Implementation of Modeling Hair from Multiple Views

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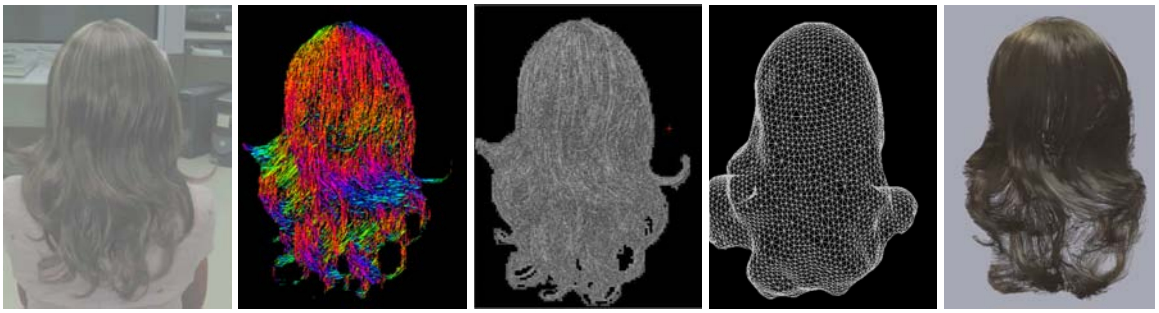

Figure 1: One of the original 40 images at different viewpoints; the computed orientation map over the hair mask extracted manually, angle encoded by color; the confidence map of the orientation, where brighter colors indicate more reliable orientation; the visual hull from silhouettes; the recovered hair geometry rendered by the method in [Marschner et al. 2003].

Modeling hair is difficult due to its complex geometry and reflectance properties [Marschner et al. 2003]. It often requires intensive user interactions. Paris et al. [Paris et al. 2004] developed an approach to capture hair geometry from a fixed viewpoint under controlled variable illumination. We developed a more practical approach in [Wei et al. 2005] that uses a hand-held camera under natural lighting conditions and does not require a specific setup. The success of this approach depends on good solutions for the following issues.

Image acquisition and camera calibration One major advantage of our technique is the practical and easy capture. An ordinary hand-held camera is used to take a sequence of images around a subject under natural conditions. The environment should be sufficiently illuminated to make sure that all parts of the hair are clearly visible, especially the dark areas.

The camera geometry recovery and auto-calibration approach can become standard in computer vision [Hartley and Zisserman 2000; **?**]. It automatically detects points of interest, establishes correspondences through projective structure and robust statistics, and auto-calibrates the underlying camera geometry through a bundle-like optimization. It usually works well for a rigid scene under natural lighting. The recent quasi-dense approach developed in [Lhuillier and Quan 2005] uses more largely separated images, therefore requiring fewer images (typically about 30 to 40 images for a full turning) for modeling. It gives a more robust and accurate geometry estimation than the standard sparse approach. We used this quasi-dense method to automatically compute the camera geometry in all our experiments.

Image filtering and orientation estimation The key to image-based hair modeling is the reliable extraction of 2D orientations of hair fibers. Paris et al. [Paris et al. 2004] use multiple oriented filters to obtain a reliable dense orientation map from multiple images at the same viewpoint under variable illuminations. Since we have only one image for a viewpoint, we found that using multiple filters does not give significant improvement and we only use one filter, a first derivative of a Gaussian, for efficiency. Although our orientation map is noisier than that in [Paris et al. 2004], the 3D reconstruction from multiple viewing directions is robust.

Synthesis of hair fibers For each image, we manually draw two masks, one for the silhouette of the subject against the background, and the other for the boundary of the hair areas. The silhouettes are used to compute a visual hull which is a good estimation of the hair surface. Then the scalp surface is taken to be an inward offset version of the visual hull. In practice, we may also use other approximations for the scalp surface such as a generic head model, or simply an ellipsoid. However, offsetting the visual hull turns out to be a very good systematic way of obtaining a reasonable estimate of the scalp that is practically difficult to accurately determine.

Each hair fiber is a smooth curve and approximated as a sequence of connected line segments. It is generated by growing one segment at each step, starting from regularly spaced root points on the scalp. The hair area masks are used to determine the region of the scalp surface from which the hair will grow. The growing direction is optimally triangulated from 2D orientations estimated in multiple views where the fiber point is visible. Visibility is heuristically determined and discussed in more details in [Wei et al. 2005]. The growth is terminated when the fiber exceeds a pre-defined length or goes beyond the hair volume.

Conclusion One result for a complicated long wavy hair style is shown in Figure 1. More results for other examples are presented in [Wei et al. 2005]. Flexibility of acquisition, little user interaction, and high quality reconstruction are the key advantages of our multi-view approach.

References

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