グラフィクスとＣＡＤ　93－5
（１９９８．１２．１０）

背景と表面毛モデルによる効率的なヘアモデル

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ヘアレンダリングとヘアモデリングに関する研究は多く行なわれている。しかし頭髪の本数が多いためメモリとCPUに対する要求は厳しい現実である。メモリの縮小とレンダリングとモデリングの所要時間を減らすために本論文は背景毛と表面毛を提案する。万単位という従来の細い毛の代わりに背景毛と表面毛を使ってメモリの縮小と時間の短縮が実現できる。背景毛は太い毛で構成できる。ヘアモデルの外観を向上するには表面に位置する背景毛を細かく分割しレンダリングする。表面毛の検出はvisible volume bufferによって行なわれる。背景毛と表面毛のレンダリング時間は従来のヘアモデルより2倍以上高速であることがわかる。

Background and Surface Hair Model for Efficient Hair Expression

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Many researches have been conducted in hair modeling and hair rendering with considerable success. However, the immense number of hair strands present means that memory and CPU time requirements are very severe. To reduce the memory and the time needed for hair modeling and rendering, a background and surface hair algorithm is proposed. Instead of using thousands of thin hairs, the memory usage and hair modeling time can be reduced by using background and surface hairs. The background hairs can be constructed by using thick hairs. To improve the look of the hair model, the background hairs near the surface is broken down into numerous thin hairs and rendered. A visible volume buffer is used to determine the surface hairs. The rendering time of the background and surface hairs is found to be faster than conventional hair model by a factor of more than two.

1 Introduction

Many researches have been conducted in hair modeling and hair rendering with considerable success. However, the immense number of hair strands present means that memory and CPU time requirements are very severe. Many efforts have been made in the past to provide realistic and effective modeling and rendering of human hair. They are broadly divided into 2 major categories: geometry-based or texture-based. Tohjo et al.[1] presented a hair model based on anisotropic reflection and bump mapping technique. This is an efficient algorithm making use of 2d texture map to simulate hair. Kajiya [7] extends this idea by using a 3d texture to create a realistic looking teddy bear using many hours of computer time. The texture based approach to hair rendering suffers a disadvantage as it is difficult to animate hair using texture. Other researchers approached this problem through the modeling and rendering of thousands of strands of hair each with its own color and geometry. Watanabe and Suenaga [2] used trigonal prism and wisp model to render hair to a certain degree of success. However, the trigonal prism looks stiff and needs to be refined for better representation of human hair. Nakajima and Agui et al. [3] generated hair image using thread model and area anti-aliasing. Their algorithm divides the hair strand into a number of fragments , which are easily stored and rendered. The hair model is improved by area-antialiasing which depends on the area occupied by the hair fragments. As every individual hair strand needs to be stored and generated separately, the performance of this model is seriously affected. Nakajima et al.[4] improved upon this thread model by introducing fractional hair model. In this improved algorithm, the generated hair strand is rotated, translated to produce addition fractional hairs with the same properties as the original hair strand. This group of hair strands is then lumped together and controlled as a single element. It can be seen that control of the hair is traded for processing speed in this method. LeBlanc, Turner and Thalmann [5] proposed a pixel blending solution to the antialiasing problem in hair rendering while Anjo, Usami and Kurihara [6] proposed a hair modeling algorithm using the cantilever beam stimulation. .

The geometry approached to hair modeling and rendering gives realistic result with thousands of geometric hairs requiring immense memory and computer time. A efficient hair model must be able to cut down the memory requirement and at the same time reduce the modeling and rendering time. To reduce the memory and the time needed for hair modeling and rendering, a background and surface hair algorithm is proposed. From everyday observation of real human hair models, it can be observed that human hair model can be considered as a combination of coarse background hair image and detailed surface hairs. Therefore, instead of using thousands of thin hairs, the memory usage and hair modeling and rendering time can be reduced by using coarse background hairs. To improve the look of the background hair model, the hairs near the surface is broken down into numerous thin hairs and rendered. A visible volume buffer is used to determine the surface hairs. The rendering time of the background and surface hairs is found to be faster than conventional hair model with very little lost in image quality.

2 Background Hair

The major requirements of background hair are that it must use less memory, fast in modeling and rendering time and yet provide a rough but accurate image of the hair model. The background hair can be constructed with geometric or non-geometric model as long as they satisfy the requirements of the background hair. A good representation of the background hair can be achieved through the use of thick hair. A thick hair approach can reduce the amount of memory needed as we can cut down the amount of hair strands tremendously. Due to the reduce number of hair strands, hair modeling and hair rendering are also much faster. In applications where the detail of the hair model is not important such as when the virtual character is far away from the view point, the thick background hair model alone can be used for fast hair modeling and rendering while consuming less memory than the thin hair model. Figure 1 shows an example of a hair model generated by the thick hair model.

Eventhough the thick background hair is more efficient than thin hair, when at close quarters, the thick background hair do not give as good appearance as the thin hair. To solve this problem, the thick background hairs at the surface are broken down into a number of thin hairs and render. Thus, the background and surface hair model consists of a surface layer of thin hairs together with a background layer of thick hairs.

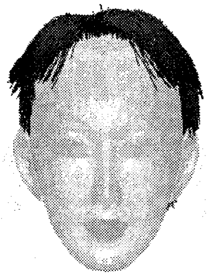


Figure 1: Thick Hair Model

Figure 2: One strand of thick hair

Figure 3: Breaking into thin hairs

3 Surface Hair

When view in close range, the thick background hair model will not be sufficient to represent realistic hairs as the human hairs are in reality very thin in nature. To improve the thick backgorund hair to portray more realism while keeping its advantage of less memory requirement and faster modeling and rendering, a visible hair volume is used to determine the hairs that are nearest to the view point. We shall call these hairs that are closest to the view point surface hairs as compared to the rest of the hairs as background hairs. After finding the surface hairs, the surface hairs are broken down into a fixed number of thin hairs. The transformation of thick hairs into thin hairs is done by first reducing the radius of the hair strand to create a single strand of thin hair. The thin hair created is then translated and rotated by a random figure predetermined. Figure 2 shows a strand of thick hair while Figure 3 shows the thin hairs generated. The thick hair is transform into thin hairs just before the rendering process so that memory is not needed to store the thin hairs generated. Therefore, memory usage is kept to a minimum as the thin hairs generated are rendered without storing them in memory.

4 Visible Volume Algorithm

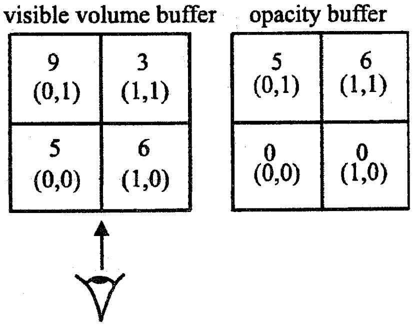
The visible volume concept utilizes the theory that hairs that are not block by any other hairs or objects are most visible and are given the opacity value of zero. The opacity values of hair that are further away from the view point have larger opacity values as their visibility are blocked by the hairs at the surface.

4.1 Classification of Hair in Visible Space

To determine which of the hair strands is at the surface, all the hair strands are classified based on their position in the real space. A visible volume buffer is created to represent the real space where the hair exists. The visible space can de divided into a number of subspace or cells of fixed size. The x,y,z coordinates of the hair fragment are used to determine which of the visible volume cell contains the hair fragment. This is carried out for all the hair fragments present and the volume of hair present in the visible volume cells are calculated and stored.

4.2 Opacity Buffer

A opacity buffer is created to determine which of the visible volume cells is visible to the view point. Consider a 2 dimensional visible volume buffer as shown in Figure 4. For the cell (0,0) , 5 units of hair are found to be situated in this cell. From the view point as shown in Figure 4, the opacity buffer(0,0) is given the value of 0 as no object blocks the view point from this cell. For the cell(0,1), the opacity value is 5 as the cell(0,0) lies in the way to the view



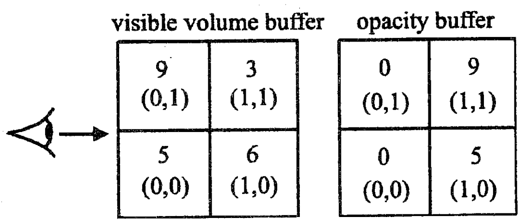
visible volume buffer

9 (0,1)	3 (1,1)
5 (0,0)	6 (1,0)

opacity buffer

5 (0,1)	6 (1,1)
0 (0,0)	0 (1,0)

Figure 4: Formation of opacity buffer



visible volume buffer

9 (0,1)	3 (1,1)
5 (0,0)	6 (1,0)

opacity buffer

0 (0,1)	9 (1,1)
0 (0,0)	5 (1,0)

Figure 5: Opacity buffer after change in view point

point. When the view point is shifted, the opacity buffer is changed and need to be recalculated as shown in Figure 5. If the opacity value is zero, it means that the hairs present in this visible volume cell is at the surface and need to be broken down into thin hairs before rendering.

5 Hair Rendering

Hair rendering has been widely researched in the past with considerable success. To enhance realism , advance rendering techniques [5][7][8] can be employed at the expense of processing time and memory. As this research focuses on efficient rendering, basic rendering techniques of z buffer and kajiya shading are used to yield reasonable results in acceptable time.

6 Modeling and Rendering Results

The images of the hair model generated by the background and surface hair model are shown in Figure 6 and Figure 7. Figure 6 shows the front view of the hair model. The hair model consists of 3477 strands of hair and 365 strands of hair are found to be visible when view from the front. Each visible thick hair of radius of 2.0 units is broken down into 10 thin hairs with radius of 1.0 unit. 18 seconds are needed to render the thin hairs while 9 seconds are needed to render the thick hairs on a onyx workstation with R4400 CPU and 500 megabytes of memory. Figure 7 shows the hair model when viewed at an angle. 705 strands of hair are found to be visible resulting in a rendering time of 33 seconds for thick hairs and 7 seconds for thin hairs. The time taken for classification of all the hair strands in the visible buffer is less than 1 second which is small when compared to the total rendering time. Memory requirement for the background and surface hair algorithm is efficient as we need only to store 3477 strands of hair for the hair model found in Figure 6 and Figure 7. We only need to render 6762 strands of hair for Figure 6 and 9822 strands of hair for Figure 7. To compare our result with a thin hair model, consider that breaking every single thick hair into 10 thin strands in Figure 6 will result in a thin hair model of 34770 strands of hair. By ignoring the different in rendering time for thin and thick hair, the improvement in rendering time for Figure 6 will be 514 percents over the thin hair model while Figure 7 will record an 354 percents improvement. Modeling time is also reduced as the number of hair modeled is reduced tremendously.

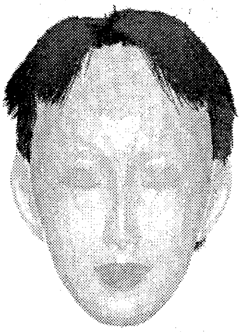


Figure 6: Thick hair model 1

7 Hair Animation

The results of applying the background and surface model to hair animation is shown in Fig. 8. Hair animation is achieved by attaching hinges to the hair fragments . In this hinge model, a hair strand is defined as one complete strand of hair

Figure 7: Thick hair model 2

Table 1: Rendering time for images in Fig. 8

	Number of thin hairs	Number of thick hairs	Time for thin hairs	Time for thick hairs
Fig. 6	365	3112	18s	9s
Fig. 7	705	2772	33s	7s
Fig. 8a	306	2137	82s	81s
Fig. 8b	335	2108	87s	79s
Fig. 8c	359	2084	92s	84s
Fig. 8d	443	2000	115s	74s
Fig. 8e	475	1968	122s	77s
Fig. 8f	476	1967	121s	72s

which is made up of 15 segments. A hair strand is modeled as a series of interconnected masses and hinges. The bending of the hinge under the influence of gravity and outside forces is determined from equation (1).

$$T_{hinge} = k_{hinge} * Q \qquad (1)$$

where T_{hinge} is the hinge torque magnitude, Q is the angular displacement of the hinge, k_{hinge} is a hinge constant.

The number of thick and thin hairs used to render Fig.8 and the rendering time is given in Table 1.

8 Conclusion

An efficient model for hair is needed if it is to find application in multimedia, virtual reality and in entertainment. Polygonal hair may be useful for fast rendering but the quality of the hair generated leaves much room for improvement. To create realistic hair, geometry is needed but the sheer numbers of hair present is the main obstacle blocking its application. The large number of hairs represent large memory requirement and long time needed for hair modeling and rendering. To alleviate these problems, the surface and background hair algorithm is proposed that not only satisfies all the requirements but also generate realistic looking images. This algorithm can also be applied in hair animation to cut down the time requirement to animate thousands of hair.

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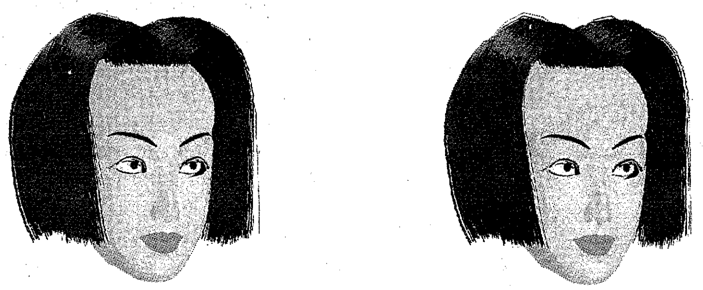

(a) Time = 0.0 unit

(b) Time = 5.0 unit

(c) Time = 10.0 unit

(d) Time = 15.0 unit

(c) Time = 20.0 unit

(d) Time = 25.0 unit

Figure 8: Animation sequence