Lighting Reconstruction for “The Matrix Reloaded”

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Introduction

The demands of photo-realism required of the effects for *The Matrix Reloaded* and *The Matrix Revolutions* led us to create a system for directly and accurately reconstructing real world lighting environments. The Lighting Reconstruction Toolkit builds on research in the area of Image-based Lighting and extends current techniques to enable the reconstruction of lighting that more closely matches the real world.

Lighting Reconstruction

Lighting Reconstruction has two main stages: **Data Acquisition,** and **Lighting Reconstruction**.

On-set photography is the primary means of real world lighting **Data Acquisition**. Of the on-set photography, multiply exposed images of chrome balls play a central roll. Kodak 20-step grey cards and Macbeth color charts play a not as obvious but also central roll. They are photographed for film response and color neutrality reference. Color temperature, exposure settings, photogrammetic reference images, and set diagrams round out the lot of information gathered.

The images and data are used to create from each group of chrome ball exposures an extended, or high, dynamic range panorama, i.e. an image representing the true color and intensity of all the lighting at a certain point in the real world. The chrome ball images serve as the raw data. The Kodak 20-step grey scale images serve as the basis for solving for the response function of the film, the key to turning film exposure measurements back in to true measurements of intensity.

Given a high dynamic range panorama, the **Lighting Reconstruction**, of which there are currently three main modes, can begin.

In the first and simplest mode, a panorama directly drives the creation of a set of directional lights. The lights represent the integrated color and intensity of either key or fill areas of the panorama. The key lights are separated out from the fill light portion of the panorama. Roughly equal solid angle sub-regions are integrated over to create the fill lights to a user-specified granularity. These lights will not change in any way with respect to the location of the object.

In the second mode, multiple panoramas, their real world locations, and a model of the environment with light source locations allow us to create lighting that varies as the key and fill lighting varied in the real world. The input key light locations and sizes are verified by triangulating their position from the panoramas. The intensity, color, cone angle, and other parameters of a spot light model are then fit to the data in each panorama. The intensity of the fill lighting is established by creating a triangulation of the panorama locations. At render time, for each object, an interpolation weight for each of the panoramas is established based on the proximity of the object to each panorama as well as the proximity of each panorama to the others. An object specific panorama is generated using the weights. From this panorama an arbitrary number of directional lights may be generated.

The third mode of Lighting Reconstruction is based on a new light primitive whose area is dynamically subdivided for each object it will light. The light fulfills the criteria that none of its sub-regions may be bigger than a solid angle threshold relative to an object being lit. The primitive when used in the creation of a simple model of the real world geometry and textured using the panoramas projected on to the model, replaces the panorama-interpolating scheme presented in the previous mode. The primitive allows for better allocation of a limited number of light samples and a better reconstruction of the object specific lighting environments.

Figure 1: Row 1 shows two differently exposed images of the same chrome ball. Row 2 shows a real image of Keanu Reeves (left) and a version of Keanu Reeves (right) rendered using the lighting from above chrome ball. Row 3 shows an image from the Burly Brawl sequence. Row 4 shows two differently exposed images of one of the chrome balls used to generate the lighting for that sequence.

Conclusion

The Lighting Reconstruction Toolkit has survived a true production environment and was combined with the Universal Capture, Skin, BRDF, Subsurface Scattering, Hair, and Cloth Simulation development efforts at ESC to create many of the realistic images seen in the movie.

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