Specular Lobe Aware Upsampling Based on Spherical Gaussians

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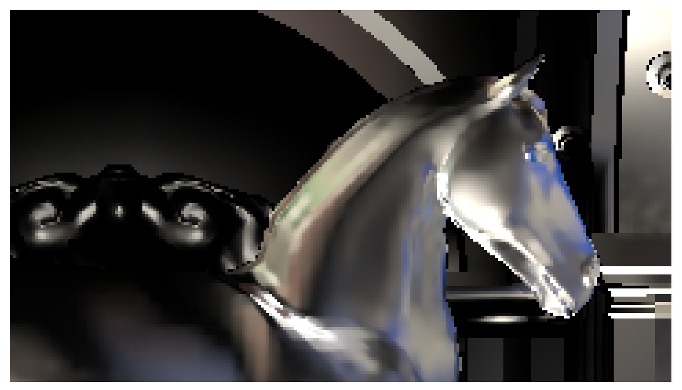
1. Introduction

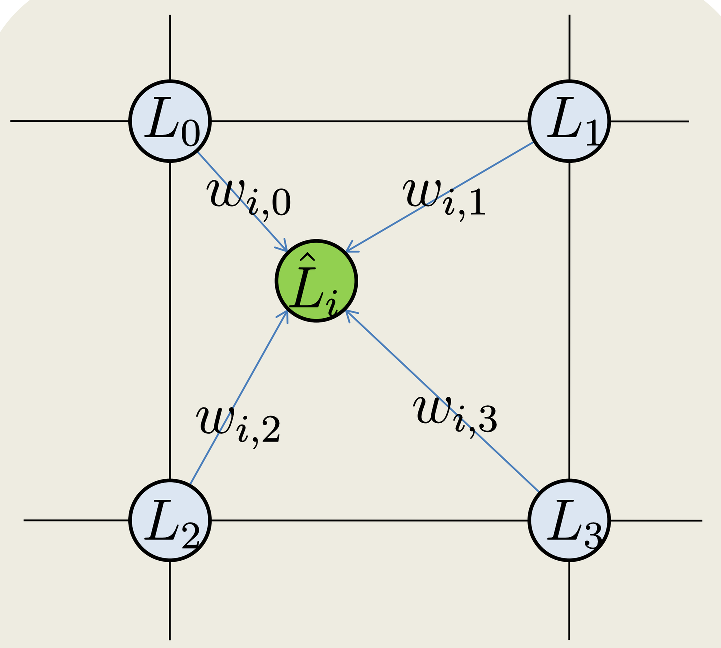
This poster introduces a novel weighting function of bilateral upsampling for specular surfaces. High-resolution rendering with expensive shaders (e.g., global illumination) is a considerable problem for real-time applications such as video games. Therefore, some bilateral upsampling based methods such as spatio-temporal upsampling [Herzog et al. 2010] were proposed to alleviate the computational burden. The main challenge of these upsampling techniques is to optimize a weighting function in order to estimate a pixel value by appropriately prioritizing samples. We propose an efficient weighting function based on a specular lobe similarity. This function is simple and has no additional storage cost. Moreover, it has no user-specified parameters. Thus it can be easily integrated with general upsampling techniques.

2. Geometry-Aware Upsampling

low-resolution image



high-resolution image



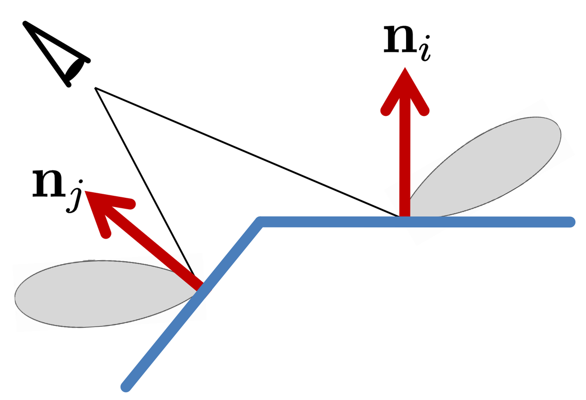
$$\hat{L}_i = \frac{\sum_j L_j w_{i,j}}{\sum_j w_{i,j}}$$

interpolation

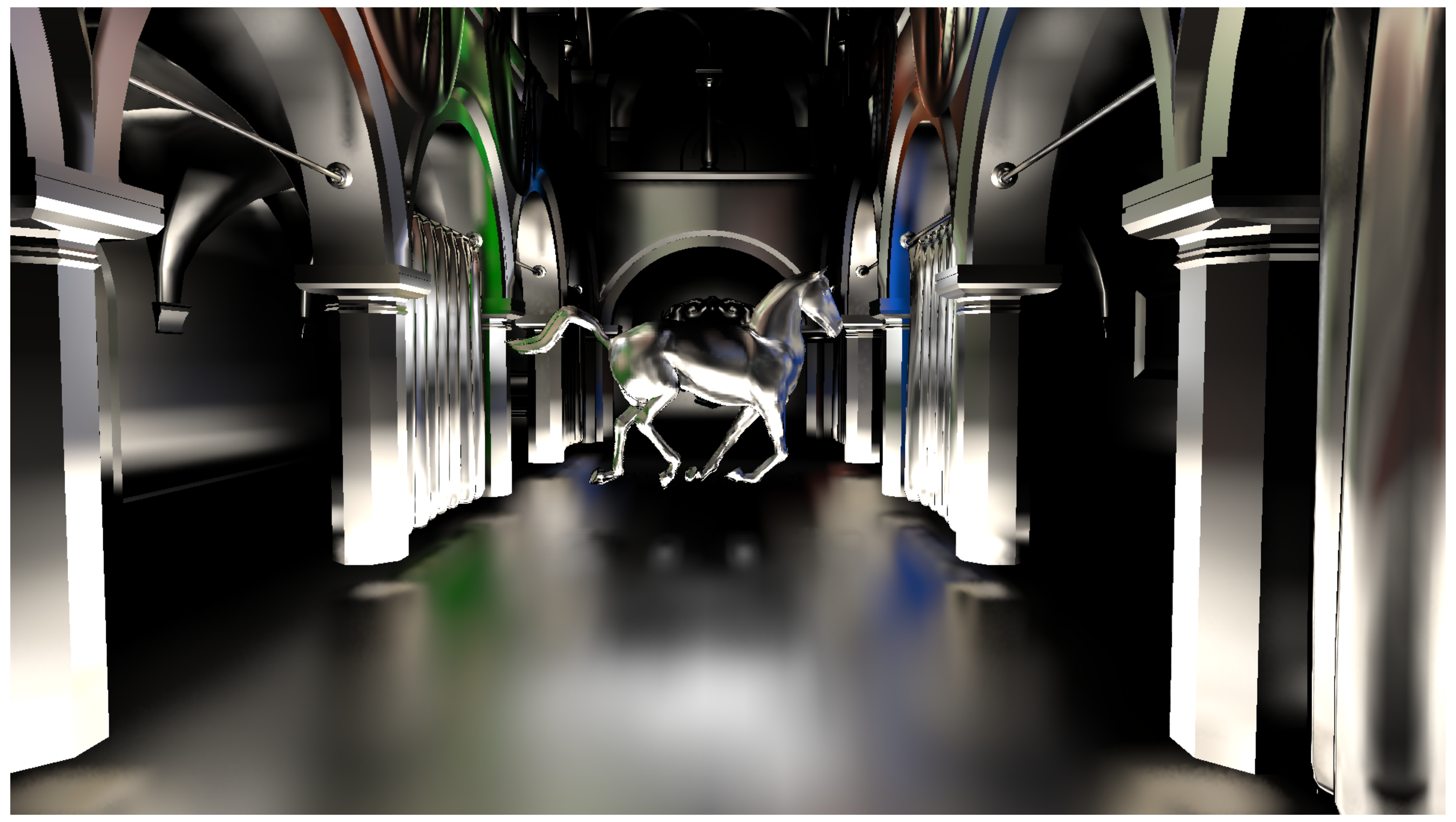
The weighting function $w_{i,j}$ commonly evaluates a similarity of pixel values.

$$w_{i,j} = \exp\left(-\frac{\|\mathbf{n}_i - \mathbf{n}_j\|^2}{2\sigma^2}\right)$$

normal based weighting function

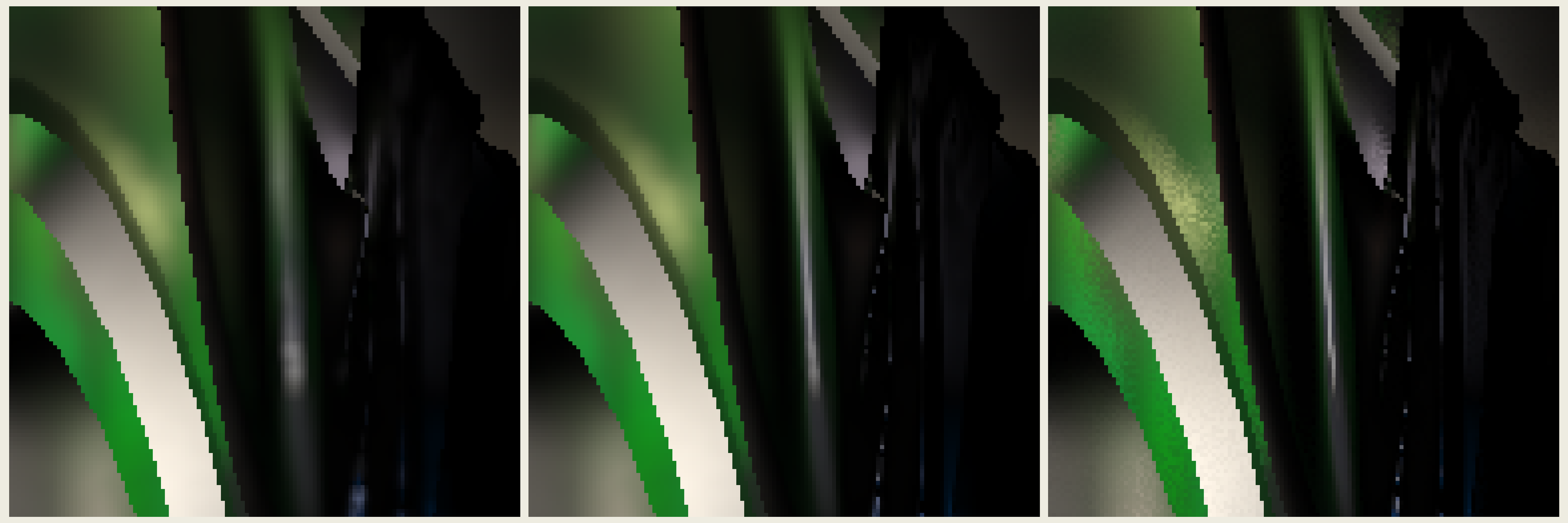


A surface normal continuity is generally used for evaluating a geometric similarity, which is well suited for diffuse surfaces because the shading results depend on the normal vectors. However, for specular surfaces, **we have to take into account not only the normal vectors but also the eye directions and the specular sharpness** to generate accurate results, since specular lobes are determined by them.



Resolution: 480x270 →1920x1080 pixels
Specular sharpness (phong exponent): 1023
GPU: AMD Radeon HD 6990

close-ups

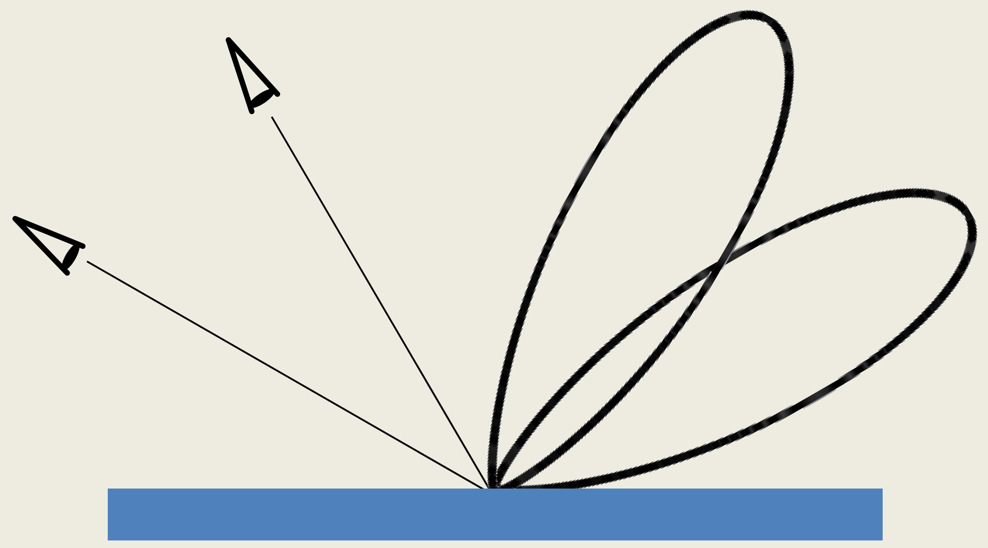


normal based ($\sigma^2 = 0.005$)	proposed	per-pixel cone tracing (The high-frequency noise is due to stochastic sampling for ray marching)
2.3 ms (cone tracing + upsampling)	**2.5 ms** (cone tracing + upsampling)	**11 ms** (cone tracing)

We here employ voxel cone tracing [Crassin et al. 2011] with spatio-temporal upsampling as an experimental example, since voxel cone tracing is known to be computationally expensive to render specular surfaces. In the image using the normal based weighting function, there are some blurring and flickering artifacts due to estimation errors. On the other hand, our method enables higher-quality upsampling without parameter tuning. Our approach adaptively reduces blurring and flickering artifacts depending on specular sharpness and eye directions.

3. Weighting Function for Specular Surfaces

Specular Lobe Similarity



There are different lobes, while the normal vectors are same.

A weighting function should evaluate a similarity of the reflected radiance between the current pixel i and the sampled pixel j, which is the inner product of the incident radiance and the reflection lobe. Assuming that the incident radiance distributions of two pixels are identical, the difference of the reflected radiance is determined by only the reflection lobes. Therefore, we introduce a weighting function $w_{i,j}$ representing the specular lobe similarity as given by computing **the inner product of the two specular lobes**.

Spherical Gaussian Approximation

Since the shape of the specular lobe depends on the BRDF model, and there is not always an analytical solution of the inner product, this poster approximates the lobes by using spherical Gaussians (SGs).

$$f(\mathbf{x}, \omega_r, \omega)(\mathbf{n} \cdot \omega) \approx G(\omega)$$

$$w_{i,j} = \frac{G_i}{\sqrt{G_i \cdot G_i}} \cdot \frac{G_j}{\sqrt{G_j \cdot G_j}}$$

As described in [Wang et al. 2009], a specular lobe is approximated with an SG. The inner product of two SGs is analytically obtained. Hence, we define the weighting function as the inner product of the normalized SGs. The range of this $w_{i,j}$ is [0, 1]. When the two lobes are same, $w_{i,j} = 1$.

Future Work

Our approach is limited to isotropic BRDFs which can be approximated by a single SG. However, this is not a problem for voxel cone tracing which also approximates BRDFs by a Gaussian lobe. In addition, we can introduce anisotropic BRDFs using several SGs with sacrificing time.
Our weighting function is also applicable for geometry aware blurring (i.e., specular lobe aware blurring). In future work, we would like to investigate the effectiveness of such filtering.

CRASSIN, C., NEYRET, F., SAINZ, M., GREEN, S., AND EISEMANN, E. 2011. Interactive indirect illumination using voxel cone tracing. Comput. Graph. Forum 30, 7, 1921–1930.
HERZOG, R., EISEMANN, E., MYSZKOWSKI, K., AND SEIDEL, H.-P. 2010. Spatio-temporal upsampling on the gpu. In Proc. of I3D 2010, 91–98.
WANG, J., REN, P., GONG, M., SNYDER, J., AND GUO, B. 2009. All-frequency rendering of dynamic, spatially-varying reflectance. ACM Trans. Graph. 28, 5, 133:1–133:10.