# Combining Spherical Harmonics and Point-Source Illumination for Efficient Image-Based Relighting

Borom Tunwattanapong
University of Southern California

Abhijeet Ghosh Paul Debevec
USC Institute for Creative Technologies

(a) Ground Truth (b) Combination with un-optimized weights (c) Combination with optimized weights

**Figure 1:** *(a): The relighting image under the Grace cathedral illumination using the full reflectance function data consisting of 253 lighting conditions. (b): An approximation of the ground truth using a combination of spherical harmonics and point lights with un-optimized weights. (c): An approximation of the ground truth using a combination of spherical harmonics and point lights with optimized weights.*

## 1 Overview

Traditional image-based relighting technique requires capturing a dense set of lighting directions surrounding the object and uses the linearity of light transport property together with the illumination data of the target environment to relight an object [Debevec et al. 2000]. However, this can be a very data intensive process because such datasets typically involve photographing hundreds of lighting directions. It is also difficult to modify or edit the data in post-production environments because the data is high dimensional. Adjustment has to be made in several dimensions in order to add artistic effects to the result. Difficulty in acquisition process is also one of the main problems. The capturing process typically lasts long enough to only be suitable for static objects. In this poster, we present a relighting technique which greatly reduces the number of images required for relighting, and still generate realistic results. We combine spherical harmonics with point lights to achieve efficient image based relighting. Spherical harmonics can efficiently capture smooth low frequency illumination [Ramamoorthi and Hanrahan 2001] while point lights capture high frequency directional illumination. Combining both techniques, we create relighting results which have both low and high frequency illumination data. This technique also benefits the acquisition process by reducing the number of required photographs which results in shorter capture time. In addition, fewer dimensions of the data can potentially simplify modification or editing of reflectance data.

## 2 Method

A lighting system such as Light Stage can project spherical harmonic illumination on the object. This means that we can directly capture spherical harmonics coefficients from photographing the object under these lighting conditions. For point-source lights, we capture the object while illuminating it with just one light at a time to simulate directional illumination. We capture point-source lighting conditions by giving more samples to the upper hemisphere which is usually brighter compared to the lower hemisphere. The number of photographs in the capture process has been limited to 20 photographs which is one order of magnitude less than the dense data set. In order to reconstruct high frequency data, we generate a residual environment map by subtracting spherical harmonic reconstruction of the original environment maps from the original maps. The residual map normally contains negative pixels which we clamp to zero in order to prevent the possibility of reducing energy from point-source illumination. We then convert the result to angular Voronoi cells of point-source light in order to compute the energy of each light. The residual maps usually contain data in brighter areas, which are mostly high frequency data, and data in some areas that have been under estimated by spherical harmonic reconstruction. We also experiment with different combinations of spherical harmonic and point lights to find the most suitable setup for the 20 photographs budget that we have (see Supplementary Document). The best setup is the $2^{nd}$ order spherical harmonic (9 images) and 11 point-source illumination which captures both high and low frequency illumination (see Supplementary Document).

## 3 Optimizing Combination Weights

Direct combination of spherical harmonics and point lights achives sub optimal relighting (Fig. 1, b). Hence, we present an approach to find the optimal combination weights of spherical harmonics and point lights. These weights present the contribution of each data to the final result. We optimize the combination of weights by reducing the difference between a reconstructed map of the original environment map and the original one. In order to obtain the difference, we project the original environment map into PCA (principal component analysis) space of spherical harmonic and point-source data to obtain a feature vector of the map in PCA space. Then we calculate the distance of that feature vector with the feature vector of the current weights. We use a bounded version of FMINSEARCH function in MATLAB to find the optimal weights that reduce the distance between two feature vectors. Subsequently, we apply the optimized weights to the spherical harmonic and point-source data to generate the final result (see Fig. 1, c).

## References

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