Composite Based Refraction for Fur and Other Complex Objects on “Bolt”

Lewis Siegel* Sean Jenkins
Walt Disney Animation Studios

1 Introduction

Creating the Rhino character for the film "Bolt" presented a unique challenge: generate realistic fur which is then viewed through a plastic, refractive hamster ball.

Figure 1: The furry "Rhino" character inside a refractive hamster ball, with reflections and "surrounding" object

Rendering hair and simulating refraction, when performed separately, are both time and memory intensive. When combined, the demand for time and memory resources increases tremendously, and likely will result in an unusable image.

To overcome these problems, a process was developed for “Bolt” which involved exporting 3D data from the render stage so that the calculation of the refraction could be delayed until the composite stage. The technique allowed for quick and easy modification of the refraction effect using standard compositing techniques. The refraction technique was also successfully integrated into the stereo process developed for “Bolt.”

2 Rendering

In order to make the result of a compositing based refraction solution appear a realistic, it was desirable to maintain as many levels of refraction as possible. Therefore, it was necessary during the rendering stage to split the ball into two parts, front and back, along the ball's silhouette edge as seen from the camera, with the Rhino character “floating” in between the two hemispheres. Unfortunately, the ball is not a perfect sphere; the surface contains several openings and indentations. As a result, a simple front/back facing evaluation was not sufficient. Instead, a geometric approached was used, evaluating the angle between the camera, the surface position, and the center of the ball, resulting in an accurate split, even for the non-spherical details on the ball's surface. The three split components – front, back and character – are rendered as separate image layers, freeing the composite artist to color correct each independently, instead of manipulating all three elements baked into a single image.

Also during rendering, a variety of 3D information for both the front and back of the ball was exported. This included surface position and normal data (in camera space), and also a painted “distortion” map which emulates irregularities on the surface of the hamster ball. In addition, as the Rhino character rolled the hamster ball through space, it was important that the refraction stay consistent in relation to the surface, and not “swim” as the distorted surface normals changed orientation. As a result, a coordinate system located in the center of the ball was used to export a set of color-coded “orientation” images which express the coordinate system as a set of basis vectors in camera space. The hamster ball surface normals could then be transformed, in compositing, back into the hamster ball's “object” coordinate system, resulting in consistent noise calculations regardless of the ball's position and orientation relative to the camera.

* Email: Lewis.Siegel@disney.com

3 Compositing

The render stage results in several types of raw, 3D output data, which can then be used in the composite stage to perform the final refraction calculation. The compositing software used, however, must provide the ability to perform arbitrary arithmetic calculations on per-pixel RGB data. The compositing software used on “Bolt” included advanced warping tools with these capabilities, along with a macro mechanism that allowed complex operations to be packaged into a user friendly format.

The first step was to create a refraction macro, capable of refracting an arbitrary image through a surface for which 3D render data had been exported. After that was achieved, it became clear that the same data could be used to perform a Fresnel-like reflection effect near the edges of the hamster ball. The result was a corresponding reflection macro. Finally, to achieve a realistic result, several layers of refraction and reflection were combined: a layer of refraction and reflection on the back of the ball, underneath a refracted layer of the Rhino character inside the ball, followed by another layer of refraction and reflection through the front of the ball. The multiple layers of refraction provided depth cues and a parallax effect while the ball was in motion, enhancing the impression that the Rhino character was truly inside a refractive sphere. Additionally, the amounts of refraction could be modulated in compositing on a per-layer and even a per-pixel basis, allowing for rapid turn around of changes due to notes from art-direction and review.

4 Stereo

Finally, with some minor modifications, the entire process was able to be made compatible with the multi-camera stereo rendering approach employed for the production of “Bolt.” The result was a seamless work-flow for the hamster ball refraction effects from start to finish.

5 Conclusion

A render-time solution to the combined challenges of hair rendering and refraction, while technically accurate, was not possible for the production of “Bolt” due to the large amounts of time and memory required over a large number of shots, and due also to the inability to quickly and easily modify the result. A novel composite based approach was used instead, providing a fast, high quality and artist-friendly solution to the problem of making the Rhino character appear to be inside an encompassing, refractive sphere.