IMAGE BASED RENDERING: *Using High Dynamic Range Photographs to Light Architectural Scenes*

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Abstract
Image Based Rendering is a digital rendering technique that uses High Dynamic Range photographs captured from a physical environment to light three-dimensional digital models. These renderings are useful for representation and design evaluation purposes. The paper discusses the rationale, advantages, and the methodology of the technique; and architectural applications are exemplified through different settings and lighting conditions.

Introduction

Three-dimensional digital models are becoming more and more common in architectural practice. Especially in later design stages, renderings often attempt to produce a realistic and detailed depiction of the building, as close to the visual experience of the built environment as possible. Transition occurs from ideation and the process of abstraction to the simulation of the space and the evaluation of the design intentions. Therefore, visualization and simulation techniques become instrumental in making sound design decisions, evaluations, and predicting the final appearance that incorporates the physical structure and the visual qualities of the designed space.

Commonly used digital techniques attempt to create photorealistic and/or physically based renderings using geometric information, materials, and light sources. However, rendered images may not provide a faithful visual representation of the space and therefore, can be misleading when used as the basis for design decisions. Some of the discrepancies are related to the capabilities of the rendering algorithms, the validity of the user inputs, and the knowledge base of the user. Currently, with the right tool and expertise, it is possible to model the geometry, material properties, electric light sources and sunlight with reasonable accuracy. However, two issues continue to be challenging:

- Surrounding buildings and vegetation are mostly ignored or simplified to achieve computational efficiency. Buildings are often depicted either in an empty environment, digitally inserted into a photograph, or created with the surrounding as part of the model. When modeled in an empty environment, the model has basically no site context (Figure 1). Images of models digitally inserted into their environments, using digital image-editing software, may look unrealistic and can occasionally be distracting (Figure 2). These first two solutions ignore the impact of site shadowing and reflections on the visual quality of the space. A common solution for creating a fully integrated model is to include the surrounding environment (Figure 3). Modeling time and computational power needed is proportional to the detail desired, and it can be prohibitive.

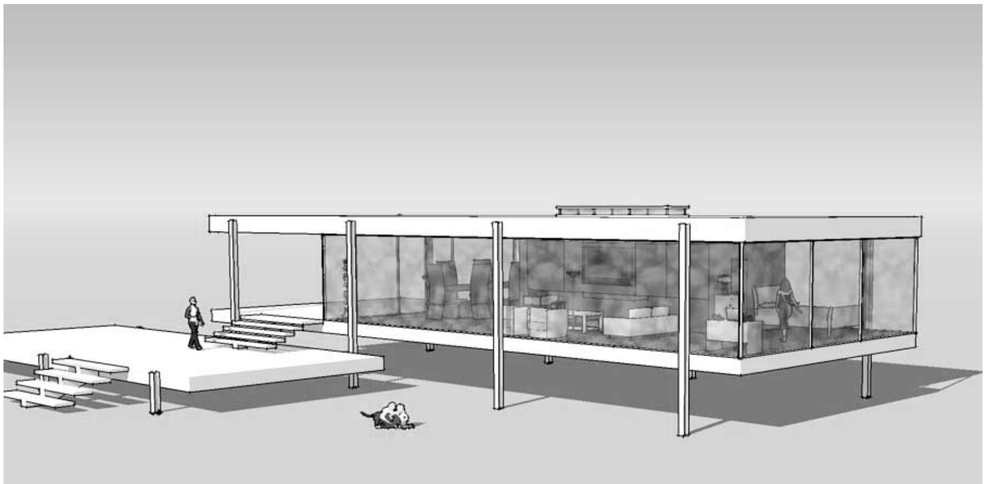

Figure 1: Digital model in an empty environment

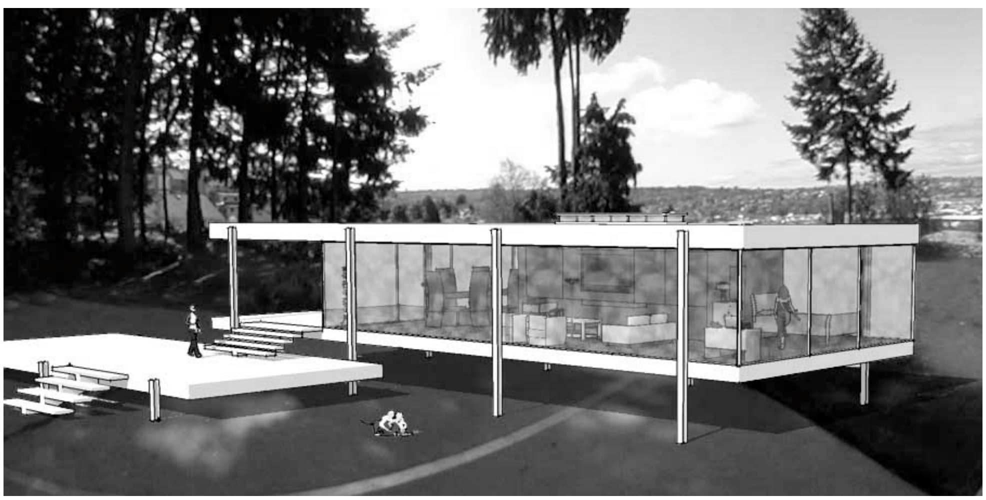

Figure 2: Digital model with the background photograph inserted as the surrounding environment

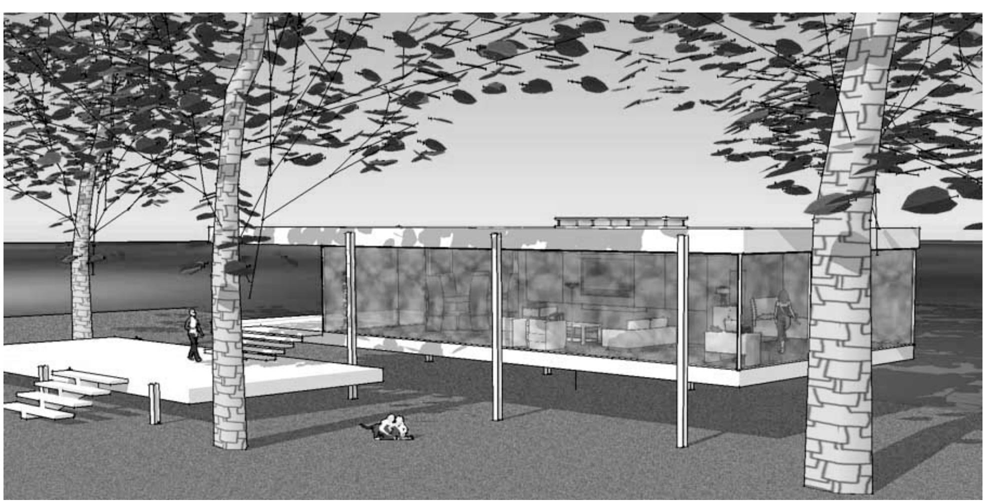

Figure 3: Digital model including the surrounding environment

- Daylighting changes during the course of the day and year, depending on the sun position (a predictable parameter) and weather and cloud cover (an unpredictable parameter). Sky luminance is defined by mathematical models through “standard skies” that can predict a range of conditions. However, these mathematical formulae do not represent actual sky conditions at any time or any location. The rendered images lack both accuracy and realism, which may hamper the evaluation of the experiential qualities of the space.

High Dynamic Range Photography and Image Based Rendering

Recent developments in High Dynamic Range (HDR) Photography[1] enable us to capture high luminance environments (such as the sun and the sky) and complex surroundings (such as the urban fabric and vegetation). Images of a physical environment along with the actual lighting information are recorded by shooting a range of exposures with a digital camera and tripod. Once these exposures have been combined into a single HDR photograph using computer software, the resultant photograph can be inserted into a digital model, using the Image Based Rendering (IBR)[2] method, to act as the light source and the background image for the model. The HDR photography can cover an 180˚ hemisphere or the full 360˚ of an environment, recording the light coming from all sides and reflected from the surrounding surfaces (Fig. 4).

A physically based rendering program can use this lighting information to light a digital model, as illustrated in Figures 5 - 8.

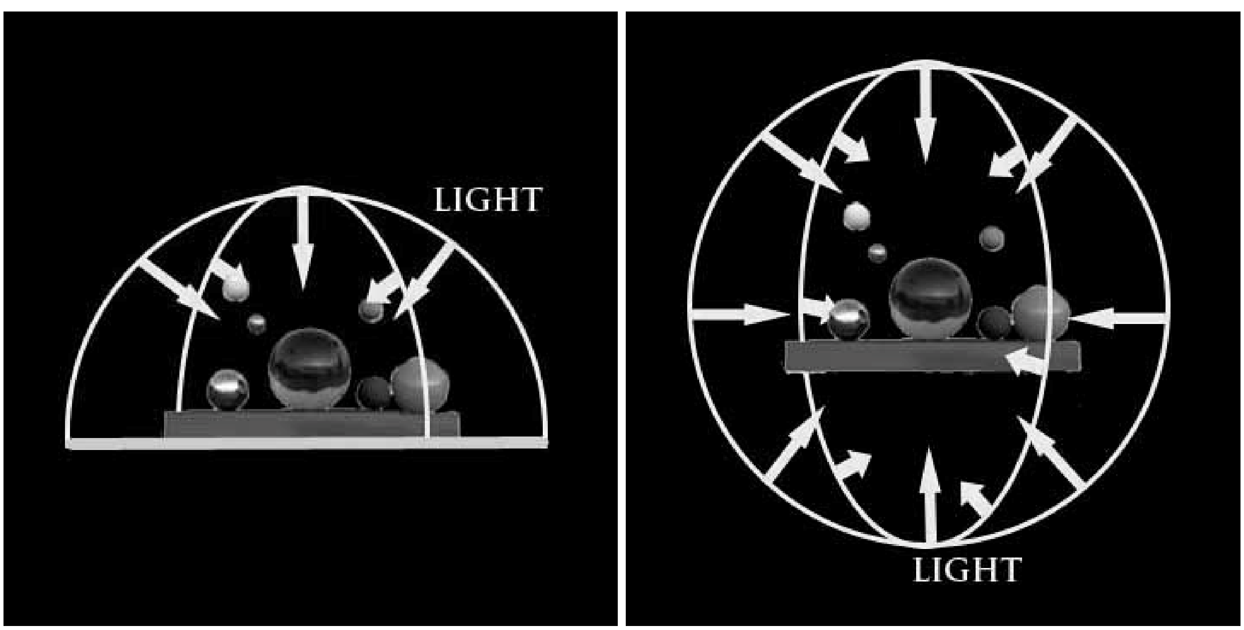

Figure 4: Either a hemispherical HDR photograph of the sky (left) or the full environment sphere (right) can light an IBR rendering

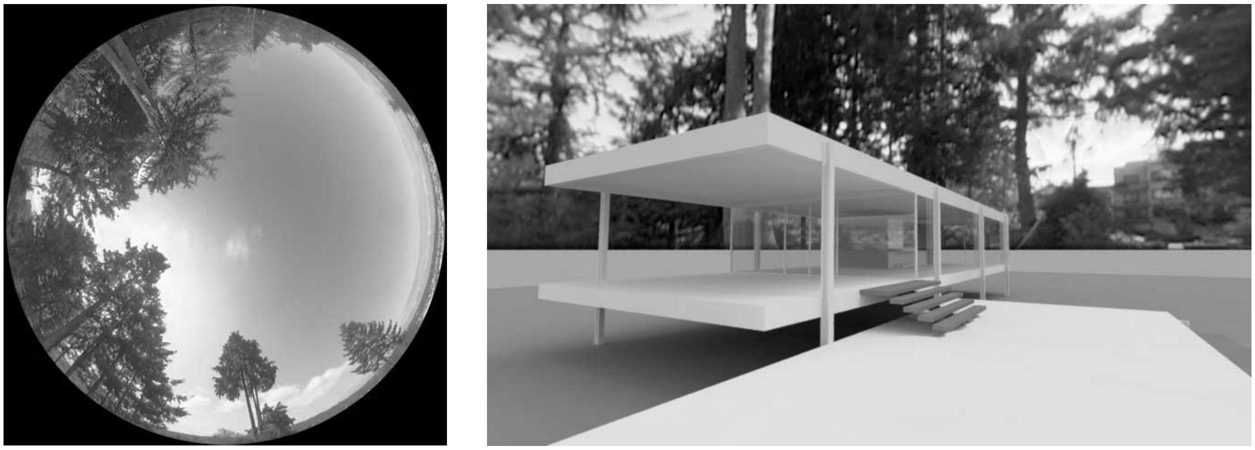

Figure 5: A hemispherical HDR photograph is used to light a digital model and create the rendering

Figure 6: Interior view

Figure 7: One vertical hemispherical HDR photograph is used to light an interior scene

Methodology

The specific method for creating an image-based rendering for architectural use consists of four basic steps:

1. HDR images must be captured or acquired, preferably of the specific architectural site at various times of the day, year, and with differing weather conditions.

2. The digital model must be constructed; detail may range from a mass model to intricate geometry.

3. The HDR photograph wrapped as a hemisphere or sphere is inserted as the light source and background for the model.

4. The rendered images show accurate lighting for the model at the time and place the HDR photograph was captured. This can be repeated with different HDR photographs and/or camera viewpoints (Figure 9).

Discussion

IBR has many promising usages within the field of architecture and lighting design. The technique can produce renderings that incorporate existing site and weather conditions at a particular location, date, and time. Use of this method negates the need to model complex environments, such as surrounding trees and buildings. The resulting renderings are visually compelling and numerically accurate: they can be used for visual appraisal and quantitative analysis to make informed design decisions since they can communicate the final appearance of the design based on the physically occurring lighting conditions. This is a major improvement over the products of more commonly used architectural modeling and rendering programs.

NOTES

1. Paul Debevec and Jitendra Malik, "Recovering High Dynamic Range Radiance Maps from Photographs," *SIGGRAPH '97* (August 1997), 369-378.

2. Paul Debevec, "Image-Based Lighting," *IEEE Computer Graphics and Applications,* March/April 2002, 22(2), 26-34.

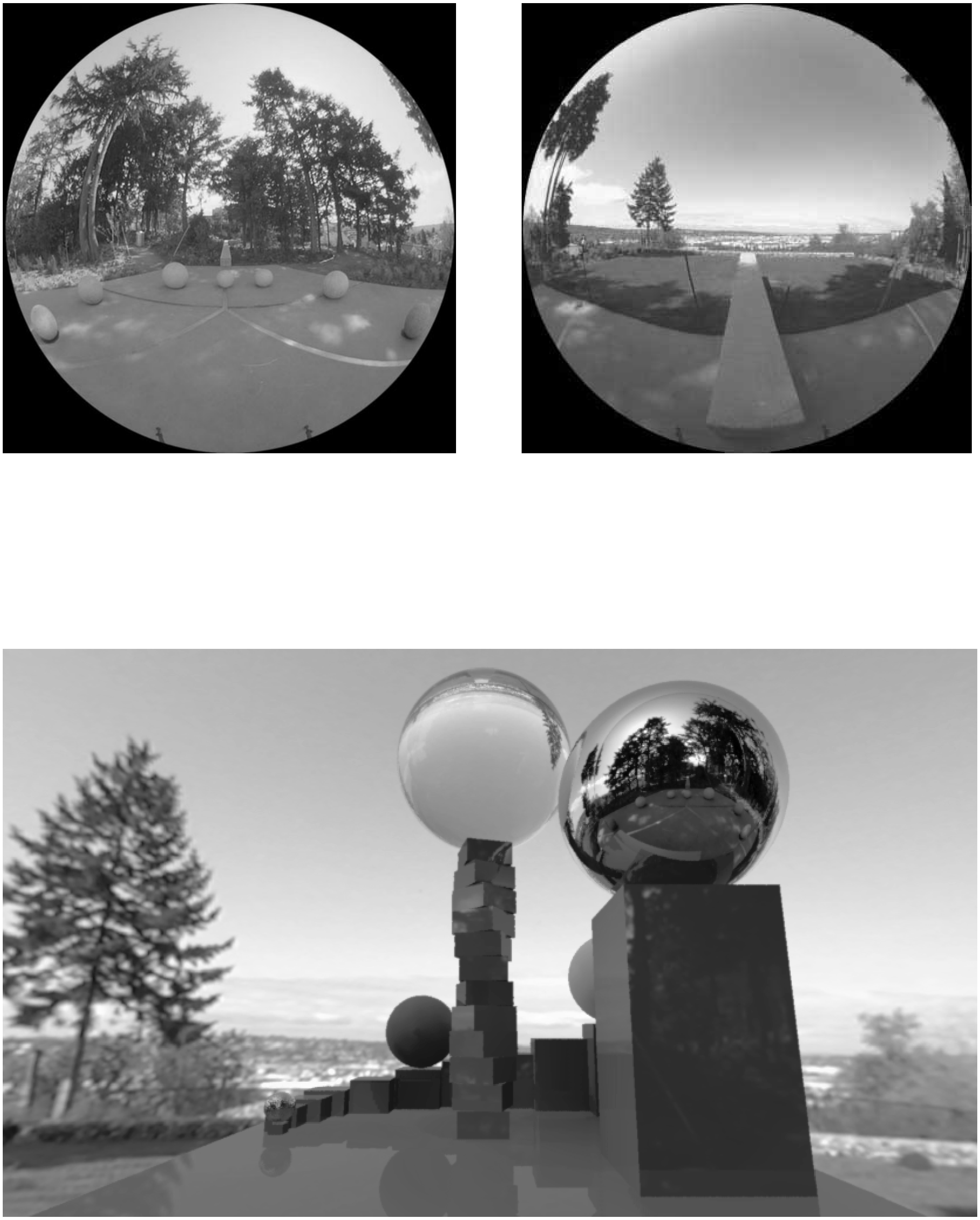

Figure 8: Two opposing hemispheres (top) are combined to light a model from all sides

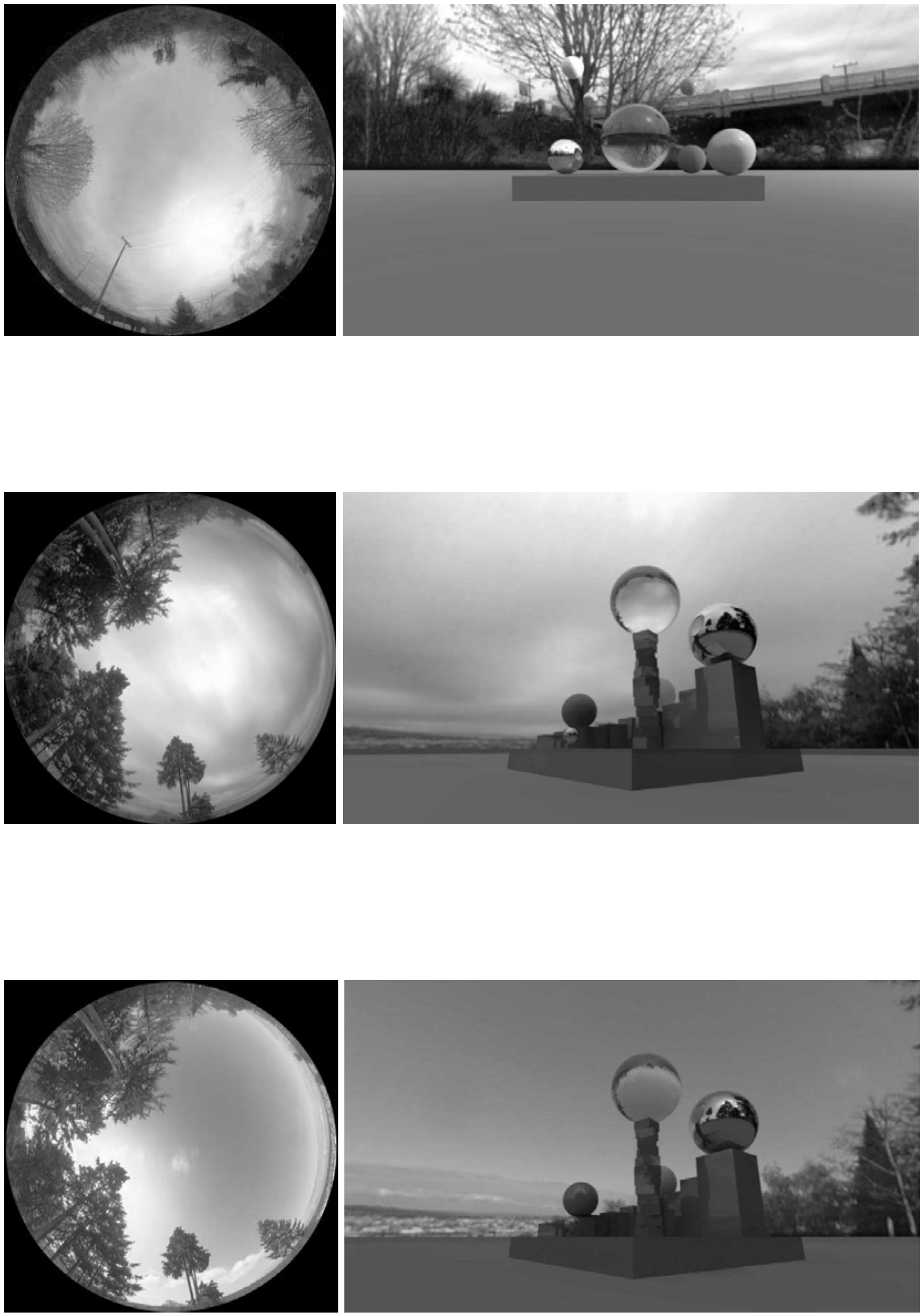

Figure 9: Various HDR sky photographs and resultant rendered images