Lighting estimation for different time periods using light probes

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Abstract

In this paper, we present a way to approximate real lighting for different time periods by using image based lighting with sparsely obtained light probes. In order to maintain lighting consistency we use of interpolation, we have tested and compared a few interpolation methods.

CR Categories: I.3.3 [Computer Graphics]: Three-Dimensional Graphics and Realism—image based lighting I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—global illumination;

Keywords: image based lighting, global illumination

1 Introduction

Computer graphics is present in a wide variety of areas ranging from entertainment to medicine or military applications, and one of its biggest challenges is generating realistic and convincing synthetic scenes. Realistic scene synthesis is dependent on a few factors, like geometry, materials and lighting. One of the most complex elements to reproduce are those related to lighting.

We would like to render scenes in different periods of the day with realistic and convincing lighting. Realistic lighting can be achieved by means of a technique called Image Based Lighting. Image Based Lighting (IBL) consists in obtaining light probes, which are omnidirectional High Dynamic Range images, and using them as environment maps during the rendering phase.

However, this technique is limited in the sense that we must obtain a new light probe for every instant we would like to render. This limitation makes the use of image-based lighting inviable depending on the time range of the scenes to be rendered due to enormous amount of work involved in obtaining the light probes.

Our main goal is to alleviate the restriction that a light probe must be obtained for every moment to be rendered. In order to do that we propose the use of interpolation to estimate the light probes for the instants that data is not available.

We propose two comparisons to validate our approximation:

- Comparing light probes obtained through interpolation and light probes obtained through the usual way, which is done by combining different exposure time images.
- Comparing the rendering a simple object using the interpolated light probe as a light source and the same object in the real scene. The object is a white cube 1.

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Figure 1: *Image obtained by using a fisheye lens.*

2 Definitions

2.1 Environment Map

Environment mapping [Hughes 2013] consists in exchanging the illumination model for a texture lookup model which contains the lighting information.

2.2 High Dynamic Range

High Dynamic Range (HDR) is an image format capable of representing a scenes great variation in luminosity. It is usually stored using floating points with 32 bits per channel. HDR images can be obtained by using special cameras like the Spheron [Spheron], or combining images with different exposure times using software like Photoshop or HDR Shop. A scenes radiance can be recovered from a scenes HDR image [Paul E. Debevec 1997].

2.3 Image Based Lighting

Image Based Lighting (IBL) [Debevec 2002] consists in capturing a scene illumination information through an omnidirectional HDR image. To capture omnidirectional images either a reflective sphere (Figure 3[Bailey 2007]) or fisheye lenses (Figure 2[Salgado]) can be used. The resulting image, called light probe, is then used as an environment map in the rendering phase. Note that a new light probe must be acquired for different locations or periods, otherwise the lighting consistency might not be maintained.

2.4 Interpolations

We have used five types of interpolations to generate new light probes from our data. The light probes were interpolatate using pixel intensities over time. For every interpolation method the set of light probes is represented by $(\dots, y_{i-2}, y_{i-1}, y_i, y_{i+1}, y_{i+2}, \dots)$, ordered by the time of acquisition. The acquisition time, or observation, is represented by the set $(\dots, x_{i-2}, x_{i-1}, x_i, x_{i+1}, x_{i+2}, \dots)$, ordered in crescent order. The interpolated light probe is y' in the formules below.

Figure 2: *Image obtained by using a fisheye lens.*

Figure 3: *Reflective sphere that could be used as a light probe.*

2.4.1 Linear Interpolation

The first interpolation is the classic linear interpolation. It's formula is as below:

$$y' = y_0 + (y_1 - y_0) * \frac{x - x_0}{x_1 - x_0} \tag{1}$$

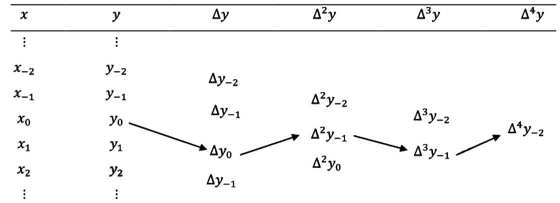
Where y represents the intensities of each pixel while x represents the time associated with the light probe's acquisition.

2.4.2 Gauss Foward Central Difference

The second interpolation method is the Gauss Foward Central Difference. The Foward interpolation uses an iterative method that adds the n-esieme central difference[Abramowitz and Stegun 1972] using the piramidal construction represented by Figure 4. This and the next method require that the observations time be separated by a constant interval h. The interpolation formula is:

$$\begin{aligned} y' &= y_i + P\delta_{1/2} + G_2\delta_0^2 + G_3\delta_{1/2}^3 + \dots \\ P &= (x - x_i)/h \\ G_{2n} &= \binom{P+n-1}{2n} \\ G_{2n+1} &= \binom{P+n}{2n+1} \end{aligned} \tag{2}$$

Figure 4: *Reflective sphere that could be used as a light probe.*



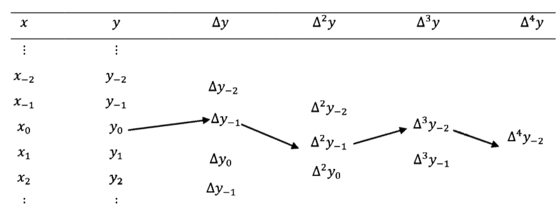
2.4.3 Gauss Backward Central Difference

The Gauss Backward Central Difference differ from the Foward in the way that the iteractions choose which central difference to use. It uses another direction in the piramidal scheme to choose which central difference will be used. The selection algorithm is represented by Figure5. The formula used is:

$$\begin{aligned} y' &= y_i + P\delta_{-1/2} + G_2\delta_0^2 + G_3\delta_{-1/2}^3 + \dots \\ P &= (x - x_i)/h \\ G'_{2n} &= \binom{P+n}{2n} \\ G_{2n+1} &= \binom{P+n}{2n+1} \end{aligned} \tag{3}$$

As stated above, the Backward interpolation

Figure 5: *Reflective sphere that could be used as a light probe.*



2.4.4 LaGrange Interpolation

Different from the Gauss interpolations methods, the LaGrange interpolation can be used with observations that doesn't have a constant interval between each other, thus making the process of gathering the light probe images a little easier. The general formula for the LaGrange interpolation is:

$$\begin{aligned} y' = & \frac{(x-x_1)(x-x_2)\dots(x-x_n)}{(x_0-x_1)(x_0-x_2)\dots(x_0-x_n)} y_0 + \\ & \frac{(x-x_0)(x-x_2)\dots(x-x_n)}{(x_1-x_0)(x_1-x_2)\dots(x_1-x_n)} y_1 + \\ & \dots \\ & \frac{(x-x_0)(x-x_2)\dots(x-x_{n-1})}{(x_n-x_0)(x_n-x_2)\dots(x_n-x_{n-1})} y_n \end{aligned} \tag{4}$$

2.4.5 Stirling's Interpolation

Stirling's interpolation is calculated taking the average of the Gauss Foward difference and the Gauss Backward difference. The main formula can be writen as:

$$
\begin{aligned}
y' &= y_i + P\frac{\delta_{1/2} + \delta_{-1/2}}{2} + \\
&H_2\delta_0^2 + H_3\frac{\delta_{1/2}^3 + \delta_{-1/2}^3}{2} + \ldots \\
P &= (x - x_i)/h \\
H_{2n} &= \frac{G_2 + G_2'}{2} \\
H_{2n+1} &= \binom{P+n}{2n+1}
\end{aligned} \tag{5}
$$

3 Experiment

As stated in the Introduction, we want to validate our interpolations using two comparisons. One of then is comparing our interpolated Light Probe with the Light Probe obtained using the usual way, and the other is rendering a white cube using the illuminating provided by our interpolated Light Probe and compare it with a shot of a white cube.

3.1 Data Acquisition

To realize our experiments, we've acquired 2 sets of Light Probes data. The first set was taken in the outside, always in the same location, starting at 10:45 A.M. and ending 20:00 P.M. The second was acquired inside a build, close to a window, commencing 11:00 A.M. and ending 19:45. We tried to take one shot every 30 minutes. For every shot of hte Light Probe another was made for the white cube, on the same position. The Table 3.1 shows the list of observations time.

Data Acquision Time		
#	Outside	Inside
1	10:45	11:00
2	11:20	11:30
3	11:52	12:02
4	12:18	12:30
5	12:48	13:00
6	13:18	13:30
7	14:35	14:40
8	15:05	15:10
9	15:30	15:40
10	16:00	16:10
11	16:30	16:40
12	17:05	17:15
13	17:40	17:45
14	18:05	18:15
15	18:35	18:45
16	19:05	19:15
17	19:35	19:45
18	20:00	

3.2 Data Validation

3.3 Interpolated Light Probe

To create the interpolated Light Probe we've chosen one observation with a poor quality and remove it form the set, and using the other observations with a good quality, generated the removed Light Probe.

3.3.1 Rendering the White Cube

For the renderization of the white cube we've chosen one particular good shot for comparinson of the white cube, interpolated the respecting Light Probe and generated the scene using the information of hte interpolated Light Probe.

4 Results

5 Conclusion

Acknowledgements

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