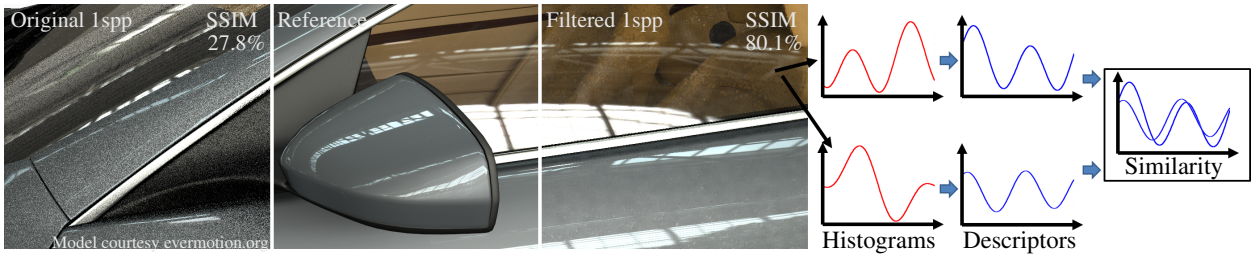
Path Space Similarity determined by Fourier Histogram Descriptors

Pascal Gautron Marc Droske Carsten Wächter Lutz Kettner Alexander Keller Nikolaus Binder Ken Dahm
NVIDIA



1 Introduction

We propose a simple technique for the efficient estimation of the similarity of light transport paths. Considering descriptors of the incident radiance, we improve both filtering [Keller et al. 2014] and caching based [Ward et al. 1988] variance reduction techniques for image synthesis that so far could not measure variations of material and lighting as they only included geometric measures of similarity, such as the divergence of normals, irradiance gradients, and the distance between vertices storing information.

2 Computing Fourier Histogram Descriptors

Detecting the similarity of light transport paths by comparing radiance distributions using histograms [Delbracio et al. 2014] suffers from the lack of a practical bound on the radiance values in light transport simulation. Given one path per pixel, we only consider its 5×5 neighborhood to determine a local interval for the representation of the radiance distribution, centered in the median of the radiance values. Its symmetric extent is defined by the distance between the median and the average, hence reliably discarding outliers. All radiance values within this interval are scaled to the range $[0, 2\pi)$, which allows for projecting them into the first 4 complex Fourier basis functions. Removing scale and phase from the resulting complex coefficients [Bartolini et al. 2002] yields a Fourier descriptor of the shape of the radiance distribution.

Based on those descriptors, we complement the classical geometric similarity criteria with a robust photometric criterion accounting for lighting and material similarities: Resembling shape retrieval, we first check whether radiance intervals overlap and compare the radiance distributions of two paths by computing the L_2-distance between their respective Fourier histogram descriptors.

3 Filtering by Path Space Similarity

Noise can be effectively reduced by combining the results from similar paths. In order to guarantee a memory footprint proportional to the frame buffer size, one single vertex is stored per path per pixel along with its geometric and photometric information. With a preference for partly-diffuse surfaces, typically the first non-specular hit along the camera path is selected. Filtering is then performed by averaging all information of pixels that have a similar Fourier histogram descriptor within a defined screen space neighborhood. Persistent filtering artifacts are avoided by increasing the similarity thresholds while progressively accumulating frames.

The efficiency and robustness of the filtering process is improved by separately considering irradiance, diffuse reflectance, glossy reflections, specular reflections, and self-emitted radiance. For arbitrary materials and lighting conditions, approximate decompositions into the aforementioned components are used.

4 Conclusion

The algorithm has been implemented as a progressive realtime screen space filtering technique within the NVIDIA Iray Interactive renderer, which supports CAD-grade geometry, lighting, and materials, including representations acquired from real-world objects. Across several scenes, the scheme achieves up to 80% structured similarity (SSIM) with the ground truth, using only a single sample per pixel. For an image resolution of 1280×720 pixels, the generation of the Fourier histogram descriptors takes about 32ms, while the subsequent filtering using a 21×21 pixel window requires about 85ms on an NVIDIA Tesla K20c GPU.

Based on the key concept of considering incident radiance, an efficient algorithm to measure similarity in path space has been introduced. The measure can be used with any sampling based image synthesis method for arbitrary content and significantly improves the performance of accurate interactive previsualization, such as in architectural and automotive design, as well as in movie production.

References

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