Capturing and Stylizing Hair for 3D Fabrication

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Technical Paper

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… Physical reproduction in general, and particularly of humans, has become a hot topic both in academia … and industry… . Recently, 3D-Systems even announced the release of a 3D-photobooth, which will facilitate 3D-portraits for the masses. … All systems have similar drawbacks, and in particular, no previous approach can capture personalized hair-styles with adequate details, while being suitable for physical reproduction.

… A person's hair-style is a defining characteristic of an individual. … Existing research in hair capture methods … do not meet the physical manufacturing constraint of a closed manifold surface, or they produce coarser reconstructions ... that lack the level of stylization, detail or colors required to produce appealing 3D-printed models. … We present the first method for stylized hair capture, which addresses current limitations of physical reproduction systems, enabling the faithful miniaturization and physical reproduction of figurines with drastically varying hair-styles. Our method automatically reduces the complexity of hair to an abstract, printable 3D surface, while still capturing the essential structural and color elements that define its style. The proposed method fits naturally into existing physical reproduction pipelines, and so our work has the potential to significantly impact the growing industry of figurine reproduction. …

… Our algorithm takes as input several color images of a person with a given hair-style from a multi-view capture system … Using these images, an initial smooth and coarse proxy geometry is obtained using multi- view stereo. This proxy is then initialized with per-vertex color information from the input images, split into multiple frequencies … Next, stylization operators are applied over the color information to achieve the desired level of abstraction… . From the stylized color information, new geometric details for the proxy are synthesized giving the artist control over the geometric appearance … . The final output of our method is a stylized mesh which abstracts the complexity of a real hair-style while still preserving its defining features …

Data Acquisition

… Our algorithm requires a coarse, low-resolution geometric proxy surface of the hair. This proxy may be generated with any 3D capture system that provides geometry and images … We use a multi-view reconstruction setup ... We use a multi-view stereo reconstruction algorithm to compute partial reconstructions from each of four orientations. These reconstructions are aligned rigidly through the Iterative Closest Points (ICP) algorithm and a single surface is obtained through Poisson reconstruction of the combined point cloud. This surface represents our geometric proxy, including both hair and face ... We manually identify the hair region through simple masking. …The proxy will serve as a base for synthesizing stylized details in both shape and color. The four rigid transformations computed from ICP are also applied to the calibrated camera views to produce virtual cameras surrounding the proxy. … We select the eight views that cover the hair volume from front, back, and both sides at two different elevations. …

Color Initialization

… The next step is to assign colors to its vertices. … Coloring the hair requires special treatment because the proxy surface only poorly approximates the volumetric nature of hair and is not geometrically accurate, so there will inevitably be inconsistencies between different views. … Hair has a very complex appearance, with strong view dependent effects, such as specular reflection, translucency and occlusions. … We separate color information into two frequency bands, low and high, using a Difference of Gaussians (DoG) filter. These color bands are processed separately according to their complementary nature and combined back together on the mesh … To be able to directly operate on intensity values we convert the images from RGB to HSV color space as a preprocessing step.

Color

For **low-frequency color** information, we assign a color $\mathbf{c}$ to each vertex of the proxy mesh by averaging color samples $\mathbf{c}^j$ from the set of views $\mathbf{V}$, weighted by their foreshortening angle $\boldsymbol{\omega}^j$ … This approach effectively removes visible color seams and attenuates view-dependent color changes …

… We therefore sample the **high-frequency color** details only from the single-best view **j***, which we consider to be the one with the highest foreshortening angle $\mathbf{w}^j$ …

Color Stylization

… The level of detail of real hair is overwhelmingly high, and we thus need to find a means to reduce the complexity while preserving its defining features. We approach this problem by employing a specialized stylization filter.

Feature-preserving 2d filter: Feature-preserving or enhancing directional filters are based on 3 main components: The estimation of the local structure, an integration/smoothing operation to reduce complexity, and a sharpening operator to enhance the desired features. …

Irregular manifolds in 3d space: … The stylization filter defined on a regular 2D image domain can be extended to operate on an irregular manifold embedded in 3-space. … We compute and store color information directly on the mesh, and will do the same for orientation tensors. Operations such as directional smoothing and shock filtering are then performed on a per-vertex basis, using the geodesic distance on the mesh surface.

Multiple views: … Information from different views will be naturally misaligned since the proxy geometry is an approximation of the hair volume and the appearance of hair may differ substantially in different views. … We merge low-frequency color information by averaging the contributions of the individual views to avoid color seams. But we must combine high-frequency components using the single-best view to avoid blurring. As a result, the high-frequency color information on the mesh will contain seams, and this can adversely impact orientation tensor computation if performed directly on the mesh. … If we compute the orientation tensor on the mesh, it will inevitably follow such seams and so will do the directional smoothing...

Coupled mesh-view stylization: … The final result is based on coupled stylization of both the mesh and the input views. This is required to keep the orientation tensor, which is computed from the views, consistent with the colors on the mesh, which are stylized using this tensor. The degree of stylization is emphasized by iteratively re-applying the method, which allows for direct artistic control. …

… We have stylized high-frequency information in HSV color space over the mesh. We wish to also stylize the geometric details of the hair, such that they are consistent with the color style. To this end, we will compute spatially-varying surface offsets **d(x)**, and displace the vertices of the proxy geometry along the normal direction **n(x)** by **d(x)n(x)**.

In conclusion, we present the first method for stylized hair capture, a technique to reconstruct an individual's actual hair-style in a manner suitable for physical reproduction. Our method generates hair as a closed-manifold surface, yet contains the structural and color elements stylized in a way that captures the defining characteristics of the hair-style.

Get the complete paper:
http://bit.ly/s2014-paper-hair
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Wednesday, 13 August; 345-515 pm
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