A Monster's Guide to Cheating in GI Class

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Monsters University is Pixar's first feature film to embrace global illumination (GI). This development necessitated many changes in our existing approach to shading characters and provided new visual opportunities. Although we leveraged a physically-based illumination model, we still employed several non-physical techniques to achieve specific looks and rendering optimizations. In this talk, we discuss three particular challenges.

Figure 1: Eye highlights. A gummy character. Hair highlights.

1 Eye highlights

On previous shows, lighting TDs would place special lights in a scene that were responsible for the gleam in a character's eyes. These lights would be carefully manipulated as the character animated. In *Monsters University*, eye highlights can result from multiple and complex light sources. We wanted to take advantage of the rich, high-dynamic-range reflections that connect a character's eye with the environment, while still providing a clean, graphic shape and the ability to direct the location of the eye highlights.

We modified our eye geometry to more closely resemble a real eye and introduced a refraction shader that traces from the bulge of the cornea to the iris, resulting in a natural distortion of the iris as the eye is viewed from all directions. By manipulating the surface normals of the cornea and iris separately, in both specular and diffuse, we were able to create a shader that captures real illumination from the scene and produces pleasing graphic shapes. An additional feature was implemented that reorients these normals towards the camera, stabilizing the position of the highlights through most eye movements.

2 Volumetric Illumination

During *Ratatouille*, Pixar developed an in-house subsurface approximation (scatter). A pre-pass is rendered and the illumination samples are collected in a point cloud. This point cloud is converted to a 3d-dimensional grid, the samples within each cell are combined together, and the resulting illumination in each cell is blurred with the neighboring cells.

While not being strictly physical, it has been a very flexible tool, and particularly well-suited for modeling gummy and glowy materials. In *Monsters University*, several characters are made from these sorts of substances. Since scatter is computed from the environment's diffuse illumination and also contributes to the indirect diffuse, the character can be convincingly integrated into the scene. Even with larger scatter distances, we were able to author shaders that behaved predictably.

Also, by controlling what illumination is recorded in the scatter point cloud, we can easily hide the details of the model. For example, the back of the mouth and the eyes are visible inside the character, but those details are distracting if they are seen through the character's skin.

3 Hair shaping and highlights

To work within our new global illumination environment, we adopted a hair illumination model based on Marschner's work [1]. We only implemented the primary and secondary rays since modeling the transmitted ray proved prohibitively expensive. Unfortunately, ignoring the transmitted ray resulted in highlights that appeared dusty or crunchy. To address this, we leveraged the existing scatter pre-pass to collect and blur the hair's specular response. This blurred illumination simulates transmission through the hair at a significantly lower cost than ray-tracing the hair volume.

Additionally, the hair illumination model was visually unsuitable for certain types of hair (especially without the transmitted ray). Many of the garments in *Monsters University* are covered with fine hair or fuzz, and a hair-based light response left the fuzz feeling disconnected from the underlying garment. Similar to techniques that we've used on previous, non-GI films, we illuminated the fuzz with surface-based normals. This married the fuzz with the garment and provided predictable backlighting behavior.

4 References

[1] Stephen R. Marschner, Henrik Wann Jensen, Mike Cammarano, Steve Worley, and Pat Hanrahan. 2003. Light Scattering from Human Hair Fibers. ACM Trans. Graph. 22, 3, (July), 780-791.

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