Gradient Domain Fusion

Ola Pietka

May 27, 2023

Introduction

The aim of this project is to explore the concepts of High Dynamic Range (HDR) images and Image-Based Lighting (IBL), which have become increasingly important in the field of computer graphics and digital media. The project will focus on the technical aspects of HDR and IBL, including their creation, manipulation, and application.

Recovering HDR Radiance Maps

To create an HDR image from a set of LDR (low dynamic range) images, I need to follow a process called "HDR merging" or "HDR compositing." This process involves combining multiple exposures of the same scene to create a single image that has a higher dynamic range than any of the individual images.

Figure 1: Exposure time 1/10.

Figure 2: Exposure time 1/40.

Figure 3: Exposure time 1/160.

Naive LDR merging

The naive LDR merging method involves taking the average of the LDR images at each pixel location. This approach assumes that the pixel values in each image are proportional to the scene radiance, which is not always accurate. This method can result in an image with improved dynamic range, but it may not be as accurate or detailed as other HDR merging methods.

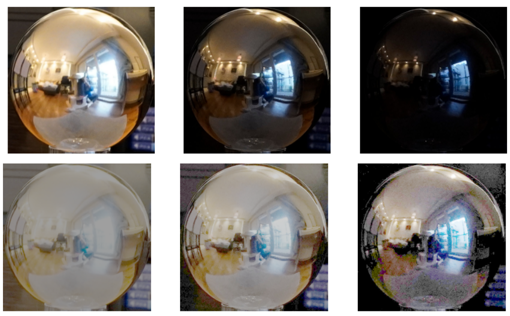

Figure 4: Top: Rescaled LDR images. Bottom: Rescaled log irradiance images from naive method.

Weighted LDR merging

Weighted LDR merging is a more advanced method of merging low dynamic range (LDR) images to create an image with a higher dynamic range. Unlike naive LDR merging, which simply averages the pixel values from each image, weighted LDR merging uses a set of weights to give more importance to pixels with better quality information.

Figure 5: Top: Rescaled LDR images. Bottom: Rescaled log irradiance images from weighted method.

LDR merging with camera response function estimation

LDR merging with camera response function (CRF) estimation is even more advanced technique for creating high dynamic range (HDR) images. This method involves estimating the CRF of the camera used to capture the LDR images and using this information to merge the images into an HDR image.

Figure 6: Top: Rescaled LDR images. Bottom: Rescaled log irradiance images from calibration method.

The graph of g versus intensity (Figures 17 & 18) is a plot of the estimated camera response function, where g is the response of the camera to light at a particular intensity level, and intensity is the pixel value of the LDR image at the same level. The plot typically shows a curve that represents the non-linear relationship between the camera's response and the intensity of light. The shape of the curve depends on the camera and the scene being photographed.

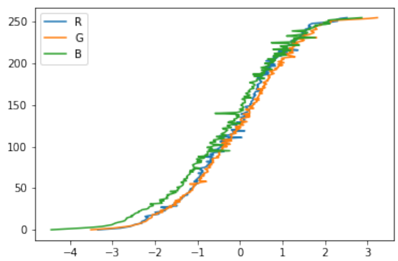

Figure 7: Plot of g vs intensity.

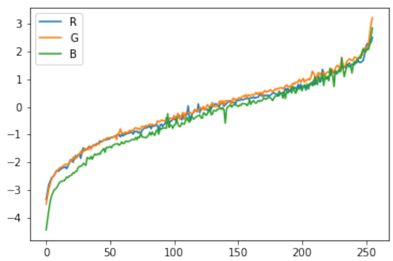

Figure 8: Plot of intensity vs g.

Comparison

In summary, the differences between these methods are the level of complexity, accuracy, and detail in the resulting HDR image. The naive method is the simplest but can result in loss of detail and contrast, while the weighted method preserves more detail and contrast. The calibration method is the most complex but can result in the most accurate and detailed HDR image.

Figure 9: Comparison of the three HDR methods: left - naive, middle - weighted, right - calibration.

```
naive:          log range =  6.553      avg RMS error =  0.371
weighted:       log range =  7.059      avg RMS error =  0.285
calibrated:     log range =  8.622      avg RMS error =  0.122
```

Figure 10: Comparison of the dynamic range and RMS error consistency of the three methods.

Rendering synthetic objects into photographs

Panoramic transformations

Since the HDR image of the spherical mirror has been obtained, the aim is to utilize it for image-based lighting. But due to compatibility issues, several programs cannot accept the ”mirror ball” format. Hence, it is necessary to convert it to another panoramic format that is widely accepted, such as equirectangular (latitude longitude).

To perform the mirror ball to equirectangular transformation, it is necessary to establish the correspondence between the two domains. This can be achieved by determining the normals of the sphere (N) and assuming a constant viewing direction (V). Using the formula R = V - 2 * dot(V,N) * N, the reflection vectors can be calculated, which denote the direction from which light is incoming from the world and bouncing off the sphere before reaching the camera. These reflection vectors can then be converted into spherical coordinates (phi and theta) by fixing the distance to the origin, r, to be 1.

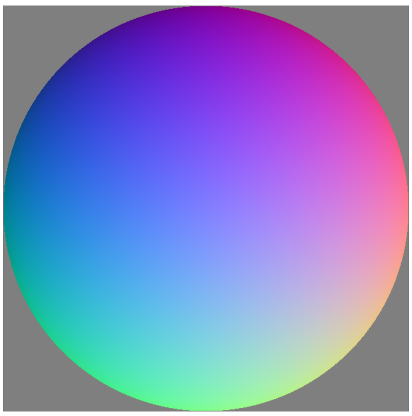

Figure 11: Normal vectors.

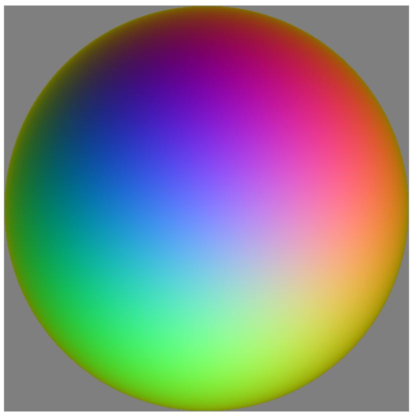

Figure 12: Reflection vectors

Figure 13: Equirectangular image from calibration HDR result.

Rendering

I render the synthetic objects using Blender 2.8 and LDR images and perform "differential render" compositing (Debevec, 1998). This can be done using a simple pixel-wise equation. Let R be the rendered image with objects, E be the rendered image without objects, M be the object mask, and I be the background image. The final composite is computed with: $composite = M * R + (1 - M) * I + (1 - M) * (R - E) * c$, where $c = 1.5$.

Figure 14: Rendered objects.

Figure 15: Rendered local geometry.

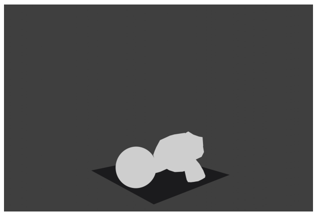

Figure 16: Rendered mask.

Figure 17: Background image.

Figure 18: Final composited result.

References

Paul Debevec. 1998. Rendering synthetic objects into real scenes: Bridging traditional and image-based graphics with global illumination and high dynamic range photography. page 1–10.