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THE UNITED STATES OF AMERICA

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August 05, 2002

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APPLICATION NUMBER: *60/297,081*
FILING DATE: *June 08, 2001*
RELATED PCT APPLICATION NUMBER: *PCT/US02/18321*

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

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Certifying Officer

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

DOCKET NUMBER
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CERTIFICATE UNDER 37 CFR 1.10
'Express Mail' mailing label number: EL585708737US
Date of Deposit: June 8, 2001

I hereby certify that this paper or fee is being deposited with the United States Postal Service 'Express Mail Post Office To Addressee' service under 37 CFR 1.10 and is addressed to the Commissioner for Patents, Washington, D.C. 20231.

By: Mamie Managan
Name: Mamie Managan

REQUEST FOR PROVISIONAL APPLICATION UNDER 37 C.F.R. § 1.53(b)(2)

BOX PROVISIONAL PATENT APPLICATION
Commissioner for Patents
Washington, DC 20231

Dear Sir:

This is a request for filing a Provisional application for patent under 37 CFR § 1.53(b)(2) entitled A REAL TIME HIGH DYNAMIC RANGE LIGHT PROBE by the following inventor(s):

Full Name Of Inventor	**Family Name** Debevec	**First Given Name** Paul	**Second Given Name** E.
Residence & Citizenship	**City** Marina del Rey	**State or Foreign Country** California	**Country of Citizenship** USA
Post Office Address	**Post Office Address** 4105 Pacific Avenue, #3	**City** Marina del Rey	**State & Zip Code/Country** CA 90292
Full Name Of Inventor	**Family Name** Waese	**First Given Name** Jamie	**Second Given Name**
Residence & Citizenship	**City** Santa Monica	**State or Foreign Country** California	**Country of Citizenship** CANADA
Post Office Address	**Post Office Address** 960-D 19th Street	**City** Santa Monica	**State & Zip Code/Country** CA 90403

1. ☒ Enclosed is the Provisional application for patent as follows: 3 pages of specification, and 0 sheets of drawings.

2. ☒ Small Entity Status is Claimed.

3. ☒ Payment of Provisional filing fee under 37 C.F.R. § 1.16(k) :
   - ☒ Attached is a check in the amount of $ 75.00.
   - ☐ Please charge Deposit Account No. 16-2230.
   - ☐ PAYMENT OF THE FILING FEE IS BEING DEFERRED.

4. ☒ The Commissioner is hereby authorized to charge any additional fees as set forth in 37 CFR §§ 1.16 to 1.18 which may be required by this paper or credit any overpayment to Account No. 16-2230.

5. ☐ Enclosed is an Assignment of the invention to , Recordation Form Cover Sheet and a check for $ to cover the Recordation Fee.

06/14/2001 MFANREIA 00000005 60297081
01 FC:214 75.00 OP

☐ Also Enclosed:

7. ☐ The invention was made by the following agency of the United States Government or under a contract with the following agency of the United States Government:

8. ☒ Address all future communications to the **Attention of Marc E. Brown, Esq.** (may only be completed by attorney or agent of record) at the address below.

9. ☒ A return postcard is enclosed.

Respectfully submitted,

Dated: 6/8/01

By: ____________________
Marc E. Brown
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A Real Time High Dynamic Range Light Probe

Summary of Purpose

In order to successfully composite CG elements into live action scenes it is crucial that the lighting of the CG object match the lighting of the scene it is being composited into. One technique people have used to reproduce the incident light in a live action scene is to create a high dynamic range photograph of a silver ball placed at that location (commonly referred to as a "light probe") and then use that light probe as a source for image based lighting techniques. Unfortunately, light probe data is both time consuming and cumbersome to produce.

Summary of Background State of the Art

Currently, in order to create a high dynamic range image of a silver ball one must take an iterative series of photographs with the exposure value of each image being stopped down by a given increment from the exposure value of the one before. In order to assure that all the captured images line up, both the camera and the silver ball cannot move in relation to each other and must thus be fixed to tripods. Later, each of the images are assembled into a single high dynamic range image using a program such as HDR Shop (give ref). If an artist wished to accurately illuminate a CG object traveling through a complex lighting environment, it would be necessary to capture these iterative photographs at numerous locations (ideally at every frame) along the object's path. Clearly, this would be an ambitious task, and it could never be achieved in real time.

Summary of Advantages over Existing Practices

One solution for creating a Real Time High Dynamic Range Light Probe is to develop a system in which multiple exposures of the same image can be captured within a single video frame. We did this by modifying a standard five point Multi-Image Filter (a faceted lens that is commonly used to create photographic kaleidoscope effects), and applying successively increasing values of neutral density gel to four of the five facets of the filter (3.333, 6.666, 10 and 13.333 stops). This modified filter effectively produces a single image that is divided up into five identical regions, with the center region capturing a "pure" view and the other four regions stopped down to their own unique exposure value. This modified filter was then placed on a standard video camera that is mounted along with a silver ball on a three-foot span of angle iron (see Figure 1).

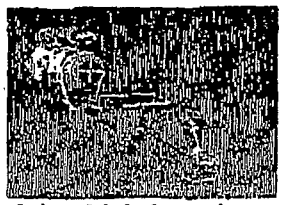

Figure 1. A real time high dynamic range light probe.

Assuming the relation between the camera and the silver ball never changes (by taping off focus and zoom controls, etc.), the Real Time High Dynamic Range Light Probe only needs to be calibrated once. This can be done in a single image by capturing several bright light sources across the silver ball's field of view, or over several images by waving a bright light source around the room. If one wished to compensate for the angle shift introduced by parallax effects from the various facets of the multi-image filter, one simply computes the arctangent of the distance between facets divided by the distance between the lens and the silver ball. By determining the number of degrees each facet is offset from the center, we are able to warp each region of the filter according to the direction space of its view of the ball. In our case, each facet's view of the ball was computed to be 2.7 degrees off from center.

$$\arctan\left(\frac{\text{distance between facets}}{\text{distance from lens to ball}}\right) = \text{offset between facets}^{\circ}$$

More accurate calibration can be done with the help of a light stage which provides a "master key" for factoring out lens distortion and imperfections in the silver ball. For all practical purposes, however, we found that simply computing the pixel shift and then overlapping each region of the multi-image filter was sufficient for performing image based lighting.

In order to capture high dynamic range light probe data at every frame along a path, one simply presses 'record' on the video camera and carries the Real Time High Dynamic Range Light Probe along the desired path. A computer program then imports each recorded frame, isolates the five distinct images in each frame, aligns them according to predetermined calibration data, and then assembles the aligned images into a high dynamic range photograph.

Figure 2 shows a raw, unprocessed image from the light probe.

Figure 2. Five exposures of a silver ball taken at exactly the same time.

Figure 3 shows several exposures of high dynamic range image that was assembled from a single light probe frame.

Figure 3. High dynamic range images captured in a single frame.

Figure 4 shows a CG object, lit with captured light from the Real Time High Dynamic Range Light Probe.

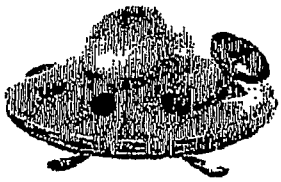

Figure 4. A CG spaceship that is synthetically lit with captured light.

Current State of Development

This simple technique will permit artists to composite CG objects into complex lighting environments, accurately reproducing high dynamic range lighting parameters for every single frame. It is a new and useful technique, which in the future will benefit from greater precision in applying the neutral density

lters to each facet of the multi-image filter, a less bulky (and light obstructing) camera rig, and higher resolution video cameras.

We are currently looking to perfect the technique and find ways to simplify its implementation into a production environment.