design, three-dimensional games and advertising design. Sense is particularly important, which requires us to realistically display real-world graphics on the computer. Texture mapping [1-2] is a process of adding surface details to the surface of the object by mapping the existing texture image to the surface of the object. Using texture mapping technology can greatly improve the realism of the image.

There are many kinds of texture mapping techniques. This article will focus on mipmap texture, bump texture mapping and multi-texture technology.

2. MIPMAP TECHNOLOGY

2.1 Introduction of mipmap technology

The most common anti-aliasing texture method is called mipmap technology. "Mip" means Latin multum in parvo, meaning "a small place has many things". The term mipmap was coined by Lance Williams. The mipmap technology helps avoid unwanted jagged edges (called jagged maps) in this image.

Mipmap technology [3-4] is one of the most widely used texture mapping technologies. Willams takes the resolution of each side of the lower-level image as one-half of the resolution of each side of the higher-level image, and the texture group of the same level of resolution consists of red, green, and blue texture array. Since this lookup table contains the texture color values of the same texture area at different resolutions, it is called mipmap. In other words, the mipmap technology is combined with the texture mapping technology, according to the distance of the observer, a single texture map is expressed in the form of multiple images at different resolutions and represents the flat texture: the largest image is placed in the front significantly , and the relatively small image retreats to the back area.

The mipmap can be described as a four-sided pyramid, as shown in Figure 1.

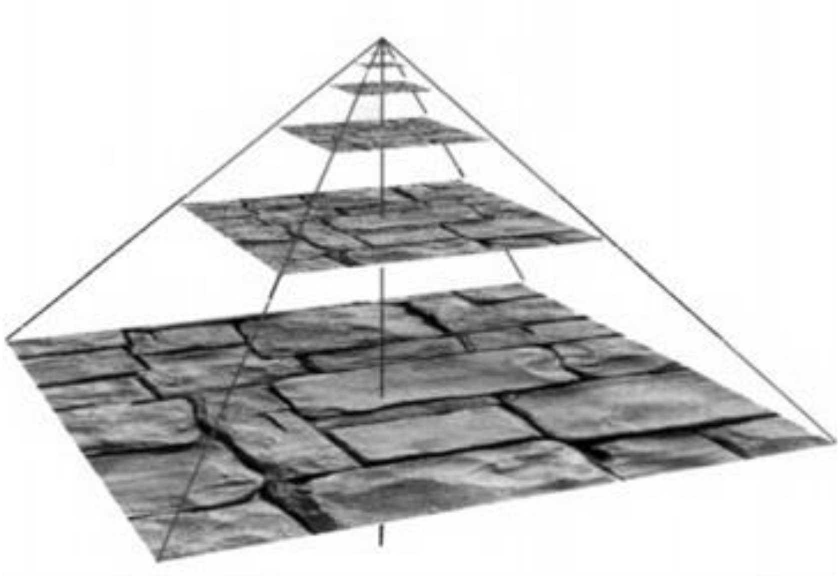

Fig. 1 Mipmap diagram

The total number of layers of the quadrangular pyramid is 7, and the bottom layer is the highest resolution texture image, which is a texture unit of 64*64. Starting from the second layer, it is 32*32,16*16, 8* 8,4*4,2*2 and 1*1 texture image units from bottom to top. That is to say, starting from the second layer, the size of the texture image is obtained by convolution of the image of the next layer and the square filter with a side length of 2 pixels. In other words, the nth layer image can be obtained by convolution of the n-1th layer image and a square filter with a side length of 2 pixels. In summary, for an image with an edge resolution of S, the total number of layers of texture is $[\log_2 S]+1$, for figure 1, its layers is $[\log_2 64]+1 = 7$, and the top layer is one pixel.

According to the scaling factor between the size of the texture image and the size of the mapped polygon (in pixels), we can select a mipmap layer as the texture of the specific polygon. The selection of mipmap layer is defined as follows, it is given by the following formula, λ is the number of layers to be selected is expressed as follows:

$$\lambda = \log_2 \rho + \mathrm{lod}_{\mathrm{bias}}$$

Among them, ρ is the scaling factor. Since the texture image is sometimes multidimensional, ρ must be the largest scaling factor in all dimensions. $\mathrm{lod}_{\mathrm{bias}}$ represents the offset detail layer, which is a constant value used to adjust the value of λ. By default, its value is set to 0.0.

If $\lambda \leq 0.0$, texture is smaller than polygon, so you need to use zoom filter. If $\lambda > 0.0$, use a reduction filter. If the selected reduction filter uses mipmap, then λ represents the number of mipmap layers.

For example, if the size of the texture image is a texture unit of 64*64, and the size of a polygon is 32*32 pixels, then $\rho = 2.0$, therefore $\lambda = 1.0$. If the size of the texture image is a texture unit of 64*32, and the size of the polygon is 8*16 pixels, then $\rho = 8.0$ (the scaling factor of x is 8.0, the scaling factor of y is 2.0, using the maximum value), so $\lambda = 3.0$.

2.2 Practical application of mipmap

In actual dynamic scenes, when a textured object quickly moves away from the observation point, the texture image must be reduced along with the projected image. But when the image is zooming out, it will produce uncomfortable flicker or jitter, and mipmap can play its effect better in this scene. Mipmap also has its advantages in occupying resources. Therefore, mipmap is more widely used in anti-aliasing processing in actual images.

But usually mipmap is used in conjunction with anti-aliasing techniques such as nearest point sampling and linear filtering. In OpenGL, there are also a large number of library functions for mipmap technology, and there are also mipmap applications in many high-end graphics software and 3D graphics cards.

3. BUMP TEXTURE MAPPING

Although texture mapping can be used to add smooth surface details, it is not suitable for simulating the surface of non-smooth objects, such as oranges and walnuts. The setting of the lighting details of the texture pattern is usually independent of the light direction in the scene. When drawing the surface of an object, the bump texture mapping [5] technology changes its shape by perturbing the surface normal vector. The color of the surface after the coloring process reflects the change of the geometric characteristics of the surface. It can express the effect of texture more realistically.

As a texture mapping technology, bump texture mapping can generate images with complex surface effects without increasing the geometric complexity of the object. Different from simple texture mapping, when the light source or the object moves, the bump texture mapping will show the change of the light and dark effect on the surface of the object, so that a smooth object surface will appear to change.

Blinn first proposed the method of disturbing the normal vector of each sampling point on the surface to obtain the realistic display effect of the uneven texture on the surface of the scene. The specific method is to add a perturbation function to the normal direction on the original surface. This function makes the smooth and slow change of the original normal direction sharp and short, and then calculates the surface of the scene through illumination to generate a rough display effect. Generally speaking, a good perturbation method should make the perturbed normal vector not depend on the position and orientation of the surface of the scene. No matter how the surface moves or observes the surface from any direction, the perturbed surface normal vector remains unchanged. Since the local coordinate system of the parametric surface is affine invariance, Blinn is perturbed based on the local coordinate system of each sampling point on the surface of the scene.

Suppose the original surface of the object is $Q(u,v)$, and $N(u,v)$ is its normal vector. Q_u and Q_v are the partial derivatives of Q to u and v respectively. The disturbance function $P(u,v)$ is continuous and differentiable. After the disturbance, the new surface $S(u,v)$ of the object is defined as follows:

$$
\begin{aligned}
S(u,v) &= Q(u,v) + P(u,v)\frac{N}{|N|} \\
&= Q(u,v) + P(u,v)n(u,v)
\end{aligned}
$$

In the formula, $n(u,v)=\frac{N}{|N|}$ is the unit normal vector of $Q(u,v)$. Taking the partial derivatives of the above formulas with respect to u and v respectively, the following two formulas are obtained:

$$S_u = Q_u + P_u n + P n_u$$
$$S_v = Q_v + P_v n + P n_v$$

In the formula, S_u、S_v、Q_u、Q_v、P_u、P_v、n_u、n_v represents the partial derivative vector and partial derivative of $S(u,v)$, $Q(u,v)$, $P(u,v)$, and n to u and v respectively. Since the disturbance function P is small, the third term on the right side of the above two formulas can be ignored, resulting in the following two formulas:

$$S_u = Q_u + P_u n$$
$$S_v = Q_v + P_v n$$

Let N_s be the normal vector of $S(u,v)$, which can be represented by the cross product of two partial derivative vectors S_u and S_v:

$$N_s = S_u \times S_v$$
$$\begin{aligned} N_s &= Q_u \times Q_v + P_u(n \times Q_v) + P_v(Q_u \times n) \\ &= Q_u \times Q_v + \frac{P_u(N \times Q_v)}{|N|} + \frac{P_v(Q_u \times N)}{|N|} \\ &= N + \frac{P_u(N \times Q_v)}{|N|} + \frac{P_v(Q_u \times N)}{|N|} \end{aligned}$$

The last two items in the above formula are the disturbance factor to the normal vector N of the original surface of the scene.

We can use several methods to specify the perturbation function $P(u,v)$. Under different perturbation functions, the texture effect will be different. For example, define an analytical expression, but if you use the look-up table method to obtain the bump value, the calculation can be reduced. According to the bump table, the value of P can be quickly obtained by linear interpolation and incremental methods, and then the approximate values of the partial derivatives P_u and P_v can be obtained from the finite difference. The bump table is built by random patterns, regular grid patterns or text shapes. For the simulation of irregular surfaces, such as raisins, the random pattern is very effective; for simulating the surface of oranges, the repeated pattern is more effective. In order to perform anti-aliasing, we can divide the pixel area and take the average value of the sub-pixel intensity.

Figure 2 is the effect drawing of the bump texture generated on a sphere with bump texture mapping. The left side is the original image, and the right side is the image after bump texture mapping.

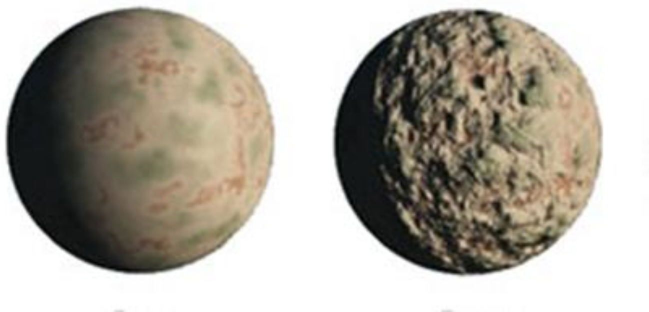

Fig. 2 Graph under bump texture mapping

Blinn's bump texture mapping method also has aliasing texture. Since the normal vector and the disturbance function are not linear, the anti-aliasing technique different from other texture mapping methods is needed.

4. MULTI TEXTURE MAPPING

Usually, we only paste a two-dimensional image onto the surface of a three-dimensional object, but sometimes in order to render a special effect, we need to paste two or more images on the surface of the object at the same time for mixing, which is called multi texture. Multi texture allows multiple textures to be applied, one by one to the same polygon in the texture manipulation pipeline. Multi texture consists of multiple texture units, each of which performs its own texture operation and transmits the processing results to the next texture unit until all the operations of texture units are completed. Figure 3 shows a sequence of multiple texture units through four texture images.

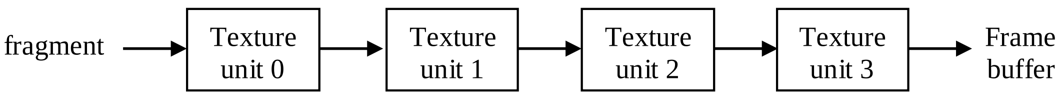

Fig. 3 Multi texture unit sequence

Before the emergence of multi texture mapping technology, if we want to paste two images onto the surface of an object, we need to go through two processes. The first process is to paste the first image onto the surface of the object and render the object; the second process is to map the generated image with the second image, and then render the object by texture blending (also known as alpha blending). Obviously, such a rendering method is wasteful and inefficient, and cannot meet the requirements of high-performance graphics rendering in terms of speed.

When using multi texture technology, if three images are to be pasted on an object, the first two images are modulated according to the modulation factor, and then the result and the modulation factor of the third image are modulated. Finally, the object is rendered after the image of the last image is modulated. In the multi texture mapping process, the object can be rendered only once, which saves about half of the time compared with the previous multiple rendering methods.

The steps to use multi texture are as follows:

(1) For each texture unit (as shown in Figure 3), the related texture states are established, including texture image, filtering method, texture environment, texture coordinate generation and texture matrix.

(2) When you assign vertices, you can assign multiple texture coordinates to each vertex, which are used for different texture units, and each texture coordinate is used for the processing of each texture unit. The automatic generation of texture coordinates and the assignment of texture array in vertex array are special cases.

Multi texture can achieve some advanced rendering techniques, such as lighting effects, decaling, compositing and detail textures.

5. CONCLUSION

This paper gives the basic concepts of texture and texture mapping, and focuses on the mipmap technology, bump texture mapping and multi texture mapping technology, and analyzes their scope of application. In the follow-up work and learning, I will continue to study the related algorithms of texture mapping, in order to get a better image realism.

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