

Point-based Hair Global Illumination (sketches_posters_0175)

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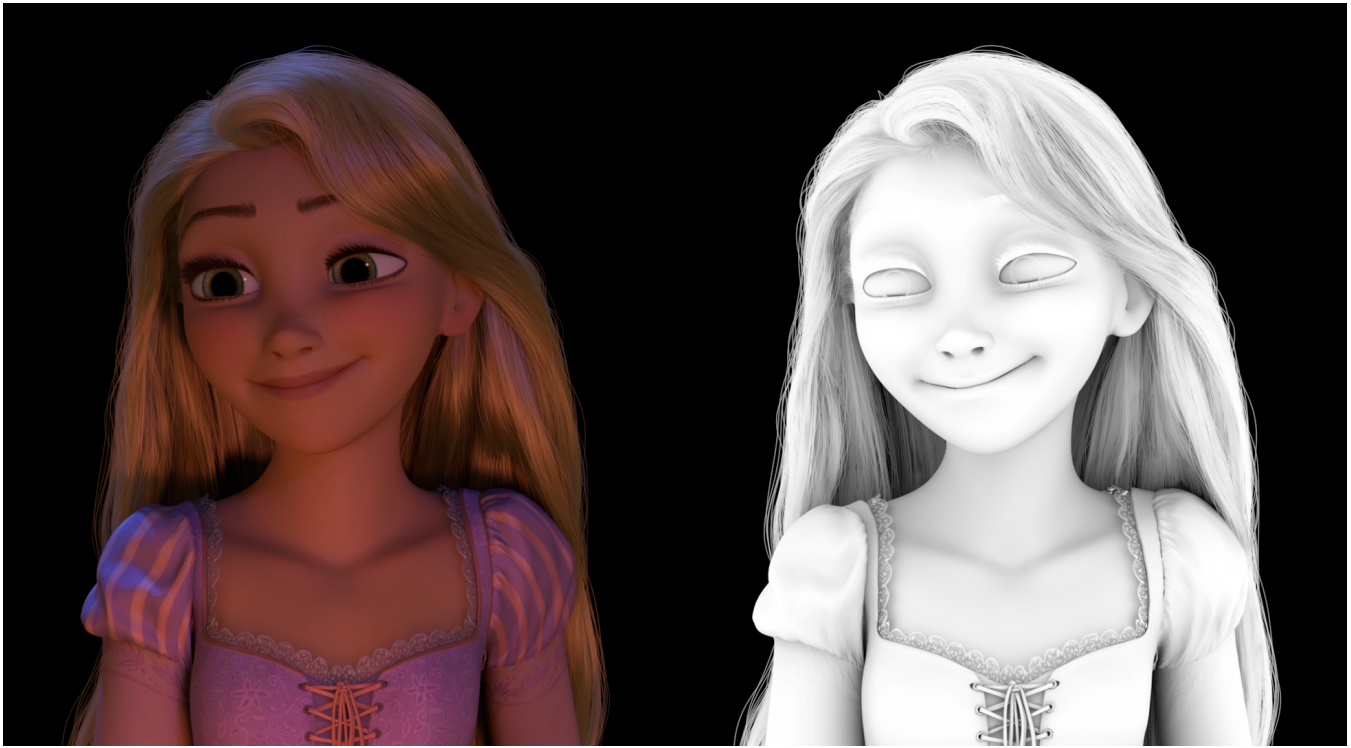


Figure 1: (a) Final render and (b) ambient occlusion component (© Disney Enterprises)

Abstract

A point-based representation was extensively used on *Tangled* to generate occlusion and indirect illumination involving the characters' hair. We describe how this was achieved in reasonable rendering times.

1 Motivation

The hair shader on *Tangled* takes into account the effects needed to make hair believable such as inter-strand scattering or secondary reflections. It is also specifically designed to be very intuitive to use by artists [Sadeghi et al. 2010]. However, we did not have a solution for ambient occlusion and color bleeding to and from the hair. Those components are essential for lighters to integrate the hair into the scene, a task further complicated by the fact that the shader also provides a highly realistic look while living in a world of stylized materials. Because of this a robust solution to computing global illumination involving the hair was needed.

In general, for *Tangled* we precompute global illumination using a point-based representation of the scene's surfaces that then

becomes the input to RenderMan's pfilter (a standalone program that uses pointclouds to precompute global illumination effects). For hair the problem is how to extract a representation that is accurate enough for closeups but compact enough to prevent filtering times from drastically increasing.

2 Hair Representation

As the hair travels along the production pipeline a number of representations are used. For visualization purposes, the hair for Rapunzel and other characters is represented as a surface. However, the real shape of the hair is encoded from animation to simulation and to final render using an increasing set of curves with an ever increasing amount of control points to accommodate the detail that each production step adds. What is initially 10 curves with 100 control points will become tens of thousands of curves with up to 2400 control points for the renderer.

For the hair occlusion to be believable, a hard surface representation cannot be used, as it introduces a harsh discontinuity between the skin and the hair itself. Similarly, while ambient occlusion is soft and featureless away from the hair it brings out small details on an object's surface very clearly (cf. figure 1b). This means we need to start with the most accurate hair representation and filter it afterwards.

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The simplest solution would be to use a pointcloud storing all of the hair's control points. This is very costly, since we want indirect illumination effects from and to the hair, but also between the different parts of the hair represented in the pointcloud. All of the points in the pointcloud would be taken into account in these computations and that would be prohibitively expensive. Hence, we will only include initially a uniformly decimated percentage of all control points, and then simplify the hair pointcloud based on a user specified parameter that will take away unnecessary points only, either because they are deep inside the volume or because they are already represented by nearby data.

3 Hair Pointcloud Filtering

To do so, we randomly (but consistently across frames) bake into the pointcloud 10 to 20% of the final render hair curves, and for each one of those curves we store approximately 1 point for every 3 pixels on screen. These points are stored in a kd-tree for faster processing as they typically range in the millions. The user specifies a radius R that determines the minimum size of features in the hair that need to be preserved in the final pointcloud. Each point generates a vectorial field pointing away from it that dies off at a distance R [Blinn 1982]. Then, for each point in the pointcloud we add up all repelling vectors. When this total vector adds up to zero the point of interest is inside the hair volume. Otherwise, the vector points in the direction in which we move away from the hair mass, and the point is on or close to a hair discontinuity, on the visible surface or on an internal density change (cf. Figure 2). This allows us to discard the points inside the hair before performing the more expensive global illumination step.



Figure 2: (a) a point inside the hair volume and (b) a point at the edge of the hair volume and their accumulated vectors.

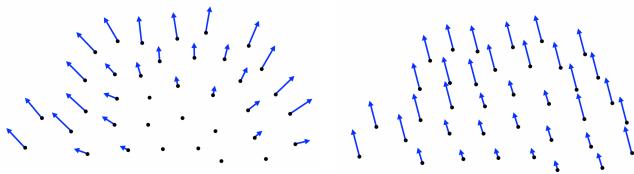


Figure 3: vectors computed with (a) a small radius and with (b) a bigger radius: smaller radii preserve more detail.

We also need to optimize as much as possible this prefiltering step. Because of its low pass filter nature we do not need to compute the vector on every single point, just the points that are further apart than a fraction of R . Similarly, as we are averaging amongst thousands of points, we can use a technique similar to importance sampling [Metropolis et al. 1953] and consider a

fraction of points at each distance instead of weighting the contribution of all of them.

With these optimizations the prefiltering accounts on average for 5% of the total time used for the global illumination computation itself.

4 Practical Considerations

We initially used the hair pointcloud without associating normals to the points, but this meant that the ambient occlusion lacked contrast at the high frequency detail level, because there was no cosine falloff on the “surface” of the hair. To overcome this we use the vectors computed in the previous step as normals associated with the hair points. This non-physical use of the normals provides us with the desired look, emphasizing the details in the hair without destroying the believability of the underlying shader.

The added detail visible in the hair also means that the requirements for the upstream departments are more stringent. The ambient occlusion brings out detail on individual strands that highlights stretching or changes in parametrization along the hair for certain shots.

Interpenetrations between Rapunzel's long hair and her body are also much more obvious when ambient occlusion is on, as it gives a cue to where the contact happens that would otherwise be absent. To make the character finaller's job easier we added another step where the hair pointcloud fades away as it approaches any other surface. This prevents overly dark occlusion at the root of the hair and makes interpenetration problems less obvious.

5 Conclusion

On *Tangled*, these techniques were used on all characters whenever the hair took on a sculpted shape. This saved time for lighters who did not need to set up so many lights and shadow maps to fake the effect. Ambient occlusion and indirect lighting on Rapunzel's hair allowed it to receive and cast the warmth that the script called for.

Special thanks to Lewis Siegel who integrated these results into the production hair shader.

References

- BLINN, J. 1982. A Generalization of Algebraic Surface Drawing. *ACM Transactions on Graphics* 1, 3, 235-256.
- METROPOLIS, N., ROSENBLUTH, A. W., ROSENBLUTH M. N., TELLER A. H. AND TELLER, E. 1953. Equation of State Calculations by Fast Computing Machines. *Journal of Chemical Physics* 21, 1087-1092.
- SADEGHI, I., PRITCHETT, H., JENSEN, H. W., AND TAMSTORF, R. 2010. An artist friendly hair shading system. *ACM Transactions on Graphics (SIGGRAPH 2010 Proceedings)* 29, 4.