Night Rendering

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Abstract

The issues of realistically rendering naturally illuminated scenes at night are examined. This requires accurate models for moonlight, night skylight, and starlight. In addition, several issues in tone reproduction are discussed: eliminatiing high frequency information invisible to scotopic (night vision) observers; representing the flare lines around stars; determining the dominant hue for the displayed image. The lighting and tone reproduction are shown on a variety of models.

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1 Introduction

Most computer graphics images represent scenes with illumination at daylight levels. Fewer images have been created for twilight scenes or nighttime scenes. Artists, however, have developed many techniques for representing night scenes in images viewed under daylight conditions, such as the painting shown in Figure 1. The ability to render night scenes accurately would be useful for many applications including film, flight and driving simulation, games, and planetarium shows. In addition, there are many phenomena only visible to the dark adapted eye that are worth rendering for their intrinsic beauty. In this paper we discuss the basic issues of creating such nighttime images. We create images of naturally illuminated scenes, so issues related to artificial light sources are not considered. To create renderings of night scenes, two basic issues arise that differ from daylight rendering:

- What are the spectral and intensity characteristics of illumination at night?
- How do we tone-map images viewed in day level conditions so that they "look" like night?

Illumination computations

To create realistic images of night scenes we must model the characteristics of nighttime illumination sources, both in how much light they contribute to the scene, and what their direct appearance in the sky is:

- **The Moon**: Light received directly from the Moon, and moonlight scattered by the atmosphere, account for most of the available light at night. The appearance of the Moon itself must also be modeled accurately because of viewers' familiarity with its appearance.
- **The Sun**: The sunlight scattered around the edge of the Earth makes a visible contribution at night. During "astronomical" twilight the sky is still noticeably bright. This is especially important at latitudes more than 48° N or S where astronomical twilight lasts all night in midsummer.
- **The planets and stars**: Although the light received from the planets and stars is important as an illumination source only on moonless nights, their appearance is important for night scenes.
- **Zodiacal light**: The Earth is embedded in a dust cloud which scatters sunlight toward the Earth. This light changes the appearance and the illumination of the night sky.
- **Airglow**: The atmosphere has an intrinsic emission of visible light due to photochemical luminescence from atoms and molecules in the ionosphere. It accounts for one sixth of the light in the moonless night sky.

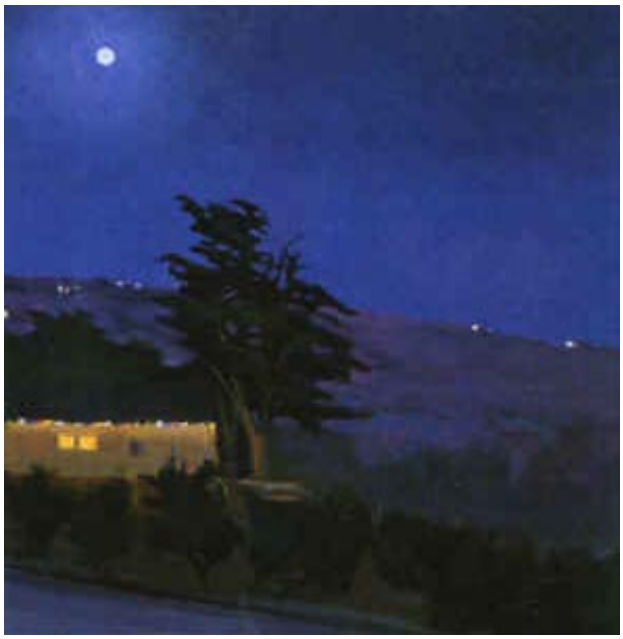

Figure 1: *A painting of a night scene. Most light comes from the Moon. Note the blue shift, and that loss of detail occurs only inside edges; the edges themselves are not blurred. (Oil, Burtt, 1990)*

Several authors have examined similar issues of appearance and illumination for the daylight sky [8, 20, 32, 35, 43, 33]. To our knowledge, this is the first computer graphics paper that examines physically-based simulation of the nighttime sky. We restrict ourselves to natural lighting, and we include all significant natural sources of illumination except for aurora effects (northern lights).