Chapter 2

Animated Skybox Rendering and Lighting Techniques

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Figure 1. *A real-time rendering of the Parthenon.*

2.1 Overview

In this chapter we briefly describe techniques used represent and render the high dynamic range (HDR) time-lapse sky imagery in the real-time Parthenon demo (Figure 1). These methods, along with several other rendering techniques, achieve real-time frame-rates using the latest generation of graphics hardware.

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2.2 The algorithm

Efficient storage and rendering of a high-dynamic range animated skybox is a significant challenge for real-time applications. In our application, the sky is represented by a series of 696 panoramic time-lapse sky images, consisting of 2.17 GB of compressed HDR imagery (Figure 2). Since the target is to share the 256 MB of video memory with the rest of the demo, we need to develop a method to compress this data.

Preprocess. The first step of our approach is to decompose the sky video into a sequence of reduced range sky images with low-frequency HDR information. This is accomplished by computing 3rd order spherical harmonic coefficients for each image, resulting in a low-frequency representation (Figure 3), and then dividing the HDR image by the low-frequency result and storing it using 8 bits per channel. The reduced range imagery can then leverage standard video codecs such as XVid or DivX.

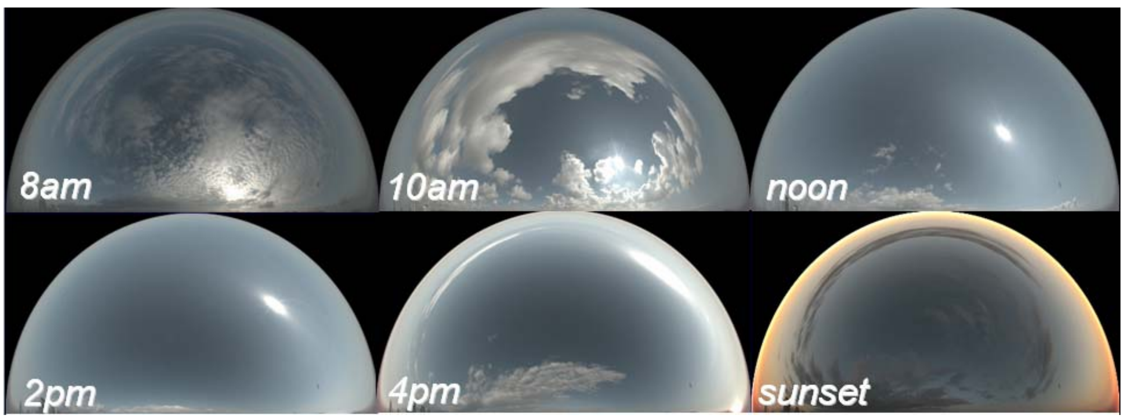

Figure 2. *Six frames from the animated sky sequence.*

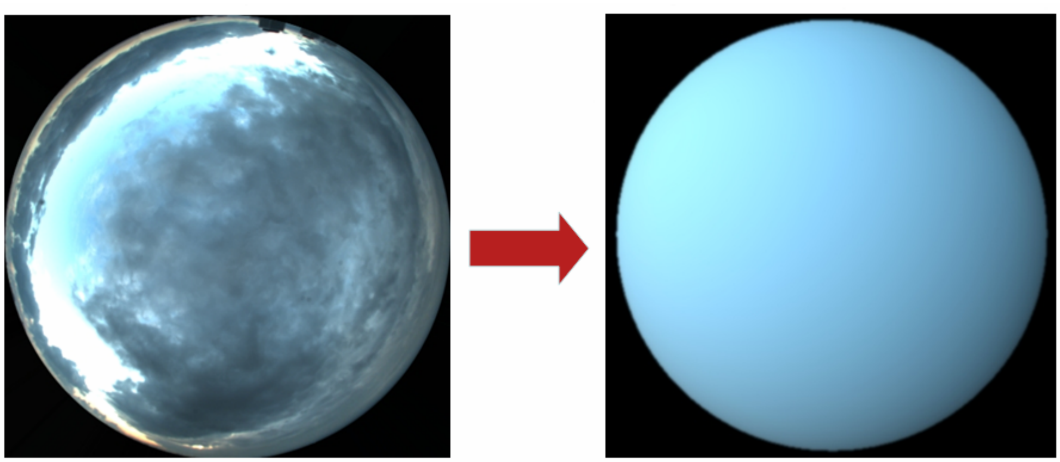

Figure 3. *From the original HDR sky image, a low-frequency approximation based on spherical harmonics is computed.*

Runtime. In order to render the skybox, a reduced range video sequence is played back into a texture that is mapped to the hemisphere.

The low-frequency HDR spherical harmonics coefficients are used in three ways. The first usage is to re-multiply the reduced range imagery by the HDR data at runtime in order to regenerate the high dynamic range imagery.

The second usage of the low-frequency HDR spherical harmonics data is to provide ambient illumination for any given time of the day, as illustrated in Figure 4. This is achieved by looking up the color of the light coming from the sky in the direction of the surface's bent normal. For direct illumination, we precompute and use a per-frame sun color that accounts for occlusion by clouds and reddening of the sun in the evening sky. The resulting illumination at different times of the day is shown in Figure 5.

The third usage is to provide a smooth transition between the distant terrain and the sky. We achieve a realistic horizon rendering result by blending between the reconstructed sky data and the approximation using spherical harmonics as we approach the horizon. Below the horizon, only the spherical harmonics approximation is used. This allows us to render the far terrain using alpha-blending near the horizon and get a smooth transition between land and sky as shown in Figure 6.

Optic flow. The running time for the demo is roughly 120 seconds, so for 690 frames of data, the video frame-rate would only be about six frames per second if it were expanded to the full length of the video sequence. To make the playback smoother, we pre-compute the inter-frame optic flow, in order to morph each frame of video into the next using the skybox pixel shader at runtime. Since the cloud motion field is relatively low-frequency for most of the video sequence, the optic flow information is stored as 16x16 images in slices of a 3D texture. Using the 3D texture allows for smooth interpolation of the flow-fields between subsequent frames.

Figure 4 *The ambient lighting at different times of the day.*

Figure 5 *The final rendered result, including direct illumination and shadow mapping at different times of the day.*

Figure 6*. Approximate horizon rendering by alpha-blending the terrain over the spherical harmonics approximation of the sky near the horizon.*

2.3 Summary

To summarize, we presented methods for efficiently storing and rendering an animated skybox. The method decomposes the sky imagery and stores it using an 8-bit high-frequency video along with 3^{rd} order spherical harmonics coefficients to capture low-frequency HDR data. We also show how we use this spherical harmonics approximation in order to light the scene.

2.4 Acknowledgements

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