Curls Gone Wild: Hair Simulation in *Brave*

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In *Brave*, Merida's hair is an important extension of her character. Like Merida, it is fierce, tempestuous, and unpredictable. We were tasked with the challenge of creating hair that possesses its own dramatic and expressive personality, but still appears realistic and physically convincing. To accomplish this, we engineered a hair system that produces believable, natural movement while providing simulation artists with tools to direct the hair's motion as the story demanded. In this talk, we will discuss the techniques we developed in production to utilize a novel hair model described in [1].

Figure 1: Hair simulation on Merida and Angus in *Brave*.

1 The hair model

The simulator discussed in [1] defines the stretching, bending, and twisting behavior of the curls. It describes a hair model that includes core springs applied to core hairs generated with a low pass filter on the original hair. This spring helps Merida's curls to maintain their tightly coiled shape, but also allows for some stretching.

The simulator uses non-linear springs to dynamically increase the stiffness of the core and bending springs when the core hair length exceeds a threshold. This approach prevents hair from unwinding during high speed motions without sacrificing its softness and bounce in periods of less intense movement.

The simulator handles interaction between nearby hairs by modelling static friction with spring forces that break after the particles exceed a velocity threshold.

2 Articulation

Merida and Elinor's hair rigs are set up to allow posing of different regions of hair. These were used by animators to create shapes for simulation artists to use as reference for the final simulation. Merida's hair rig is based on a multi-bend deformer that facilitates accurate posing of the hairs. It also contains controls for deformations such as pinching. The hair rig on Elinor manipulates her two braids and deforms a tetrahedral mesh that is then simulated.

3 Controlling the uncontrollable

One of our goals for *Brave* was to provide simulation artists with a complex hair simulation setup that both maintains stability and gives the hair a consistently lively feel throughout the film, regardless of the characters' actions.

A significant challenge in animated films is working with a solver that expects physically plausible movement as input, but receives exaggerated, physics-defying character animation instead. To address this, we developed a special IFG (Inertial Field Generator) working only in the up/down direction. This force virtually adds or removes vertical acceleration from the hair particles. We can tone down the effect of exaggerated vertical movement on the hair, as well as amplifying the effect when we want to see more bounce.

To ensure that the hair returns to a reasonable shape even after heavy motion, we applied high bending stiffness at the root of each hair, then ramped it down to a lower value at the tip to allow the ends of the hair to move freely. The result is hair that is active and responsive to movement, but retains its original form. This strategy proved especially useful for Angus's tail. The animation on the tail nub influences the movement of the stiff upper region of the tail, but the rest of the hair is still able to swish around naturally.

It was important to produce coherent movement in the hair without making it look like a solid mass. We did this by manipulating the behavior of the hair-to-hair contacts. Hairs on the outer shell of the hair volume are more likely to break apart, while hairs on the inner shell easily cling to other hairs and create stronger contact forces. As a result, the hair moves in a roughly unified manner, but still contains enough flyaway hairs to look messy and natural.

We also wanted to introduce subtle variations in movement across different hairs. For each hair, we generated a random value which we added to some key parameters of the solver, including mass and stiffness. While global parameters control the overall movement, the slight noise from one hair to the next gives each strand a unique motion that is different from its neighbors.

External forces such as wind are key elements in creating a realistic simulation. We found that our traditional wind models could not accurately represent the decrease in wind intensity as it passes through a thick, layered volume such as Merida's hair. We developed a new kind of wind that takes into account the occlusion coming from characters, sets, and props, as well as the hair itself. We generate a signed distance function from the collision body meshes and the hair curves, and for each hair particle we ray-march against the wind direction to compute its degree of occlusion.

References

[1] IBEN, H., MEYER, M., PETROVIC, L., SOARES, O., ANDERSON, J. AND WITKIN, A. 2012. Artistic simulation of curly hair. Technical Memo 12-03a, Pixar Animation Studios.

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