Generating Realistic Human Hair for “The Matrix Reloaded”

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Introduction

In recent years, there have been a few successful applications of realistic computer generated hair in the entertainment industry. For *The Matrix Reloaded* we had to face new challenges. First, we had to handle both close ups and scenes with hundreds of human characters with hair. The task was further complicated by the fact that the CG hair needed to exactly match the styling of familiar heroes from the film: Agent Smith and Neo. Also because of the rendering methods we chose for our virtual actors the hair solution needed to work in a ray tracing context with many lights. Our in-house hair styling tool together with some key rendering techniques made it all possible.

Styling Hair

During the early stages of hair R&D for *The Matrix Reloaded* we tried to use Maya Fur as our hair styling tool. Eventually we decided against it, as it did not provide us with enough freedom to match the detailed hairstyles of the principal actors. Alternatively, we developed an in-house hair styling tool called Gossamer.

Gossamer is a set of plugins and scripts for Alias|Wavefront Maya. It has all the parameters of Maya Fur, but also provides functionality that allows the user to directly move control points on "guide" hairs which are then used to generate many interpolated hairs. The interpolated hair is rendered in real-time using OpenGL in Maya (see Fig. 1). This allows artists to see the hairstyle as it would appear in the final rendered image while they are working. Gossamer also provides the ability to clump areas of hair for further hairstyle control. (We would like to acknowledge Eric Soulvie for his early development work on the Gossamer tool.)

Rendering Hair

Hair objects are generated procedurally during rendering time from a hairstyle description generated by Gossamer. In the beginning, each hair was generated as a very thin NURBS patch because originally mental ray, our renderer of choice, did not support curve rendering. This approach worked well only up to a certain level of complexity. We collaborated with mental images to implement a new fast and memory efficient "hair" primitive in the renderer.

A couple of more techniques are used to reduce the memory usage. One is to subdivide a hair object into partitions. Each partition is treated as a separate object with its own bounding box. If a partition is in the back of character's head and its bounding box is completely occluded by the head object, hairs in that partition will never get generated. The other one is using mental ray's geometry shader object instancing feature. It was very effective especially when rendering many Agent Smiths. Rendering hair for ten Smiths was virtually the same as rendering hair for one Smith.

Hair Shadow and Lighting Reconstruction

With either of two commonly used shadowing methods, shadow maps and ray traced shadows, it is difficult to produce nice, soft hair shadows. One proven solution to this problem is the deep shadow map, but our real world Lighting Reconstruction setups consisted of many light sources. Generating and maintaining a deep shadow map for each light would have been a pipeline nightmare. Instead, we use a volumetric approach which we call a shadow tree.

The shadow tree is an octree representation of the hair's density which is constructed during the initialization stage of the render. During rendering, the shadow tree is only visible to shadow rays. When a shadow ray intersects the shadow tree's bounding volume, it reads the density value of each intersected voxel and uses these values to attenuate the light accordingly.

Results

Below we show the results of our techniques. Fig. 2 and 3 show full CG renderings for Agent Smith and Neo. Fig. 4 is a photograph, which demonstrates how close we can match the real hairstyle and look. The image on the bottom is a frame from the film. All hair but the one in the middle is computer generated for this 3-d head replacement shot.