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 see Figure 1.

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Figure 1: *White cube used for comparison.*

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 interpolated using pixel intensities over time. For every interpolation method the set of light probes is represented by $(\ldots, y_{i-2}, y_{i-1}, y_i, y_{i+1}, y_{i+2}, \ldots)$, ordered by the time of acquisition. The acquisition time, or observation, is represented by the set $(\ldots, x_{i-2}, x_{i-1}, x_i, x_{i+1}, x_{i+2}, \ldots)$, ordered in crescent manner. The interpolated light probe is y' in the formulae 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. Its formula is as below:

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

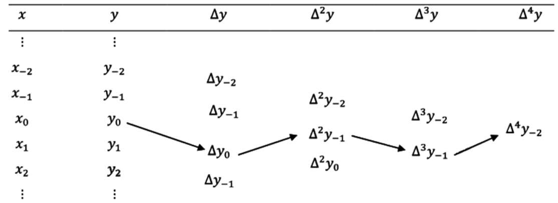
Where y represents the intensities of each pixel while x represents the time associated with the light probe's acquisition.

2.4.2 Gauss Forward Central Difference

The second interpolation method is the Gauss Forward Central Difference. The Forward interpolation uses an iterative method that adds the n-esieme central difference[Abramowitz and Stegun 1972] using the pyramidal construction represented by Figure 4. This method and the next requires that the observation times are acquired at an regular time 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.*



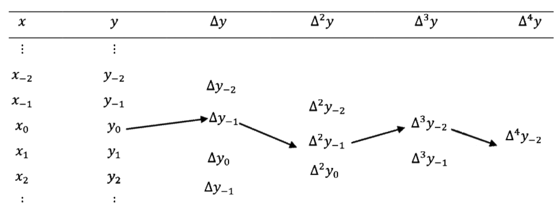
2.4.3 Gauss Backward Central Difference

The Gauss Backward Central Difference diffesr from the Foward in the way that the iteraction chooses which central difference to use. It uses another direction in the pyramidal scheme to determine 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

Lagranges interpolation advantage in relation to Gauss methods are that it does not require regularly spaced data to work, 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 can be calculated by taking the average of the Gauss Forward difference and the Gauss Backward difference.

The formula can be writen as:

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

3 Experiment

As stated in the Introduction, we want to validate our interpolations by using two kinds of comparisons. In one of them, we compare interpolated light probes with the light probes obtained by conventional means, while in the other we compare a shot of a white cube with a rendering of a white cube, using image based lighting using an interpolated light probe that was created using the same time the shot was taken.

3.1 Data Acquisition

To realize our experiments, we have acquired two sets of light probe data. The first set was taken outdoors, always in the same location, starting at 10:45 A.M. and ending 20:00 P.M. The second was acquired indoors, 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, we also took a shot of a white cube. The Table 3.1

Data Acquisition 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 probes

To create both the linear and Lagrange interpolated light probes we have used all data available with the real time associated with them. However, for the Gauss interpolated light probes we have used only a subset of the data available, the main reason for that was that we had to space our data evenly with at least a one-hour interval between them., For Gauss interpolation, we have considered that the time difference between each acquisition for the light probes 8 through 20 was 30 minutes.

3.4 Distance between HDR images

We have defined a simple distance to compare two HDR images, which is given by:

$$
d = \sum_{i}^{n}\sum_{j}^{n}\sum_{channel} \mid Image1[i][j].channel - Image2[i][j].channel \mid \tag{6}
$$

3.4.1 Rendering the White Cube

Using the distance previously defined, we have determined for each of the chosen scenes two interpolations with least distance compared to the real light probe. These interpolations were used to render a white cube modeled in Maya. The chosen renderer was nvidias Mental Ray, which supports image based lighting.

4 Results

5 Conclusion

In this paper, we have explored a way to alleviate the restrictions surrounding the use of light probes by using interpolations.

We were not entirely successful in our white cube rendering comparisons, however interpolating a light probe proved feasible, especially with linear interpolation.

AS for our next steps, we would like to explore other local low order interpolations like quadratic or cubic interpolations. We would like to explore these interpolations in order to avoid black areas in HDR images like those we see in Lagrange and Gauss interpolations.

Acknowledgements

References

ABRAMOWITZ, M., AND STEGUN, I. A. 1972. *Handbook of mathematical functions: with formulas, graphs, and mathematical tables*. No. 55. Courier Dover Publications.

BAILEY, L., 2007. A_large_mirror_ball_on_the_promenade_-_geograph.org.uk_-_532274.jpg. http://commons.wikimedia.org/wiki/File:A_large_mirror_ball_on_the_Promenad_geograph.org.uk_-_532274.jpg.

DEBEVEC, P. 2002. Tutorial: Image-based lighting. *IEEE Computer Graphics and Applications*, 26 34.

HUGHES, VAN DAM, M. S. F. F. A. 2013. *Computer Graphics Principles and Practice*. Addison-Wesley Professional.

PAUL E. DEBEVEC, J. M. 1997. Recovering high dynamic range radiance maps from photographs. In *Proceedings of SIGGRAPH 1997*, ACM Press / ACM SIGGRAPH, Computer Graphics Proceedings, Annual Conference Series, ACM, 369–378.

SALGADO, E. F. Up close and personal with the very large telescope. http://www.eso.org/public/images/potw1049a/.

SPHERON. Spheron. https://www.spheron.com/products/cgi-computer-generated-imagery.html.