Simulating Clothing and Hair for the Characters in Monsters, Inc. as presented by Mark Henne

Christopher E. Davis - chris2d@cs.unm.edu
University of New Mexico
Computer Science Colloquia Spring 2003

April 4, 2003

The convincing simulation of hair for computer graphics is a very difficult task. The computational time required to simulate a single head of hair is amazing, and for Monsters Inc. there were several characters who exhibited entire bodies covered with hair. For example James P. Sullivan (Sulley) has over 3 million hairs on his body.[1] As such it is obvious that the animators and programmers must find an alternate solution to simulation of every hair, but keep the simulation convincing. Likewise, cloth is a difficult simulation to perform, yet there were many places in Monsters Inc where cloth was used. This paper will be a very brief discussion of the approach used in Monsters Inc. with a discussion about how current research is moving these techniques from non-real time rendering to real-time interactive computer graphics.

When the animators and programmers started the project to simulate cloth and hair they had to decide to make some compromises. Among these compromises was the use of key hairs and low tessellation of cloth surfaces. The programmers and animators had the difficult task of collaborating to produce a cartoon styled physics system. This system had to render the vast majority of scenes(80-90 %) correctly the first time without hand "tweaking" of the settings. A much smaller percentage of scenes should require "tweaking" (5-10 %), and similarly a small percentage (5-10 %) should require hand correction

(turning objects invisible, etc.). In spite of all of their compromises Monster's Inc. required an astounding 2.5 million rendermarks compared to the previous record holder Toy Story 2 with 1.1 rendermarks.[1]

The hair simulation was based on a spring and hinge model. Each hair was made of a series of springs connected together via hinges. Hair was given mass and a basic physics model is applied to the system. By adjusting the hinge and spring parameters the animators could simulate a wide variety of hairs. In order for this computation to be feasible the programmers had to use key hairs in their simulation and interpolate the hairs positions and values in between the key hairs. This process is known as tweening.

The cloth simulation was also based on a spring and hinge model. This time the springs and hinges were connected in a degree 6 vertex model. This results in a mesh of triangles. In order to minimize computation and to preserve the animated and soft feeling of the piece, the cloth was only allowed to form large soft folds. They also optimized the mesh, using more faces on the front of the shirt than on the back.

In order to provide more adjustability and flexibility to the system, programmers were forced to add a inertial field operation. This inertial field allowed them to add to the inertial vector used for calculating the simulation's behavior. If they added a positive value they were in effect increasing the natural effect, and adding a negative value they were cancelling some of the already present inertia. This technique allowed the animators to fix problems with the cloth and hair without being forced to hand animate thousands of frames.

The method to compute the simulation was very similar to the shaders written for Renderman. Since Pixar was a partner on this film along with Disney, this should come as no suprise. Basically, a single small program or function call is executed repeatedly on each vertex (hinge). Renderman also allows for fragment style processing where a larger collection of these vertices are processed

at once.[3] This technique has recently been adopted by real time graphics card designers like ATI and NVIDIA. NVIDIA and Microsoft recently co-developed and released Cg and High-Level Shader Language. Both products allow designers to run programs known as vertex or fragment programs entirely on the graphics processor present on modern programable 3D graphics cards.[2] This is exciting news for the real time graphics community. The GPUs (Graphics Processing Unit) present on modern 3D cards allow programs to process tens of millions of vertices in real time. What this means to a animator simulating hair or cloth is that their simulation need not take a week, it can now be done in real time or close to real time.

To summarize, hair and cloth simulations are tasking computational problems. Both models utilize a spring and hinge physics based simulation system. To facilitate the economical deployment of these simulations, compromises in reality have been made. The number of hinges, springs, and key elements have been reduced to reduce the cost of rendering. New advances in programmable hardware and high level languages to program them are allowing developers to bring new levels of realism to real time graphics. The simulations present in modern real time graphics are what was previously thought only possible in slow off-line renders just a matter of years ago.

References

[1] Monster's Inc. Homepage. Disney Enterprises, Inc. and Pixar Animation Studios 2002.
http://www.monstersinc.com

[2] R. Fernando and M. Kilgard (2003). *The CG Tutorial: The Definitive guide to Programmable Real-Time Graphics*. Boston: Addison Wesley

[3] Pixar Animation Studios (2000). *The Renderman Interface*
https://renderman.pixar.com/products/rispec/rispec_pdf/RISpec3_2.pdf