

# Styling by painting and real time animation of hair using basis-dependent hair strands

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## ABSTRACT

Techniques to simulate hair in virtual humans focus on hair modeling, hair animation and hair rendering. We propose a system for modeling and animating in real time using standard OpenGL on commodity graphic cards. For styling, we propose a paint tool to determine a set of gray scale images that allow us to establish hair density and hair length values, as well as other useful parameters, and for animation, we use a simplified physically based method that computes physics only on some hairs, which we call basis hairs, calculating other dependent hairs from them.

### Keywords

Hair styling, physical based animation, real time, paint hair

## 1. INTRODUCTION

Techniques to simulate hair in virtual humans focus on hair modeling, hair animation and hair rendering [Mag02]. Some techniques use alpha-mapped textured surfaces [Koo02] to simplify the model, making it independent of the number of hairs. Results are suitable for real time applications but produce a flat hair model. The texture map is not suitable if we get a dynamic source of light.

In [Da193] a method is proposed for modeling hair where the user defines interactively some characteristics such as density, distribution and orientation then the hairstyle is completed based in this characteristics.

Other approaches exploit hair's tendency to form clusters due to static electricity, so the hair modeling is done using clusters or wisps [Kim00][Pla01][Che01]. Animation is computed on these clusters or wisps, defined by a skeleton curve. These skeleton curves are

then rendered using more curves to complete the hair model. The results obtained are visually good but in some cases [Pla01] the rendering process is too slow for real time applications.

Another approach [Kim02], although it also exploits hair's tendency to form clusters, consists in modeling hair in a hierarchical way so first we get a general hairstyle and then we can make changes locally. This approach has been tried for animation [Ber03]. It is not real time animation since the maximum time to compute 10 seconds-long animation was about 5 minutes.

Also we have the alternative of modeling hair strand by strand [Anj92][Tha96][Kur93][Cha02]. In these approaches hair is modeled and animated using chains of connected particles and the animation is usually physically based. However, due to the huge number of hairs the rendering process is left as an afterthought. In some methods [Cha02], the animation process is simplified to calculate hair to hair intersections. Another method is introduced by Hadap et al [Had01], where the hairstyle is modeled as streamlines of a fluid flow so using the continuum property of a fluid hair to hair interactions can be represented. Bando et al [Ban03] use sets of particles that serve as sampling points for the volume of the hair and are scattered along the hair model.

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For hair rendering, the Kajiya and Kay model [Kay89] is normally used to simulate light scattering from hair. Marschner et al [Mar03] extends this model by adding new measurements like transmission and internal reflection.

We propose a system for styling and animating hair. For styling, we use a paint tool to determine a set of gray scale images that allow us to establish hair density and hair length values, as well as other useful parameters. For animation, we use a simplified physically based method that computes physics only on some hairs, which we call basis hairs, calculating other dependent hairs from them.

## 2. HAIR MODELING

### 2.1 Hair Structure

Although the use of NURBS would allow us to achieve smooth lines their processing time is larger than for polylines [Van97]. In addition we can always get a smoother a polyline using interpolation between its nodes if so desired. For simplicity we choose to use polylines to represent hair strands.

### 2.2 Paint-Styling Tool

The process of styling hair can be very awkward and tedious due to a huge number of strands that compose the hair [Dal93]. There are two characteristics that must be incorporated in a hair styling tool: interactivity and ease of use. Interactivity allows users to see and control their artwork in real time and modify it if something goes wrong. Ease of use allows users to design hairstyles in a fast way and reduces the tediousness of hair styling.

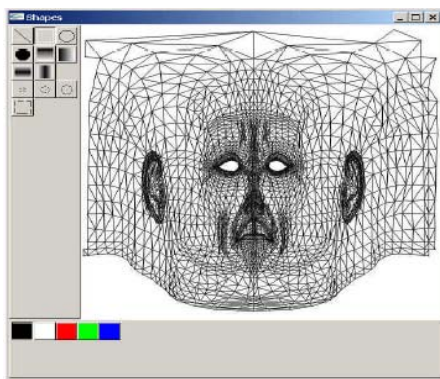


Figure 1. Our paint-styling tool

Based on those characteristics we propose that for styling hair we allow users to specify hair properties

by painting on scale gray images. When users are creating these images, they can see in other window the 3D hair style specified by the image they are painting. To establish this relationship, on the painting area we display a 2D representation of the 3D model (Figure 1) i.e. the model's texture map, to aid the user on determining where to paint.

In general, hair properties are determined by a function that allows us modify the density of the hair and its length, as well as other hair properties if so desired, based on the gray level, so for darker values we have minimum values and for brighter colors we have maximum values (Figure 2).

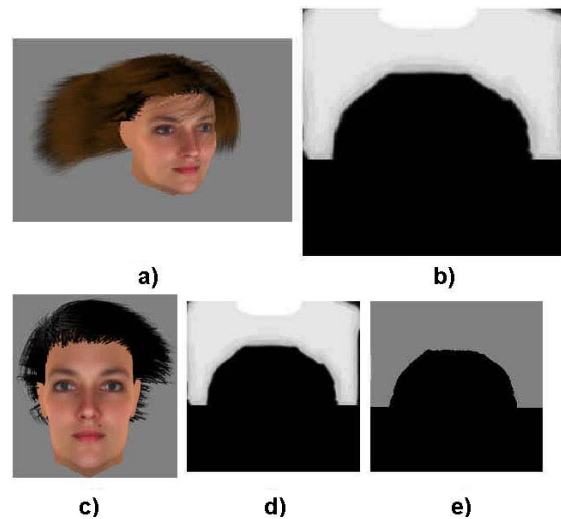


Figure 2. a) Long hairstyle, b) Density image and length image are the same in this case. c) Short hairstyle, d) Density image, e) Length image

Finally, our styling tool is also applicable for other hair-like objects such prairies and Hawaiian skirts (Figure 3).

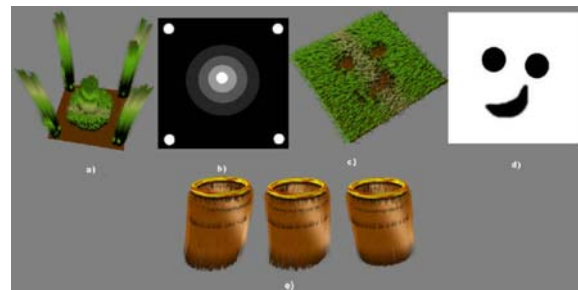


Figure 3. a) A prairie, b) Density image and length image are the same in this case c) A prairie face, d) Density image and length image are the same in this case e) Hawaiian skirts

### 3. ANIMATION

For animation we use a standard damped particle-spring model, where springs are drawn as polylines. We connect these particles to each other by springs and dampers.

The physical model reacts to the force of gravity and wind forces. To solve the resultant equations of motion we use either Euler or Verlet methods because they are easy to implement and although the first method tends to be unstable we reduce this effect by damping and by selecting a relatively small step size. Verlet is more stable, so a larger step size can be used.

Avoiding penetration of hair is done using an ellipsoid to approximate the head model and spheres with zero radius, i.e. points for each hair strand node.

#### 3.2 Optimization by use of basis and dependent hair strands

To avoid processing the equations of movement for all the hair strands, we took some ideas from the approaches where hair is modeled using wisps. There the animation is calculated in clusters. We propose a modified method that allows us to reduce the calculation of equations of movement, while avoiding the “sticky” look that one gets from using wisps when it is deemed desirable (Algorithm 1).

- Seed hairs on the 3D model's scalp (or wherever hair is desired)
- For each face of the 3D model, pick randomly some hair strands as basis hairs and associate the closest non basis hairs as dependent hairs
- While animating hair
  - For each basis hair strand
    - Calculate equations of movement and keep the results ( $r_{old}$ ,  $r_{new}$ )
    - Calculate  $\Delta M = |r_{new} - r_{old}|$
    - For each associated non basis hair strand change the position of all its nodes by  $Position(x, y, z) + \Delta M$

**Algorithm 1. Basis-Dependent Hairs Strands**

This method makes animation much faster (Table 1)

It is important to note that we can obtain clumpy hair (Figure 4) if so desired by using  $Position(x, y, z) + \Delta M - clumpiness$  instead of  $Position(x, y, z) + \Delta M$  where Clumpiness can vary from 0 (clean hair) all the way to the distance from the basis hair to the associated hair, where we obtain maximum clumpiness.

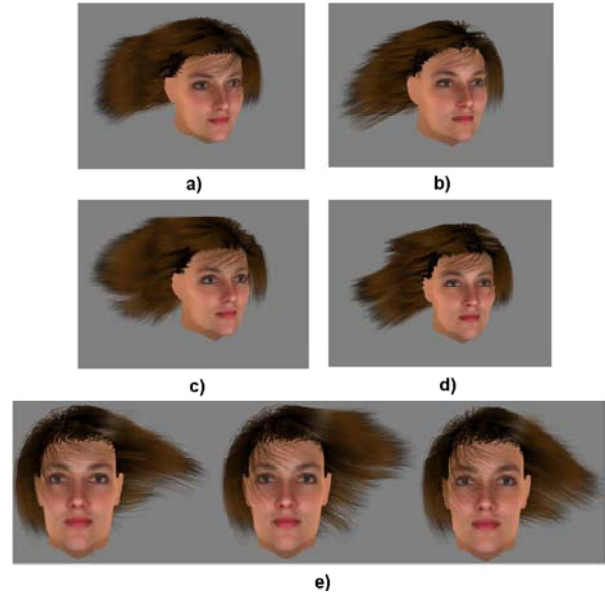
Total Hairs	Basis Hairs	Non Basis Hairs	fps
5000	5000	0	20
5000	2500	2500	30
5000	500	4500	60
14000	14000	0	8
14000	7000	7000	10
14000	1000	13000	20

**Table 1. Interpolation Performance<sup>1</sup>**



**Figure 4. Clumpy (left) and clean (right) hair**

From pictures, we can see that there are almost no visual differences between the pictures that have the same total number of hair strands (Figure 5 a, b, c, d), this results shows that the algorithm used to process fewer equations is adequate to achieve visually good results at an interactive frame rate (Figure 5e).



**Figure 5. a) 5000 Basis Hairs, 0 Non Basis Hairs at 20 fps, b) 500 Basis Hairs, 4500 Non Basis Hairs at 60 fps, c) 14000 Basis Hairs, 0 Non Basis Hairs at 8 fps, d) 1000 Basis Hairs, 13000 Non Basis Hairs at 20 fps e) An animation sequence from left to right**

<sup>1</sup>System Specifications: Petium 4 Mobile, 1.7 GHz, 256 MB RAM, GeForce 4 440 Go 32 MB, Windows XP

## 5. CONCLUSIONS

We have presented a system for human hair styling and animation adequate for real time. From results shown in table 1 it is noticeable that performance is optimum even using a typical laptop PC. Our physically based animation optimization using basis and dependent hair strands allows realistic movement of hair and improves the system performance without sacrificing visual results. Clumpiness can be incorporated easily, with no effect on performance.

Thanks to our paint interface, our styling tool allows users to design interactively, intuitive and in a fast manner a variety of hairstyles.

## 6. FUTURE WORK

To improve the “volume” and general aspect of hair we must efficiently implement hair to hair shadows.

We are working to expand the capabilities of our paint program to design more complex hairstyles, controlling the direction of hair growth to represent different degrees of hair curliness and defining other hair characteristics such as stiffness.

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