

The Alchemy Screen-Space Ambient Obscurance Algorithm



Morgan McGuire
NVIDIA & Williams College

Brian Osman
Vicarious Visions

Michael Bukowski
Vicarious Visions

Padraic Hennessy
Vicarious Visions





Concept Art

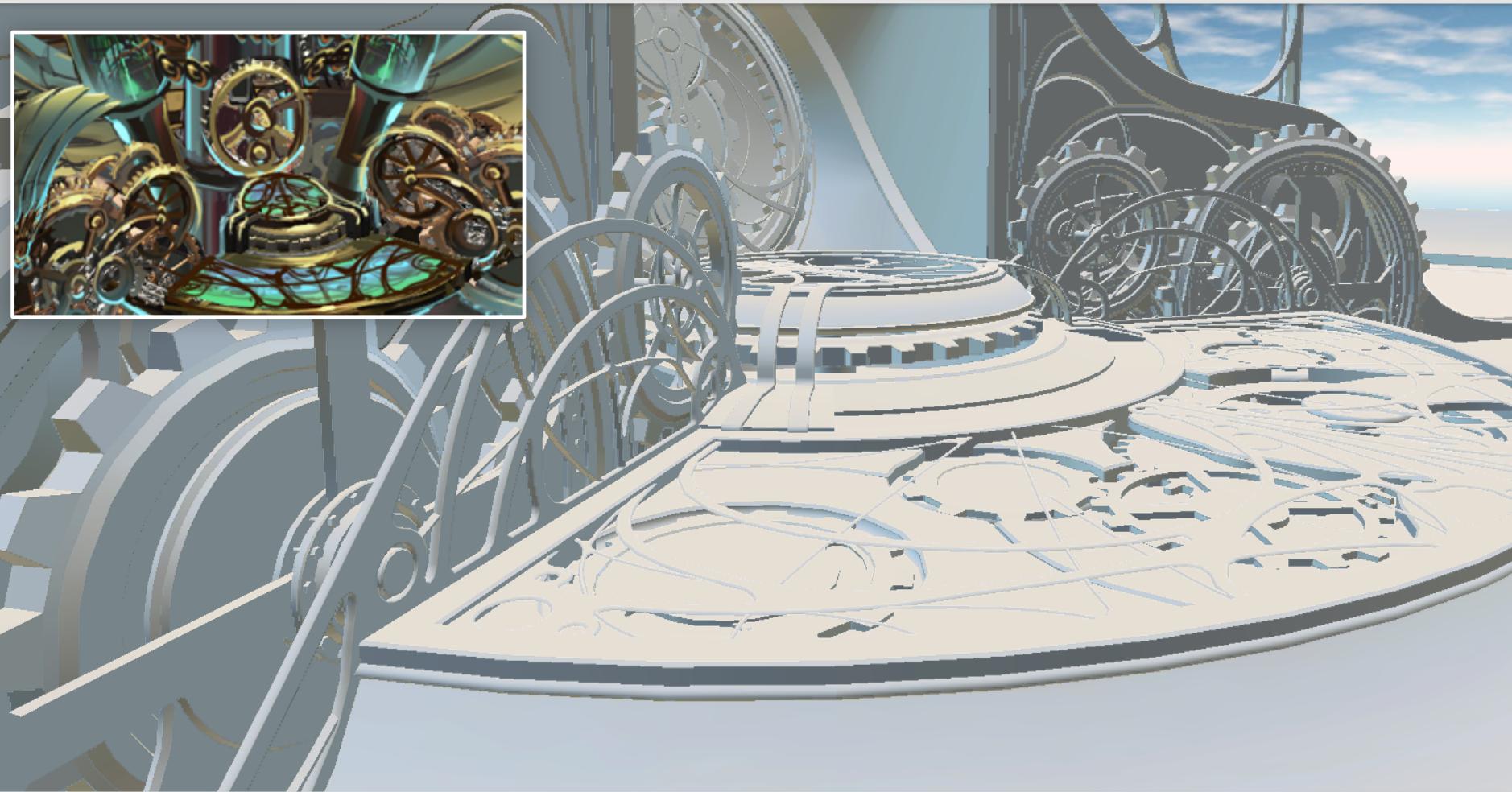


Concept Art

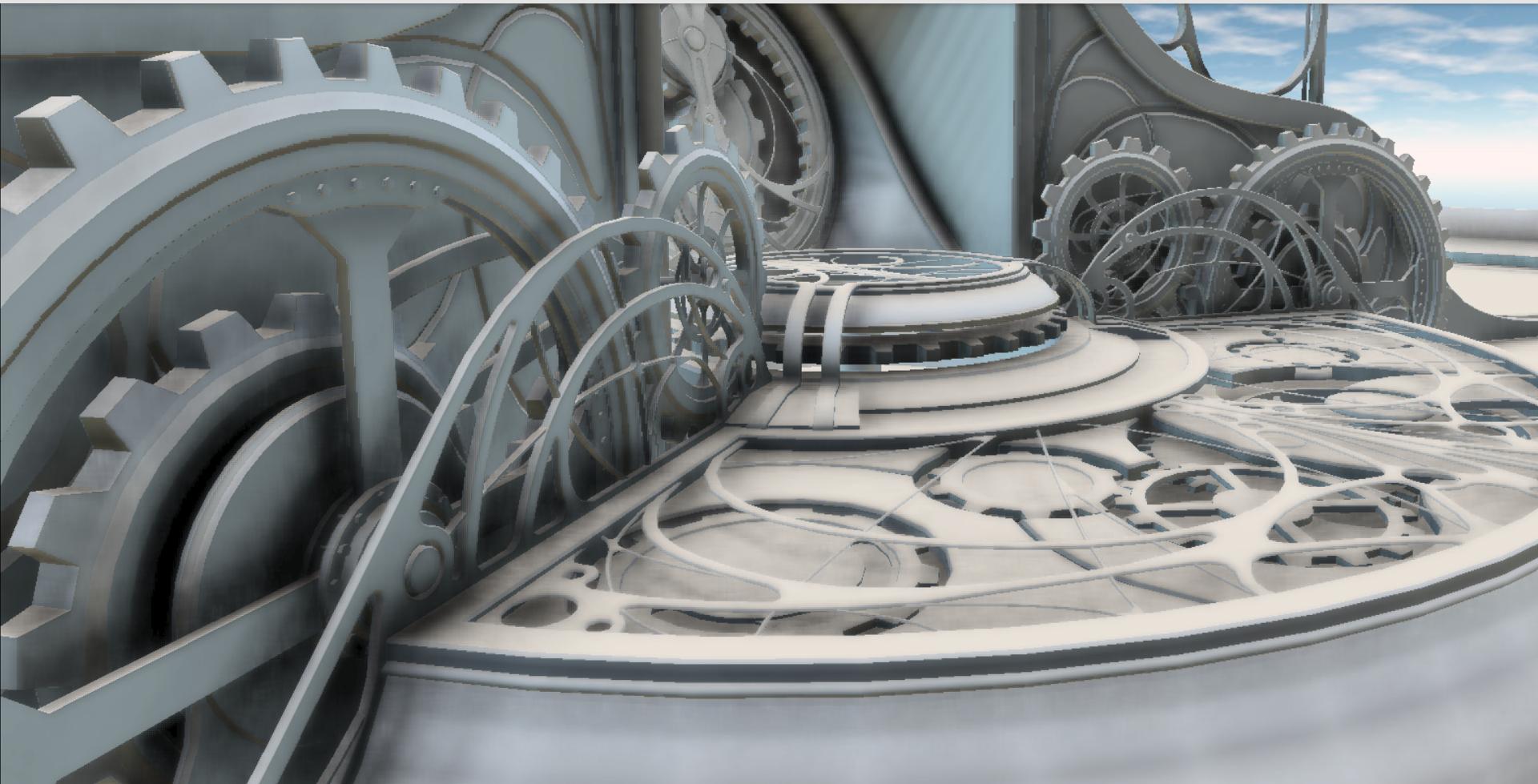


Concept Art

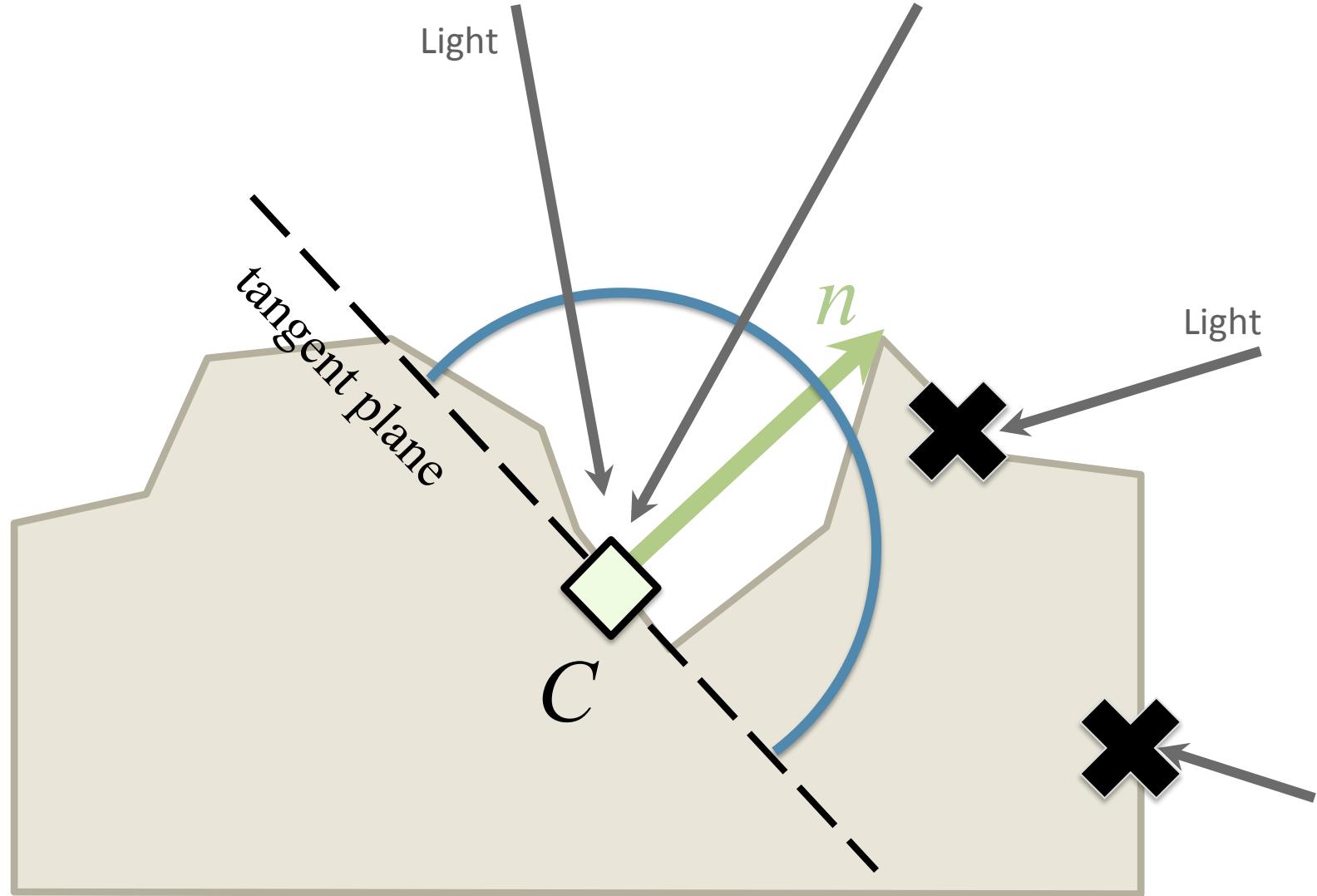
Environment Lighting



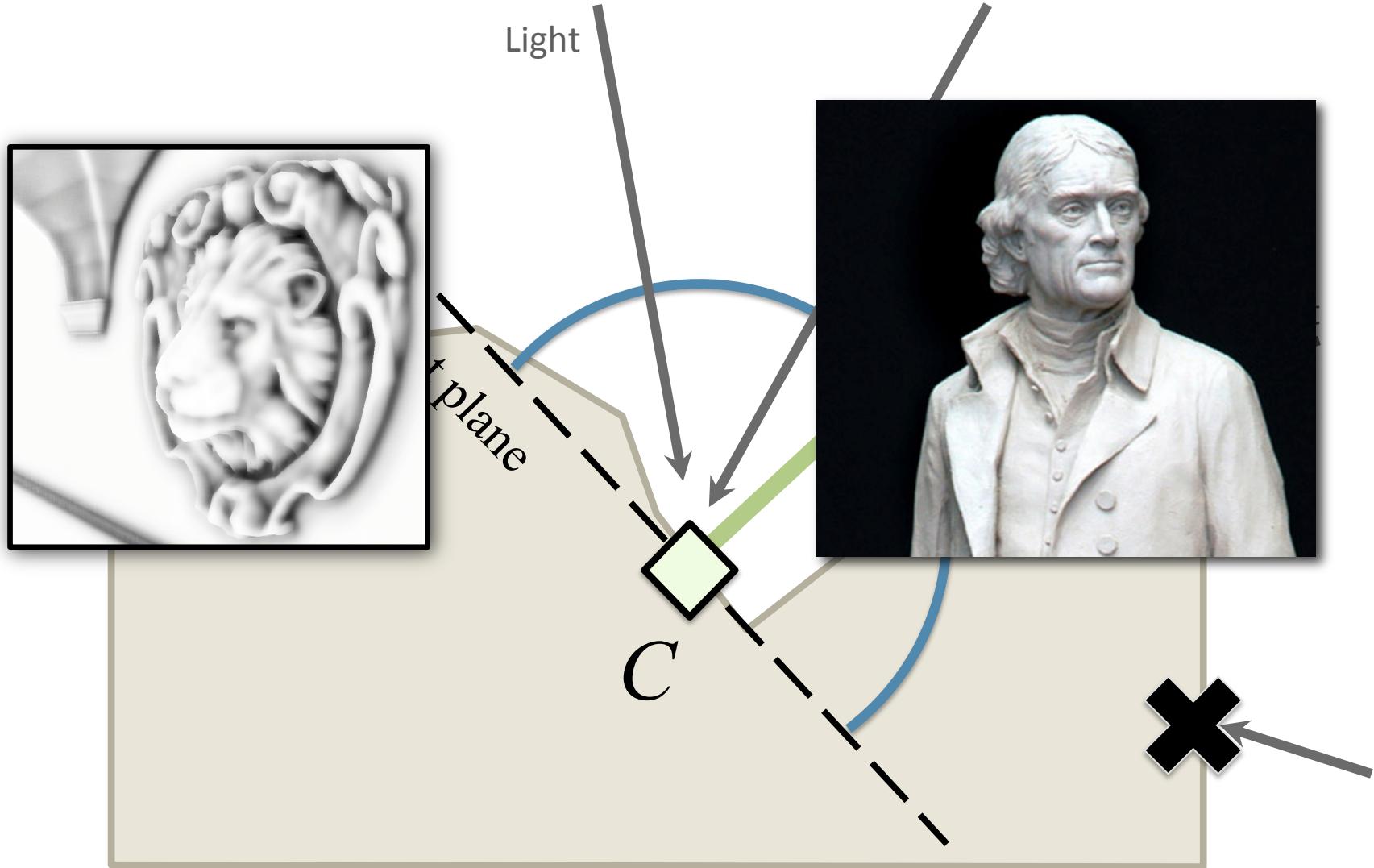
Ambient Obscurrence



Ambient Obscurrence (AO)



Ambient Obscurrence (AO)



Ambient Obscurance (AO)

$$A_r^*(C, \hat{n}) = \frac{1}{\pi} \int_{\Omega} V(C, C + r\hat{\omega}) \hat{\omega} \cdot \hat{n} d\hat{\omega}$$

[Cook and Torrance 1982]

$$A_r(C, \hat{n}) = 1 - \int_{\Omega} [1 - V(C + \hat{\omega} \min(t(C, \hat{\omega}) + \epsilon, r))] \cdot g(t) \cdot (\hat{n} \cdot \hat{\omega}) d\hat{\omega}$$

[Zhukov et al. 1998]

Desiderata

Performant

(~2 ms on Xbox 360 @ 720p)

Robust

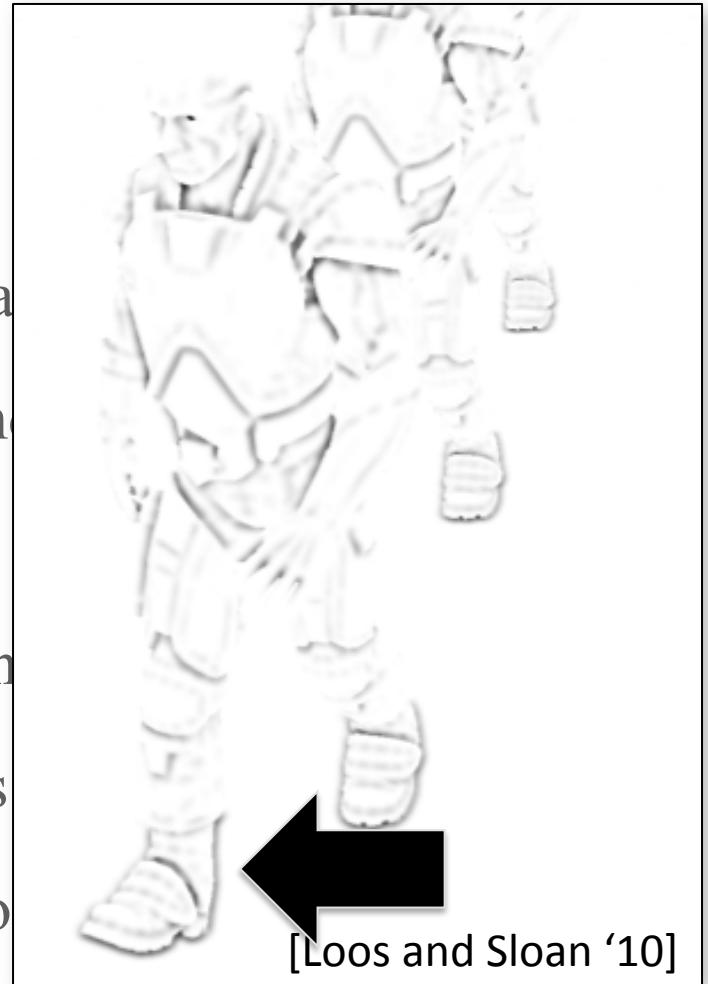
Predictable

Plausible

Accurate

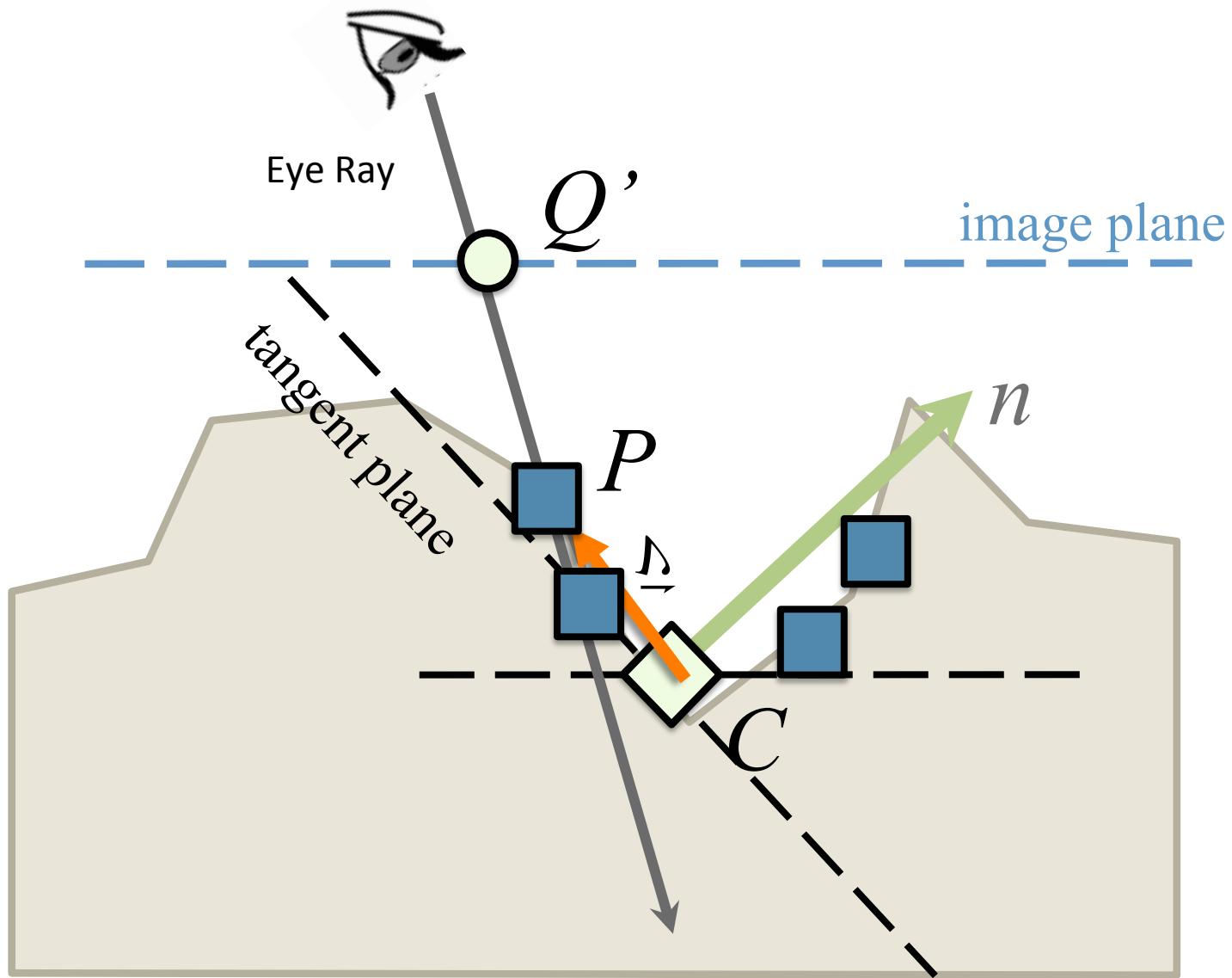
Related Work

- Unsharp masking [Luft ‘06]
- SSAO [Mittring 07, Shanmugam et al. ‘08]
- Precompute visibility [Oat and Schröder ‘08]
- SSDO [Ritschel et al. ‘09]
- Horizon-based [Bavoil and Saini ‘09]
- Volumetric AO [Szirmay-Kalos et al. ‘09]
- Volumetric Obscurrence [Loos and Sloan ‘10]



Algorithm

Geometric Derivation



Algebraic Derivation

$$A_r(C, \hat{n}) = 1 - \int_{\Omega} [1 - V(C + \hat{\omega} \min(t(C, \hat{\omega}) + \epsilon, r))] \cdot g(t) \cdot (\hat{n} \cdot \hat{\omega}) d\hat{\omega}$$

[Zhukov et al. 1998]

$$V(C, \hat{\omega} \min(t(C, \hat{\omega}) + \epsilon, r)) = 0 \Big|_{\hat{\omega} \in \Gamma}$$

$$A = 1 - \int_{\Gamma} g(t(C, \hat{\omega})) \hat{\omega} \cdot \hat{n} d\hat{\omega}$$

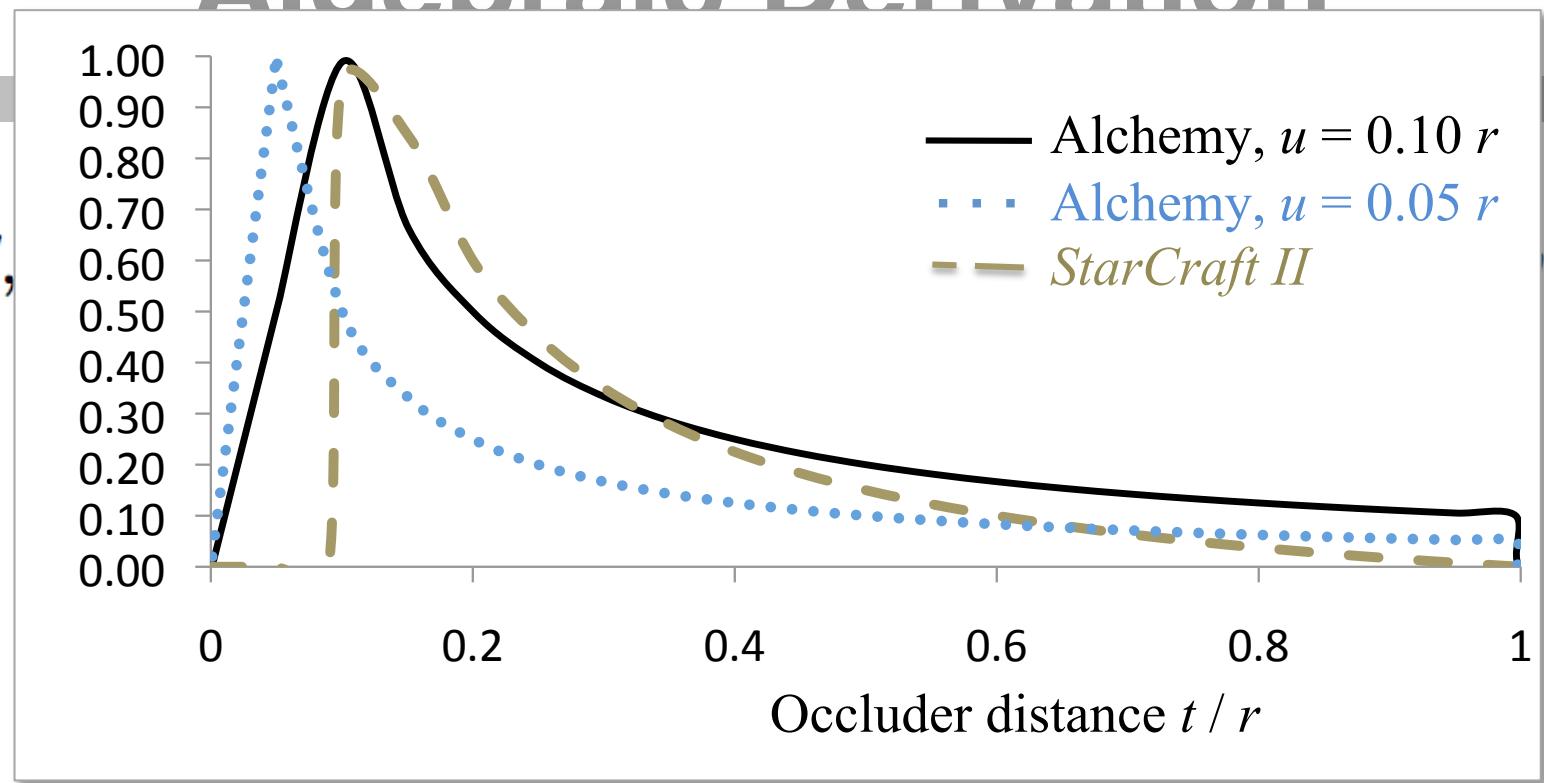
$$g(t) = u \cdot t \cdot \max(u, t)^{-2}$$

Algebraic Derivation

$A_r(C,$

) $d\hat{\omega}$

1998]



$$g(t) = u \cdot t \cdot \max(u, t)^{-2}$$

Algebraic Derivation

$$A_r(C, \hat{n}) = 1 - \int_{\Omega} [1 - V(C + \hat{\omega} \min(t(C, \hat{\omega}) + \epsilon, r))] \cdot g(t) \cdot (\hat{n} \cdot \hat{\omega}) d\hat{\omega}$$

[Zhukov et al. 1998]

$$V(C, \hat{\omega} \min(t(C, \hat{\omega}) + \epsilon, r)) = 0 \Big|_{\hat{\omega} \in \Gamma}$$

$$A = 1 - \int_{\Gamma} g(t(C, \hat{\omega})) \hat{\omega} \cdot \hat{n} d\hat{\omega}$$

$$g(t) = u \cdot t \cdot \max(u, t)^{-2}$$

$$A \approx 1 - \frac{2\pi u}{s} \sum_{i=1}^s \frac{\max(0, \vec{v}_i \cdot \hat{n}) \cdot H(r - ||\vec{v}_i||)}{\max(u^2, \vec{v}_i \cdot \vec{v}_i)}$$

Equation

σ = Strength multiplier, e.g., 1.0
Higher = darker shadowing
Lower = lighter in shadows

$$A \approx \max \left(0, 1 - \frac{2\sigma}{s} \cdot \sum_{i=1}^s \frac{\max(0, \vec{v}_i \cdot \hat{n} + z_C \beta)}{\vec{v}_i \cdot \vec{v}_i + \epsilon} \right)^k$$

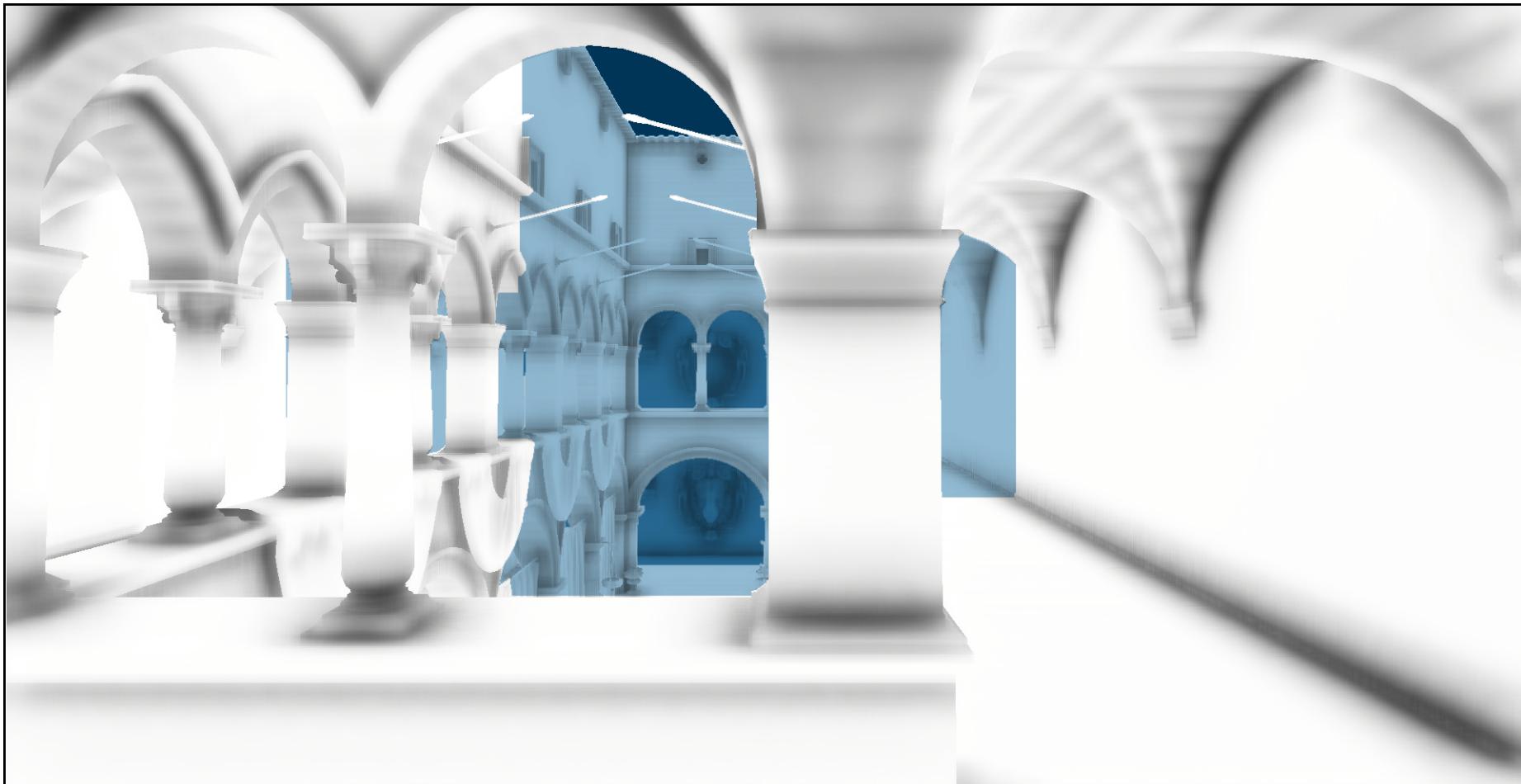
s = Samples per pixel, e.g., 4-12
Higher = less variance
Lower = faster

β = Shadow bias, e.g., 10^{-4}
Too high = offset obscuration
Too low = self-shadowing

ϵ avoids divide-by-zero, e.g., 10^{-5}

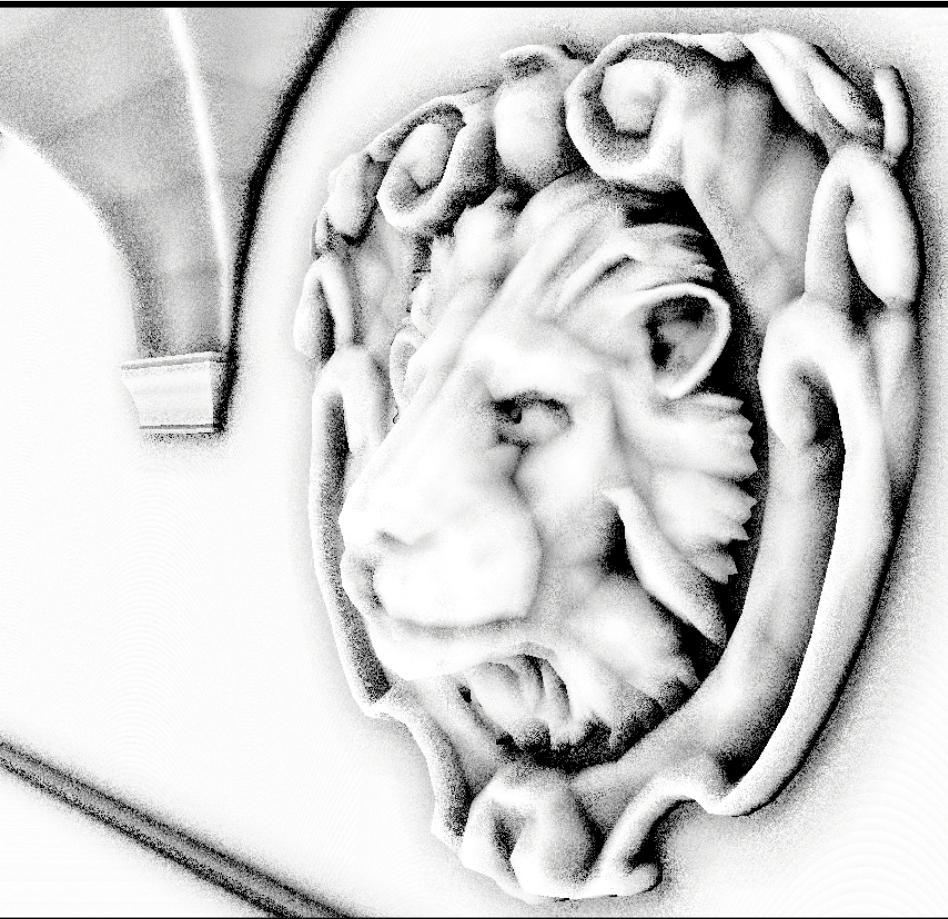
k = Contrast multiplier, e.g., 1.0
Higher = sharper obscuration transition
Lower = blur shadows

Shader LOD

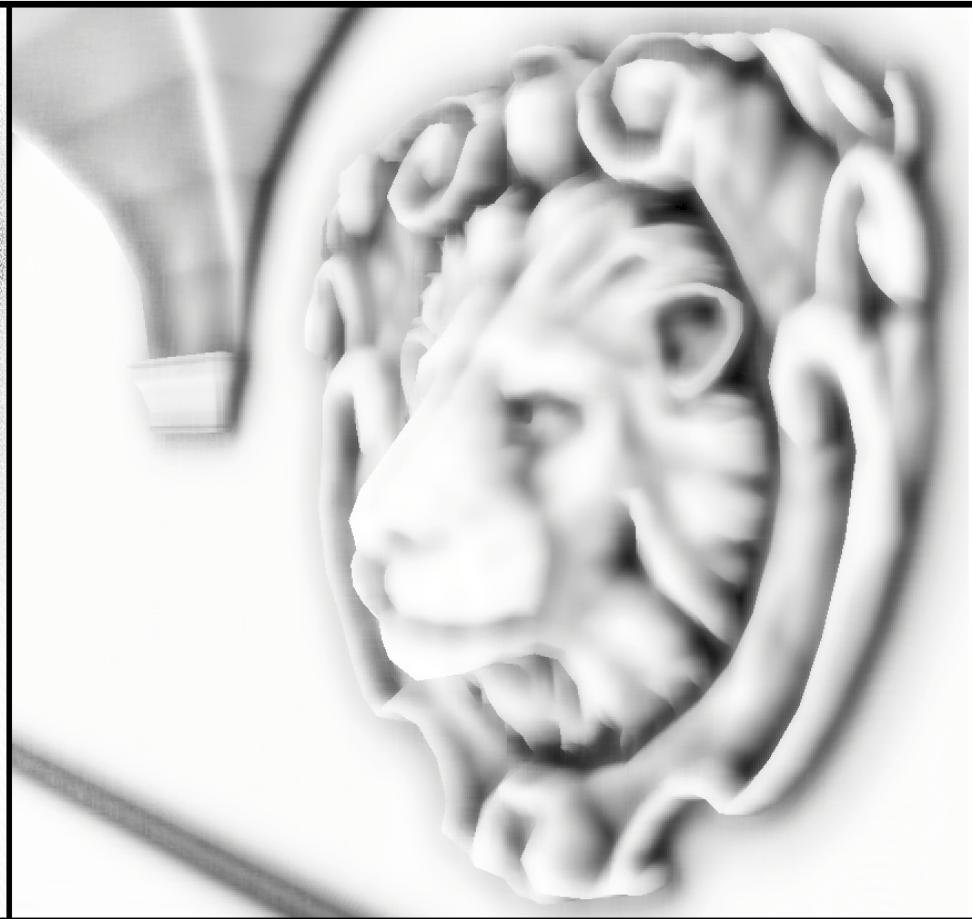


Samples per pixel: 0 4 8 12

Cross-Bilateral Reconstruction



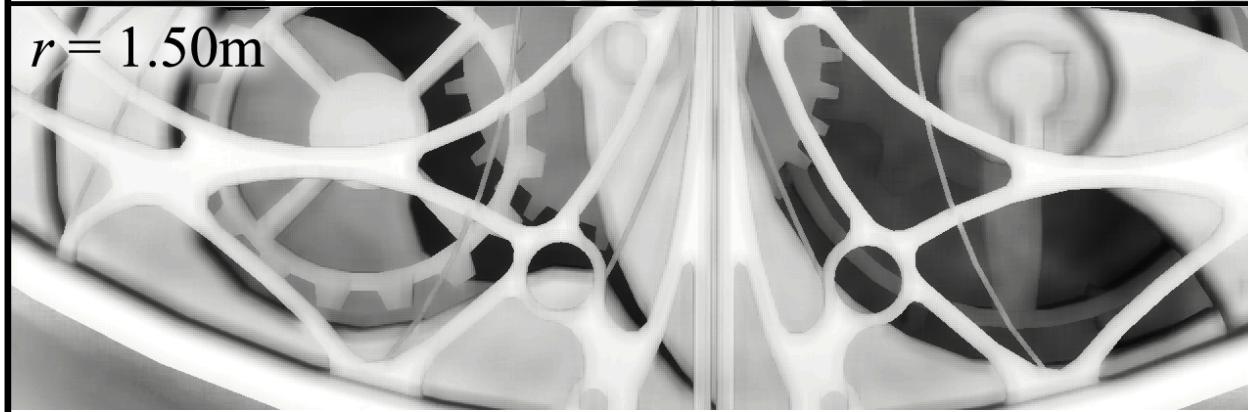
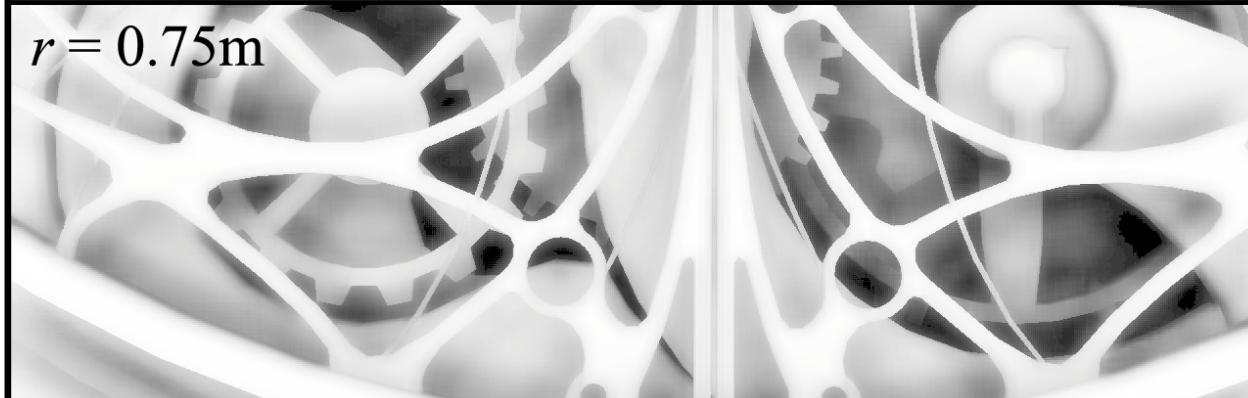
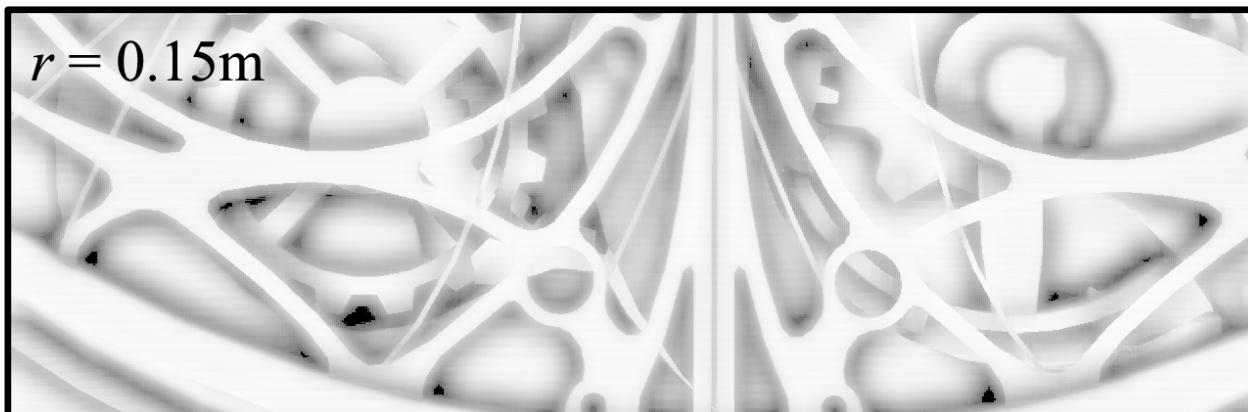
Raw obscurance estimate,
tuned to over-darken for visualization



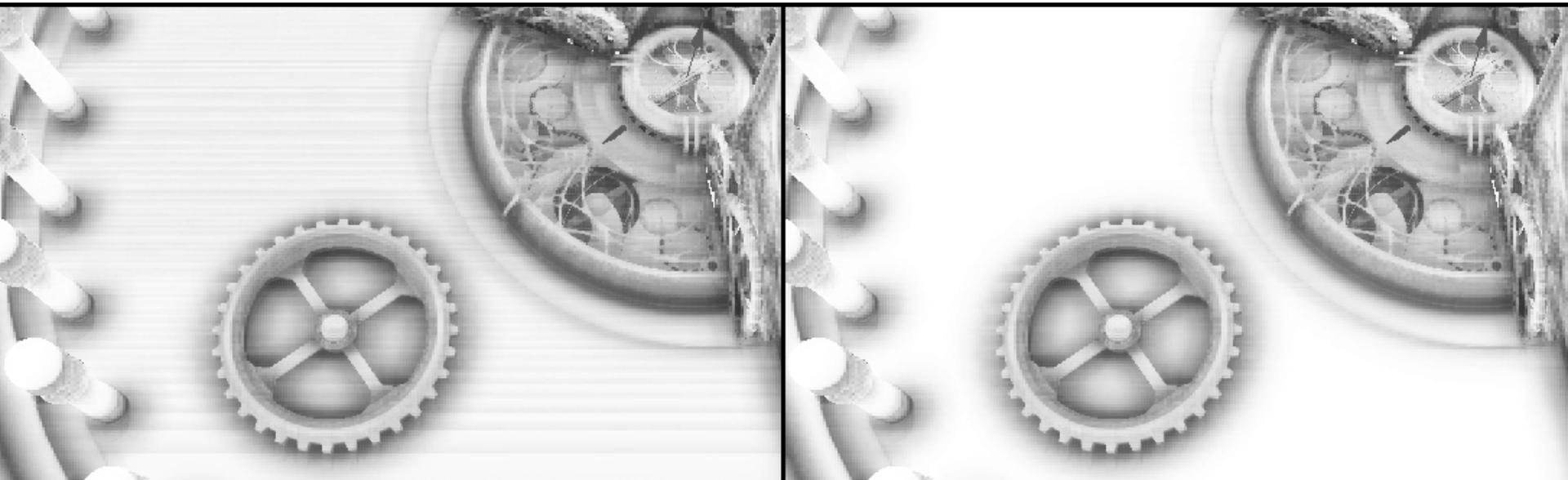
Cross-bilateral reconstruction with
“separated” depth edge-preserving
Gaussian kernel

Varying Parameters

Varying Obscurrence Radius



Bias



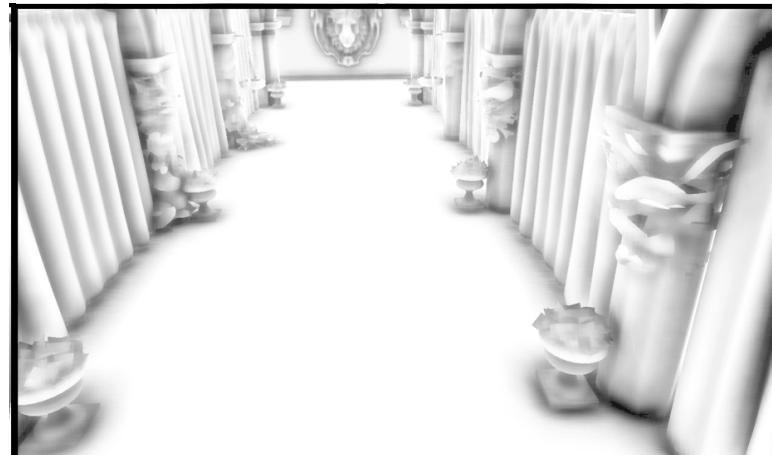
$\text{Bias } \beta = 0 \text{ m}$

$\text{Bias } \beta = 10^{-4} \text{ m}$

Artifacts due to roundoff errors at
16-bit depth precision

Performance at 1280x720

	Xbox 360 ~D3D9	GeForce 460 SE D3D9	GeForce 580 GTX D3D11 / GL4		
Samples/band	3	4	4	3	2
Maximum bands	1	1	3	3	3
Registers	6 vec4	15 scalar	15 scalar	15 scalar	15 scalar
32-bit words/pix IO	28	28	40	31	22
Accessibility time	2.3 ms	0.6 ms	2.0 ms	1.5 ms	1.0 ms
Filter pixel width	11	11	13	13	9
Filter time	2.0 ms	1.6 ms	1.0 ms	1.0 ms	0.7 ms



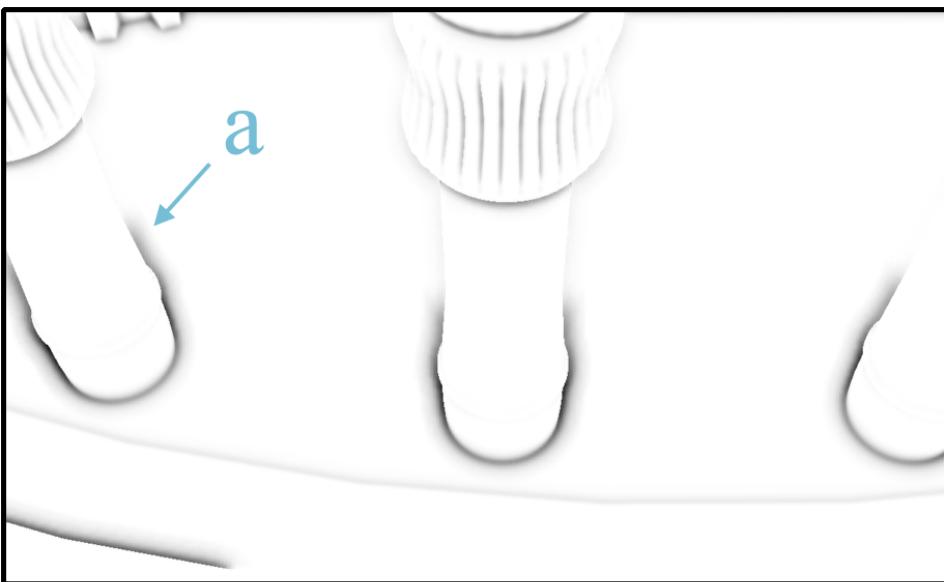
Limitations

- Guard band
- View dependent / mitigated by conformance
- Clamp radius *very* close to near plane

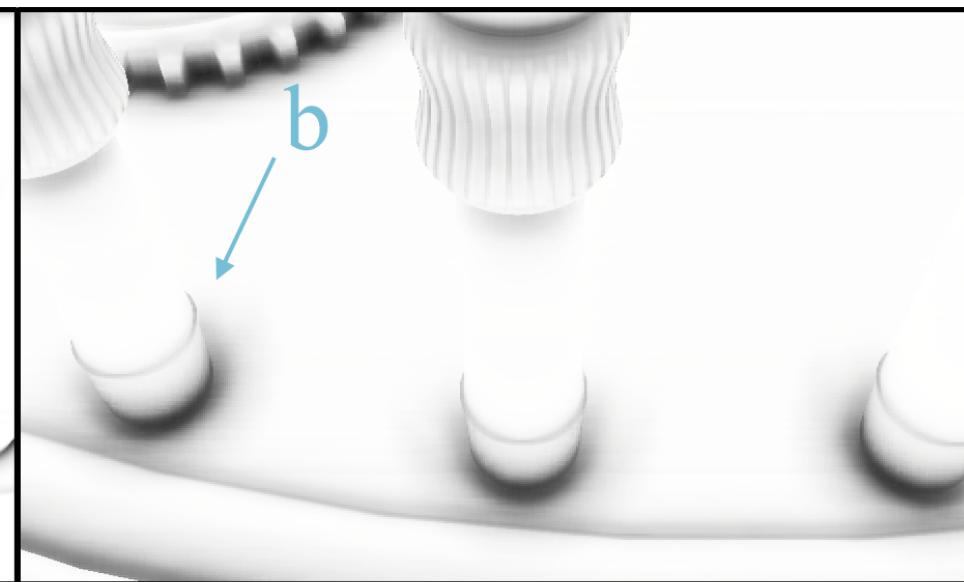
Comparison

Contact Shadows

Volumetric Obscurrence

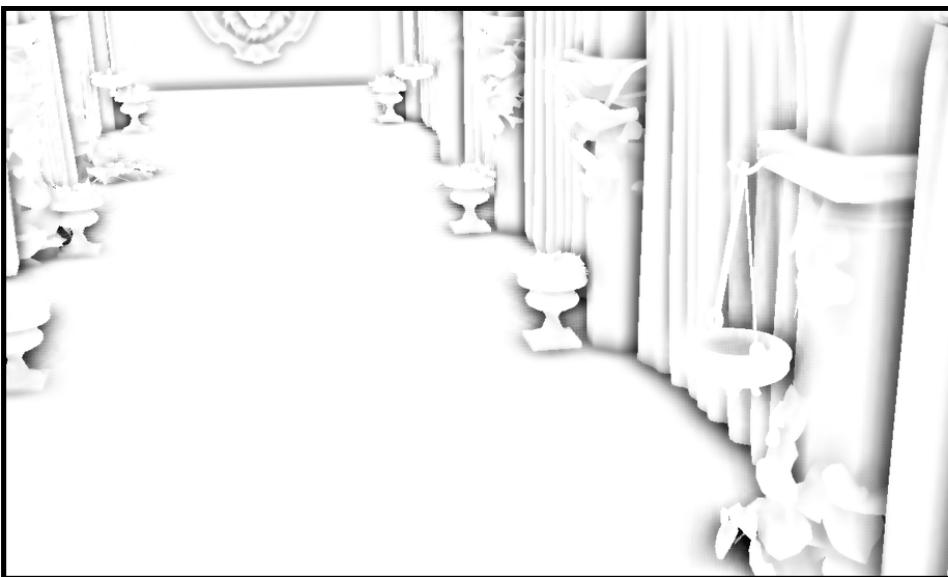


Alchemy AO



Contact Shadows

Volumetric Obscurrence



Alchemy AO

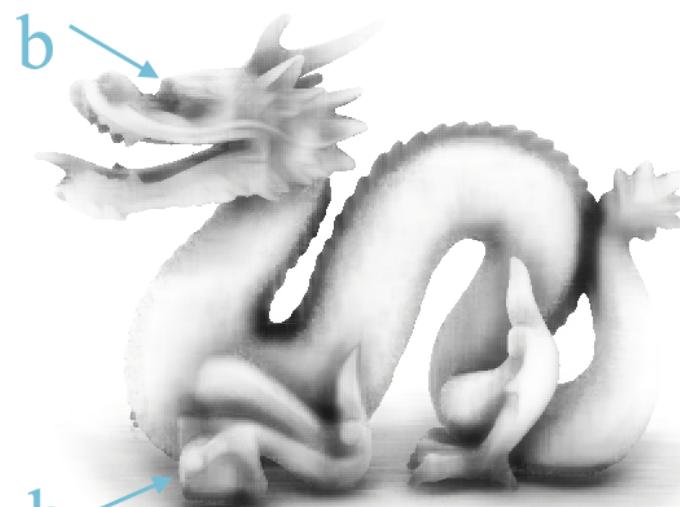


Viewing Angle

HBAO



Alchemy AO



Important Game Cases

The Alchemy Screen-Space Obscurrence Algorithm

Video Results

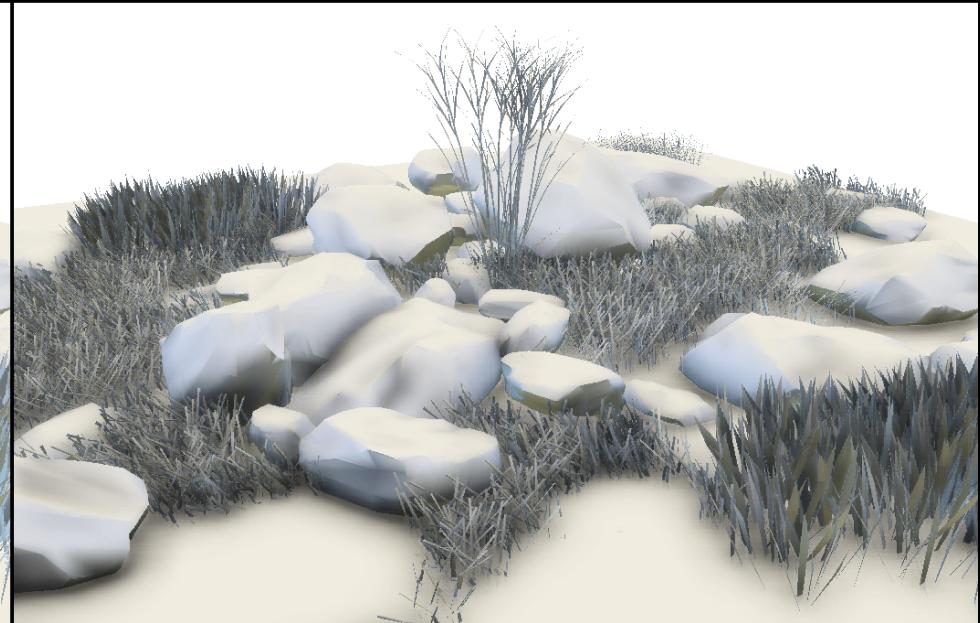
High Performance Graphics 2011

Fine Foliage Details

Environment Only

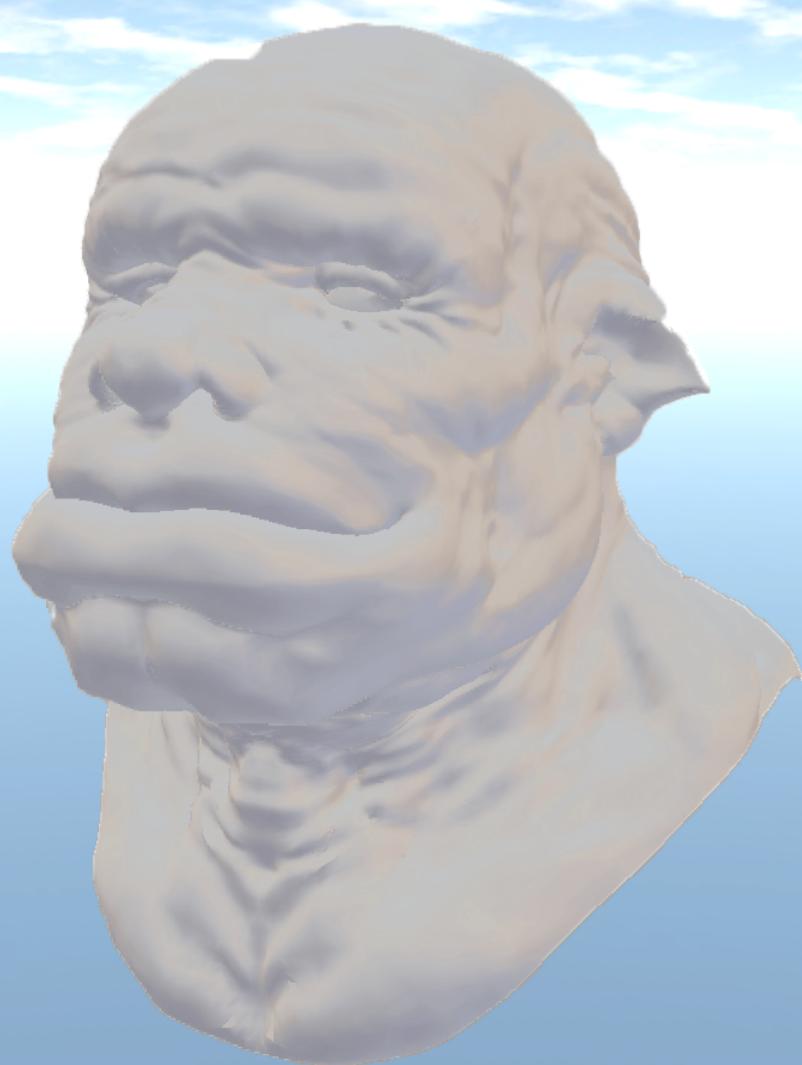


Modulated by Alchemy AO



Character

Environment Only



Modulated by Alchemy AO



Summary

Insights

- Robust and predictable
- Adjust falloff function for performance

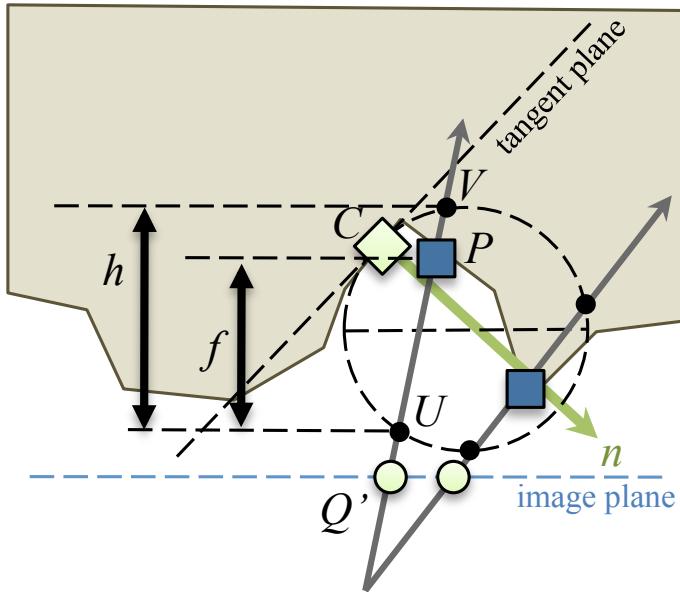
Properties

- Intuitive parameters
- Contact shadows conform to surface
- Scale across hardware generations

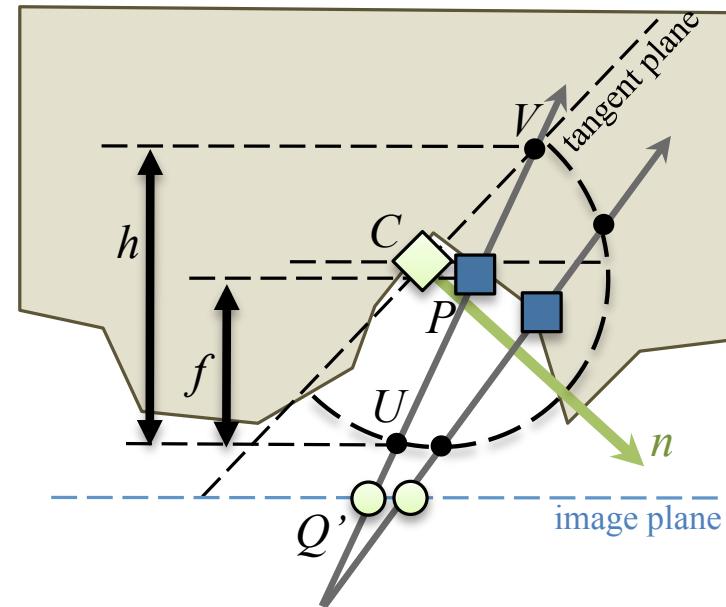


e-mail morgan@cs.williams.edu for GLSL source

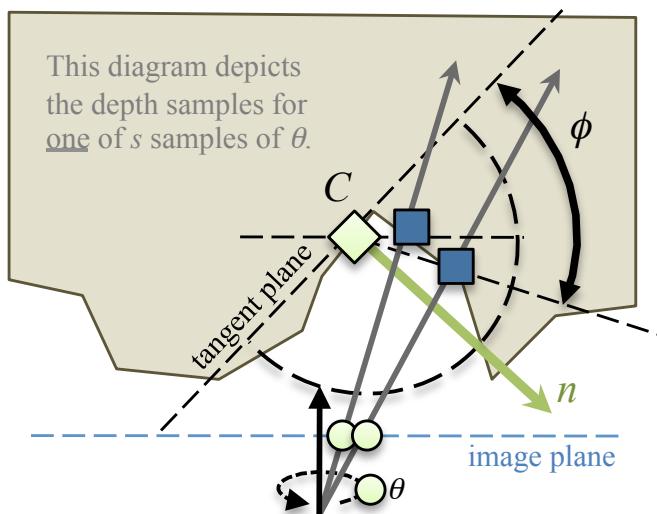
ADDITIONAL MATERIAL



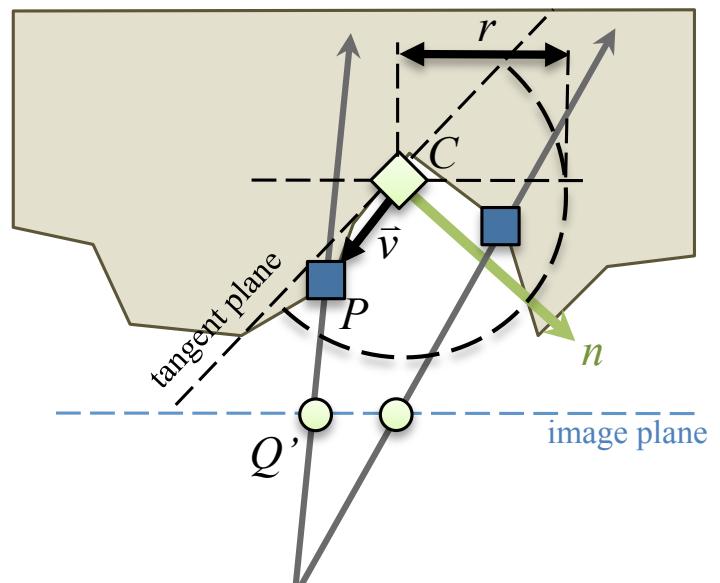
Szirmay-Kalos et al. [09, 10]
(Volumetric AO)



Loos and Sloan [10]
Volumetric Obscuration



Bavoil and Sainz [08,09]
(Horizon-Based AO)



The New Alchemy Algorithm