Hair Modeling and Animation

1. Research Team

Project Leader: Prof. Ulrich Neumann, *IMSC and Computer Science*

Other Faculty: Prof. Marie-Paule Cani, *INPG/IMAGIS*

Post Doc(s): Reyes Enciso, John P. Lewis

Graduate Students: Tae-Yong Kim, Florence Bertalis

2. Statement of Project Goals

The goal of this project is to add realistic, styled hair to computer representations of humans. Although computer face modeling dates from the 1970s, three dimensional head models have lacked realistic hair. In the 1990s algorithms for short hair or animal fur were introduced, but long or stylized hair remained out of reach.

While hairstyle is not an important consideration in most human interactions, unrealistic or missing hair on a virtual character may be distracting and destroy the intended illusion. The Hair Modeling project allows virtual humans or avatars to have a complex and realistic hair styles such as pony tails or braids if desired (Figure 1).

3. Project Role in Support of IMSC Strategic Plan

Hair Modeling is one of several IMSC projects that are intended to allow expressive human representations in virtual spaces. Both Hair Modeling and the Facial Expression Processing project focus on problems that need to be addressed in order to allow natural interaction with virtual characters, but for which few established technologies exist.

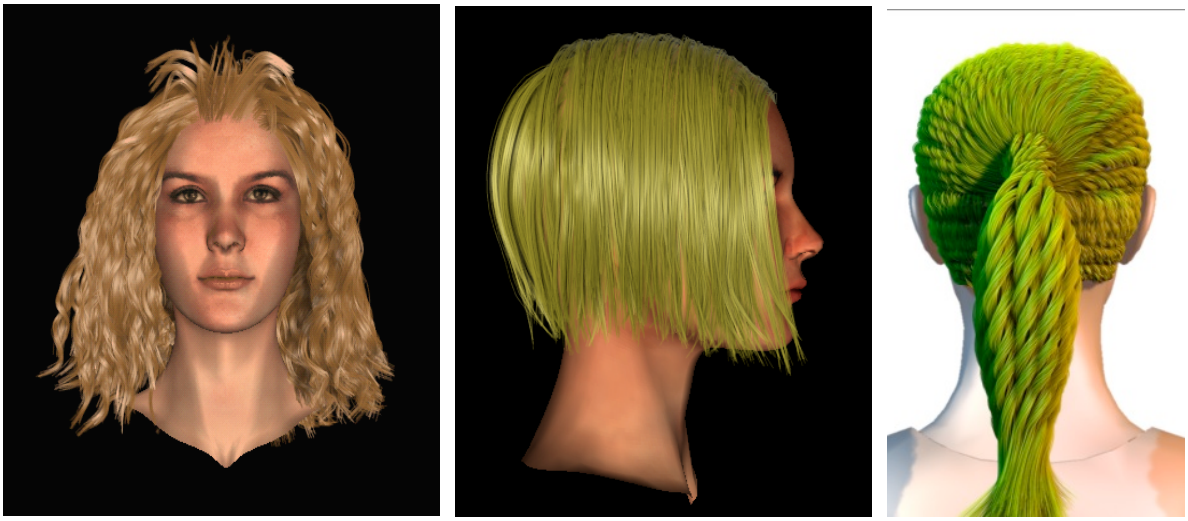

Figure 1 - Examples of realistic and creative hair styles created with our system

4. Discussion of Methodology Used

Although specifying and rendering a single hair, or a few hairs, is in the domain of existing computer graphics techniques, the central problem in both modeling and rendering hair is the sheer number of individual hairs that are needed to create the impression of realism. In the modeling arena, specification of the location of every hair individually is impractical. In rendering, this is reflected in performance issues, particularly when it is required that hairs cast shadows on other hair.

We have addressed the issue of specifying the positions of large numbers of individual hairs with the *Thin Shell Volume* [1], a higher level modeling controller that allows placement and sculpting at the level of a strand of hairs. A virtual analogue of combing is used to position the individual hairs within the strand. To provide further control, the thin shell volume can be applied hierarchically. Individual hairs are grouped into strands; these strands can be shaped into larger structures such as braids. In the multi-resolution system hair can be manipulated at any level of detail from an individual hair to a large area containing hundreds of thousands of hairs shaped into various structures.

The Hair Modeling and Animation project addresses the rendering issue with *Opacity Shadow Maps* [2], a fast technique for producing aggregate self-shadowing in hairs. Opacity Shadow Maps are somewhat similar to the Deep Shadow Map technique, but adopt a different rendering order to dramatically reduce memory requirements. Specifically, parts of the scene that include hair are rendered in slices with progressively greater distance from the light source. A two-dimensional opacity map is updated as each slice is rendered; this map contains the accumulated density of hair material from the current location of the slice to the light (two such opacity maps can be used to allow bilinear interpolation of the hair density).

5. Short Description of Achievements in Previous Years

Our achievements in previous years consist of the modeling system based on the Thin Shell Volume controller and its multi-resolution version, and a rendering subsystem using the Opacity Shadow Map technique. Opacity Shadow Maps are well suited to hardware acceleration, and our OpenGL implementation is capable of rendering a complete self-shadowed head of hair in several seconds.

5a. Detail of Accomplishments During the Past Year

During the past year dynamic control and animation of hair has been investigated, resulting in the *Adaptive Wisp Tree* [4]. This algorithm adaptively recomputes a multi-resolution volume representation for moving hair as it clusters and separates due to physical dynamics. This approach is required to obtain the correct appearance of long hair on a moving head, but it also leads to computational savings since the representation simplifies hair-to-hair collision computations.

6. Other Relevant Work Being Conducted and How this Project is Different

For many years hair was considered one of the most difficult problems in computer graphics. Successful methods for producing animal fur and short hair have now been demonstrated, but long hair remains a difficult problem, and the difficulties show up in both modeling and rendering rather than being confined to a single arena.

The rendering and modeling of hair has been addressed by other research groups, and bi-level modeling approaches in which a "wisp" or cluster of hair can be sculpted as a single entity have been proposed by several groups. Our current contributions are three-fold:

1) The extension of bi-level modeling to a full multi-resolution approach
2) Modeling and rendering are addressed within a single system. This is significant: without a unified attack on the problem, the limitations of a conventional rendering system can cripple a custom hair modeling approach, or vice versa.
3) Animation of hair as it dynamically clusters and separates, without significant perceived interpenetration.

The success of our unified approach can be seen from the figures.

7. Plan for the Next Year

The Hair Modeling project is completed and the key PhD student has graduated and been hired by a company that does special effects for films. As new students arrive, their interest in continuing or extending this work will be gauged.

8. Expected Milestones and Deliverables

The current deliverables consist of the Hair Modeling system itself (50,000 lines of C++ code, using OpenGL on the Windows platform) and three detailed descriptions of the components of the system [1.2.3].

9. Member Company Benefits

Representations of humans in virtual spaces (avatars) often appear primitive and unnatural, and interaction with such avatars is not yet appealing. Primitive and unrealistic hair representations contribute to this problem. The Hair Modeling project provides member companies with the first comprehensive solution for three-dimensional virtual human hair.

10. References

[1] T. Kim and U. Neumann, A Thin shell volume for modeling human hair, *IEEE Computer Animation*, pp.121-128, 2000.
[2] T. Kim and U. Neumann, Opacity Shadow Maps, *Eurographics Workshop on Rendering*, pp. 177-182, 2001.

[3] T.Y. Kim and U. Neumann, "Interactive Multiresolution Hair Modeling and Editing," *ACM Transactions on Graphics* and *Computer Graphics*, proceedings of *ACM SIGGRAPH 2002*, Vol 21, No. 3, pp. 620-629, San Antonio TX, July 2002.
[4] F. Bertails, T.Y. Kim, M-P. Cani, and U. Neumann, Adaptive Wisp Tree – a multiresolution control structure for simulating dynamic clustering in hair motion. IMSC internal report (submitted for publication).