Simulated Spectral Light Transport in Coastal Waters Using Adaptive Photon Mapping

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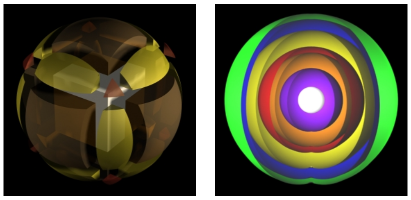

1 Introduction

This poster addresses the so-called *boundary bias* associated with Photon Mapping [Jensen 2001] as well as bias resulting from sparsely populated spectral maps. This work is done in the context of modelling spectrally and spatially variant coastal waters for remote sensing applications. We are particularly interested in simulating hyperspectral scenarios where it will be necessary to model detectors that are sensitive to tens, if not hundreds, of wavelengths. This new approach differentially searches the photon map based on boundary distances and spectral bands. It is being developed within a ray-tracing environment known as DIRSIG [Schott et al. 1999], which is used for modelling remote sensing scenarios and developing algorithms for the terrestrial regime. The current work is a key element in extending its capabilities to the littoral and oceanic domain. The final water modelling environment will be used to develop water quality and underwater target detection algorithms based on existing remote sensing platforms and to quantitatively define the design requirements of future remote sensing systems.

2 Approach

Boundary bias is addressed by modifying the traditional Euclidean distance function adaptively when boundary distances are less than the search radius:

$$D' = \left[\left(\frac{P_x}{B_x}R - O_x\right)^2 + \left(\frac{P_y}{B_y}R - O_y\right)^2 + \left(\frac{P_z}{B_z}R - O_z\right)^2\right]^{\frac{1}{2}},$$

where O is the search site, P is the photon location, and R is the search radius. B denotes the axial distances to the boundary from O, which may be obtained directly by tracing or interpolated from a pre-computed database. The search volume is found by subtracting caps from a sphere and accounting for intersections.

Compared to an RGB map using an equivalent amount of memory, a *hyperspectral* photon map is very sparsely populated on a per-wavelength basis. This would normally require increasing the search volume in order to encompass enough photons to reduce the noise, resulting in an increased bias associated with the radiance estimate. The method presented for spectral bias compensation first finds the mean radiance locally and then estimates the spectral distribution by expanding the search:

Spectral Bias Compensation Algorithm

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Evaluate the localized mean radiance, $\overline{L_\lambda}$
$N_\lambda \leftarrow [\textit{Number of wavelengths}]$
for $i = 1$ to $N_\lambda$ do
    Evaluate expanded volume spectral radiance, $L'_{\lambda_i}$
end for
Calculate mean of spectral radiances, $\overline{L_\lambda}' = \sum_i L'_{\lambda_i}/N_\lambda$
Calculate localized spectral radiance, $L_\lambda = \left(\overline{L_\lambda} \cdot L'_{\lambda_i}\right)/\overline{L_\lambda}'$
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The result of this approach is that the spectrally integrated radiance will minimize bias due to the sparseness of the map and the spectral distribution will not be dominated by noise.

3 Conclusion

Photon Mapping provides a practical and efficient strategy for implementing a radiative transfer algorithm within simulated coastal waters. The bias reductions described in this poster allow the strategy to be applied in a hyperspectral environment and minimize the errors due to boundary conditions where targets of critical importance are found or hidden.

References

JENSEN, H. W. 2001. *Realistic Image Synthesis Using Photon Mapping*. A. K. Peters.

SCHOTT, J. R., BROWN, S. D., RAQUENO, R. V., GROSS, H. N., AND ROBINSON, G. 1999. An advanced synthetic image generation model and its application to multi/hyperspectral algorithm development. *Canadian Journal of Remote Sensing 25*, 2.

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