Artistic Hair Modeling

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Hair simulation for animated films must create varied hair styles and handle the tradeoff between artistic needs and technical goals. A Pixar hair model and recent deep learning-based methods deal with this tradeoff and create intuitive tools for artists

Hair Simulation in *Brave*

- The hair model used in the Pixar movie *Brave* is a physically-based model based on the mass-spring systems.

Figure 1: Merida and her horse from the movie *Brave*. ©Disney/Pixar

- The bending spring stably controls the bend between the rest and current poses of the hair while maintaining the helical shape of the curls. The bending force can be calculated by the following equation, where k_b is the spring coefficient, c_b the damping coefficient, t_i the reference vector, and e_i the current pose of hair.

$$f_b(k_b, c_b)_i = k_b(e_i - t_i) + c_b(\delta v_i - (\delta v_i \cdot \hat{e}_i)\hat{e}_i)$$

- The core spring allows flexible curly hair yet maintains shape. It prevents the hair from unwinding when the characters undergo extreme acceleration. The core spring force is calculated by the following equation, where b_i is the current core and $\bar{b}_i$ the original core.

$$f_c(k_c, c_c)_i = k_c(\|b_i\| - \|\bar{b}_i\|)\hat{b}_i + c_c(v_i \cdot \hat{b}_i)\hat{b}_i$$

Figure 2: Curly hair without and with core springs. The hair on the left image can't maintain the shape of the hair and unwinds to its maximum extension. Iben et al.

- The hair pruning algorithm improves efficiency and reduces memory usage.

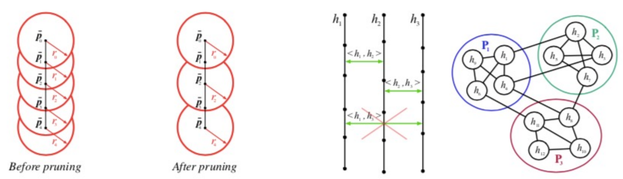

Figure 3: Two types of hair pruning. Iben et al.

Approaches to hair simulation & styling

- Physically-based hair simulation:
  - Mass-spring systems
  - One-dimensional projective equations
  - Rigid multi-body serial chain
  - Dynamic super-helices

- Attaching hair to the scalp:
  - 2D placement
  - 3D placement
  - Uniform distribution

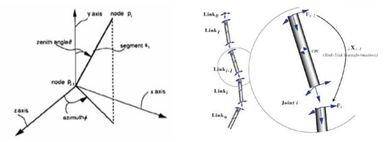

Figure 4: Left: the polar coordinate system for a hair segment. Right: hair strand as a rigid multi-body serial chain. Ward et al.

- Hairstyling:
  - Geometry-based hairstyling:
  The Pixar hair model groups individual hair and controls each cluster with a guide hair. Other methods include parametric surface and multi-resolution editing.
  - Physically-based hairstyling:
  Physically-based models reduce the amount of user control by defining key parameters. Commonly used methods include cantilever beams, vector fields, and motion fields.

- Hair generation from images & videos:
  "A data-driven approach to four-view image-based hair modeling" talks about a deep learning method that allows input images to be from different hairs.
  "Dynamic hair modeling from monocular videos using deep neural networks" presents a lightweight method that constructs high-quality dynamic hairs from videos taken by commodity video cameras or downloaded from the internet.
  "Hairnet: Single-view hair reconstruction using convolutional neural networks" introduces a deep learning model that generates the full hair geometry from a single-view image. As a result, this method is highly efficient and can be used in real-time.

Figure 5: A 3D hair model generated from one single-view image using HairNet. Zhou et al.

- Hair generation from sketches:
  "Deepsketchhair: Deep sketch-based 3d hair modeling" presents a sketch-based hair model using three neural networks. The third neural network enables hair editing.

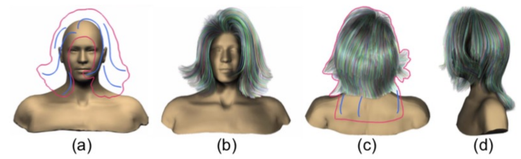

Figure 6: The Deep Sketch-based method uses a hair mask and a few strokes (a) to create a hair model (b). The user can make adjustments (c), and the system will update the hair model (d). Shen et al.

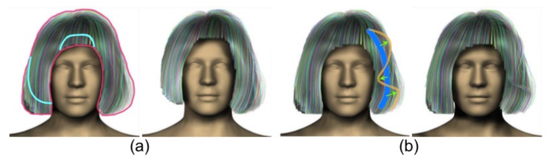

Figure 7: The Deep Sketch system provides auxiliary tools that support cut (a) and local deform (b). Shen et al.

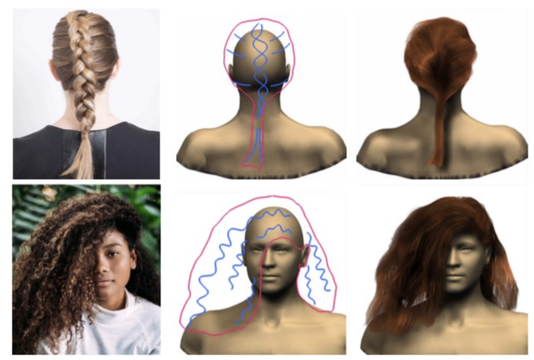

Figure 8: The Deep Sketch-based method doesn't support certain hairstyles because of low resolution of the orientation fields and a lack of training data. Shen et al.

Proposed Work

- Shen et al suggest that more intelligent interfaces or technologies like VR could be investigated to enable better interactions and more powerful 3D hair editing.
- In the short term, my goal is to implement a 3D hair model using the Pixar method.
- I would also like to combine this model with deep learning to create a sketch-based tool that allows hair editing and a greater degree of artistic freedom.

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