EG 2016 - Posters, The Eurographics Association, pp. 37-38. The definitive version is available at http://diglib.eg.org/ (http://dx.doi.org/10.2312/egp.20161055).

Skyglow: Towards a Night-time Illumination Model for Urban Environments

Tom Minor[1] and Robert R. Poncelet[1] and Eike Falk Anderson[1]

[1]The National Centre for Computer Animation, Bournemouth University, United Kingdom

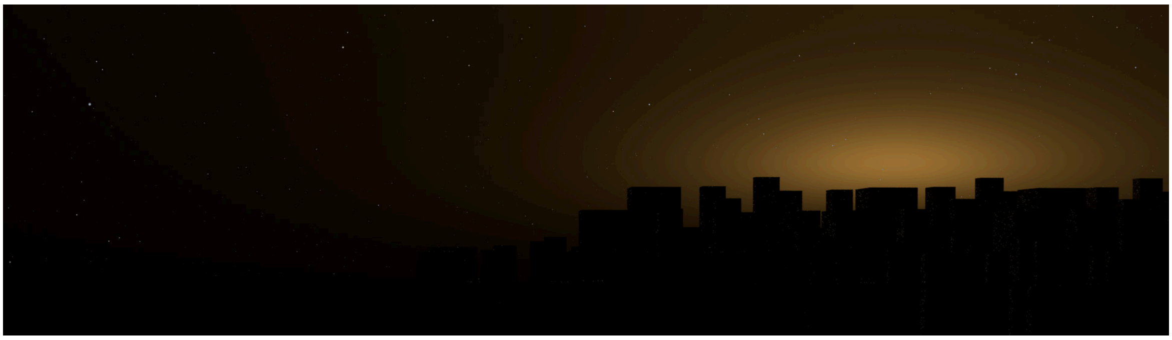

Figure 1: *Rendering urban night sky with "skyglow" using the RenderMan RIS renderer.*

Abstract

For night-time scenes in computer graphics there exist few consistent models or implementations for sky illumination, and those that do exist lack the feature of light pollution from artificial light sources. We present initial results for a physically-based night sky model including this "skyglow". Our model extends the existing models with the aforementioned "skyglow" from artificial light sources, using a technique derived from equations developed in the field of astronomy and adapted for a computer graphics context. Our current model has been implemented for Pixar's RenderMan renderer and also been trialled with ShaderToy.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Animation; I.6.8 [Simulation and Modeling]: Types of Simulation—Visual

1. Introduction

The best known night sky model currently in use is that developed by Jensen et al. [JDD*01], which accounts for the different illumination sources (excluding skyglow) contributing to the colour of the night sky and their positions in the sky, and our model builds primarily on this work. Skyglow is the effect of artificial light spill, i.e. light pollution, from urban areas reflecting from atmospheric particles. This lightening up of the night sky above built-up areas due to artificial light sources is a noticeable omission in existing night-time illumination models. Consequently in the visual effects industry either photographic background images that include skyglow are used, or the skyglow effect is painted in by artists. We aim to remove this limitation by adding skyglow (Figure 1) to existing methods for night sky rendering.

2. Related Work

Atmospheric rendering is the first step to rendering a night sky. A comprehensive computer graphics model for rendering the atmosphere was presented by Nishita et al. [NSTN93] and expanded on by Preetham et al. [PSS99], describing techniques for atmospheric scattering, the phase functions for different types of atmospheric particles and ray-marching integration methods. This formed the basis for the night sky model developed by Jensen al. [JDD*01], which calculates the contributions of the different types of natural light sources that result in the colour of the night sky. A sky rendering model combining the existing daytime and night-time models was presented by Undeger [Und09]. While the model by Jensen et al. [JDD*01] is quite comprehensive, light contributed by artificial light sources, including light pollution leading to skyglow, is not

EG 2016 - Posters, The Eurographics Association, pp. 37-38. The definitive version is available at http://diglib.eg.org/ (http://dx.doi.org/10.2312/egp.20161055).

included in this model. Outside of the computer graphics domain, in the field of astronomy, where light pollution is a problem for those observing the night sky, models for predicting skyglow from artificial light sources have been developed to allow astronomers to find suitable observation sites. Both Garstang [Gar86] and Yocke et al. [YHH86] describe analytical methods for modelling skyglow. A comprehensive survey and review of different light pollution models was presented by Garstang [Gar91]. For our work we adapted these methods to the computer graphics domain and used them to extend the night sky model by Jensen et al. [JDD*01] with an accurate representation of skyglow.

3. Towards a Night Sky Model including Skyglow

We have implemented our model using RenderMan RIS, adding skyglow to the night sky. For this we represent the urban area from which light pollution emits as a disk [Gar86] from which light samples for each sub-ray sample are taken using disk point picking [Wei], with radius and location of the skyglow source disk implemented as user-specified parameters. A further user-defined variable P that provides the population size combined with an approximation of contributed lumens per person L [Gar86] provides the intensity of artificial light reflected upwards by the ground as $I_{up} = \frac{LP}{2\pi}\{2G(1-F)cos\psi + 0.554F\psi^4$, where F is the fraction of light radiated directly upwards from the source, G is the Lambertian reflectivity of the ground, and ψ is the zenith distance of an upbound light ray. We then employ the atmospheric ray-marching equation proposed by Yocke et al. [YHH86] – implemented with optimisations similar to those described by Nishita et al. [NSTN93] – to determine the skyglow component of our illumination model:

$$I(\lambda)_{r+\Delta r} \simeq \frac{\phi(\lambda,\theta)}{4\pi} b_{scat}(\lambda) F_s(\lambda)\Delta r - \langle b\rangle_{ext}(\lambda) I_r(\lambda)\Delta r + I_r$$

Here I is the spectral irradiance, λ is the wavelength of light, r is the distance along the ray, Δr is the distance between sub-ray samples, $\phi(\lambda,\theta)$ is the phase function defining the distribution of photons scattered by particles of a given wavelength with the scattering coefficient $b_{scat}(\lambda)$ and the integration function for the extinction coefficient $\langle b\rangle_{ext}(\lambda)$, and $F_s(\lambda)$ is the flux from the source in $Wm^{-2}\mu m^{-1}$ for a given wavelength. The equation is integrated in a definite manner, i.e. for every sample along the ray there are multiple light source samples I_r. The sum of the light sample result, multiplied by Δr is the skyglow component (Figure 2), which is used as the intensity value of the skyglow colour. We then add the skyglow component to the night sky resulting from the method by Jensen et al. [JDD*01]. As described there, stars are not raytraced but composited from a generated star map image – as skyglow in urban areas can be brighter than some stars, the maximum value of the skyglow value and the star brightness value is used where bright pixels representing stars in the star map are encountered, and only the brightest stars remain visible.

4. Conclusions and Future Work

We have presented an initial model for night sky rendering that includes skyglow from light pollution, which is still work in progress and has a number of limitations that we hope to address in the future. So far we only calculate the intensity and distribution of skyglow, using an estimate of its colour, which we hope to improve

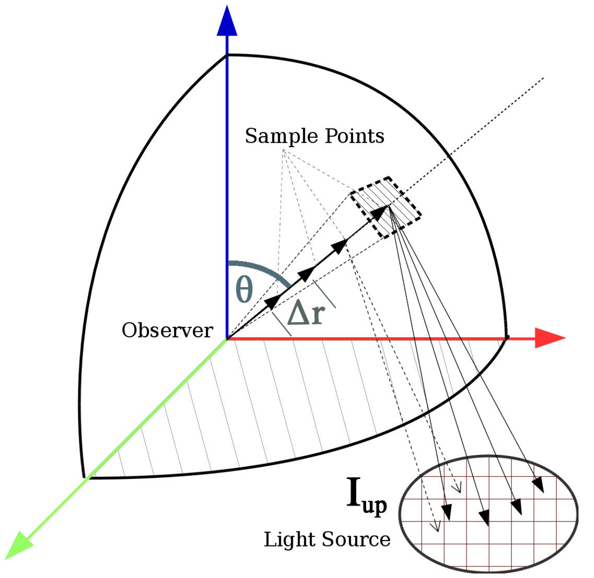

Figure 2: *Atmospheric ray-marching, sampling light from the disk representing the urban area.*

through adding a more accurate method for obtaining the colour of the skyglow. Another aspect that we hope to address is the effect that clouds have on the intensity and colour of skyglow, which is currently not taken into account.

References

[Gar86] GARSTANG R.: Model for Artificial Night-Sky Illumination. *Publications of the Astronomical Society of the Pacific 98* (1986), 364–375. 2

[Gar91] GARSTANG R.: Light Pollution Modeling. In *IAU Colloq. 112: Light Pollution, Radio Interference, and Space Debris* (1991), pp. 56–69. 2

[JDD*01] JENSEN H. W., DURAND F., DORSEY J., STARK M. M., SHIRLEY P., PREMOŽE S.: A physically-based night sky model. In *Proceedings of the 28th Annual Conference on Computer Graphics and Interactive Techniques* (2001), SIGGRAPH '01, ACM, pp. 399–408. 1, 2

[NSTN93] NISHITA T., SIRAI T., TADAMURA K., NAKAMAE E.: Display of the earth taking into account atmospheric scattering. In *Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques* (1993), SIGGRAPH '93, ACM, pp. 175–182. 1, 2

[PSS99] PREETHAM A. J., SHIRLEY P., SMITS B.: A practical analytic model for daylight. In *Proceedings of the 26th Annual Conference on Computer Graphics and Interactive Techniques* (1999), SIGGRAPH '99, pp. 91–100. 1

[Und09] UNDEGER C.: Modeling daytime and night illumination. In *Proceedings of the 2009 Summer Computer Simulation Conference* (2009), SCSC '09, Society for Modeling & Simulation International, pp. 33–39. 1

[Wei] WEISSTEIN E. W.: Disk Point Picking. MathWorld–A Wolfram Web Resource. http://mathworld.wolfram.com/DiskPointPicking.html. 2

[YHH86] YOCKE M., HOGO H., HENDERSON D.: A Mathematical Model for Predicting Night-Sky. *Publications of the Astronomical Society of the Pacific 98* (1986), 889–893. 2