CS451
Ambient Occlusion

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Most materials are from “Reaistic Ray Tracing” by Shirley and Morley

Update (in case you didn't know…)

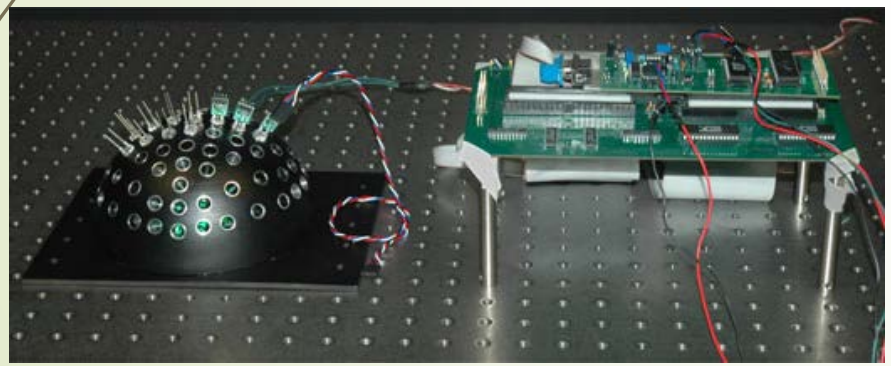
- Your grades have been posted
  - PA1~PA5, all quizzes, and midterm
- PA 6 solution has been posted
- PA 7 is due Dec. 8th, 11:59pm
  - Examples have been posted
  - Remember that your light source is NOT from openGL
  - Change from **double inshadow(Point3d& p)** to **bool inshadow(Point3d& p, Point3d& light)**
  - Any questions on this?
- PA 8 on ambient occlusion is optional (10%)

Review

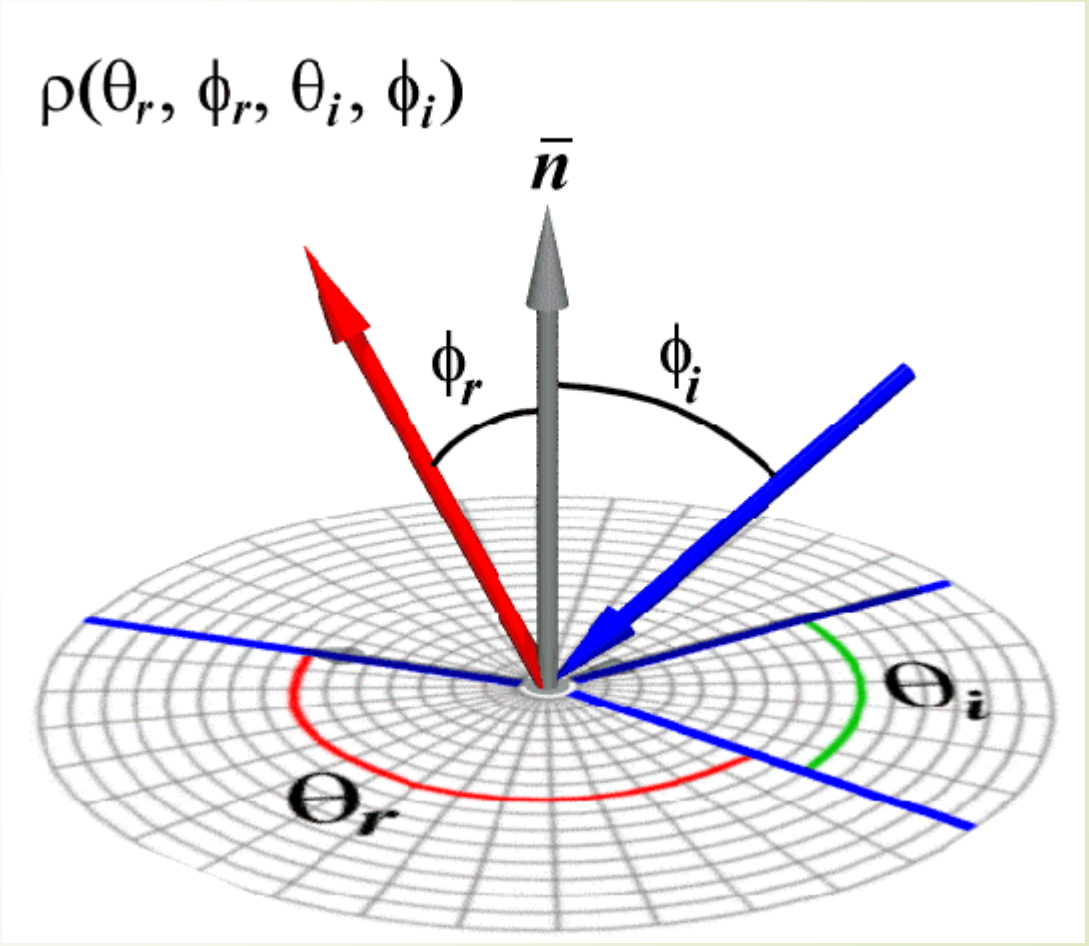
- How much light hits a point x
  - Irradiance $\Phi = \frac{\Delta q}{\Delta A \Delta t \Delta \lambda}$ has unit $J/sec/m^2/nm$
- BRDF (bidirectional reflectance distribution function)
  - A 4D function $\rho(k_i, k_o)$ where k_i and k_o are points on the hemisphere
  - $\rho(k_i, k_o)$ defines the reflectance of all possible incoming and outgoing directions
  - For ideal diffuse surface Lambertian $\rho(k_i, k_o)$ is a constant

Review

- BRDF $\rho(k_i, k_o)$

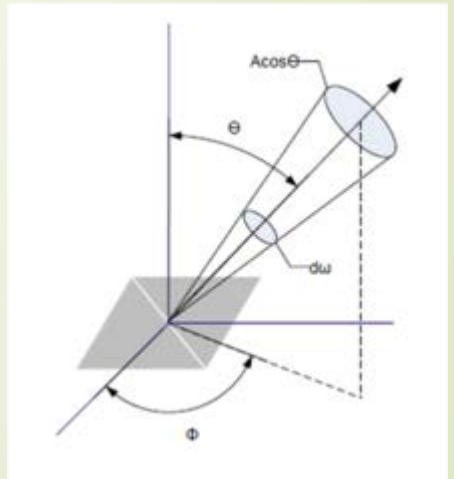


BRDF Measurement Device
Ben-Ezra et al. CVPR08



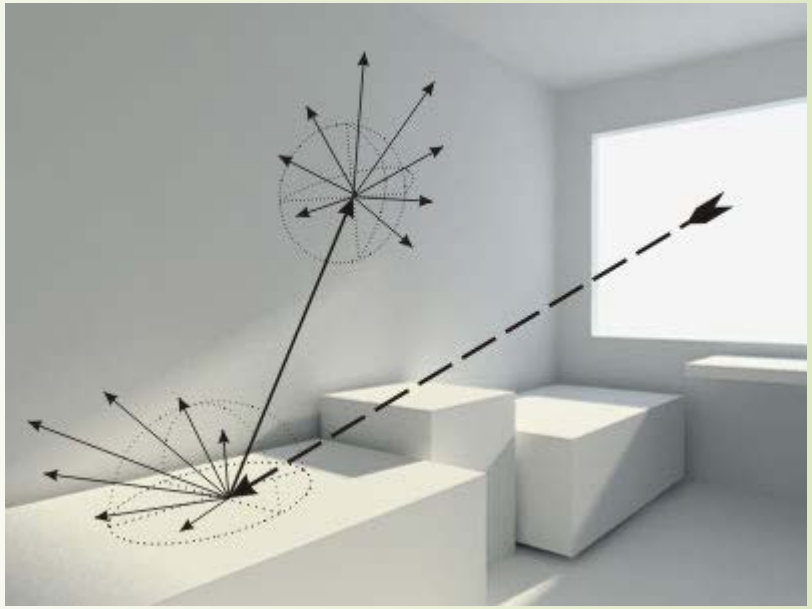
Radiance

- How much light hits a point x from a given direction
  - Imagine a truncated cone placed around the point x
  - Solid angle, steradiance, between 0 and 4π
  - The truncated cone can tilt around the hemisphere centered at x
  - radiance $L = \frac{\Delta\Phi}{\Delta\omega \cos\theta}$ has unit $J/sec/m^2/nm/steradiance$
  - Important: Radiance is invariant to the distance to light
  - Finally, the irradiance Φ at x from all directions is
    - $\Phi = \int_{\omega} L(\omega)\cos\theta\, d\omega = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\frac{\pi}{2}} L(\phi,\theta)\cos\theta\sin\theta\, d\theta\, d\phi$



Path Tracing

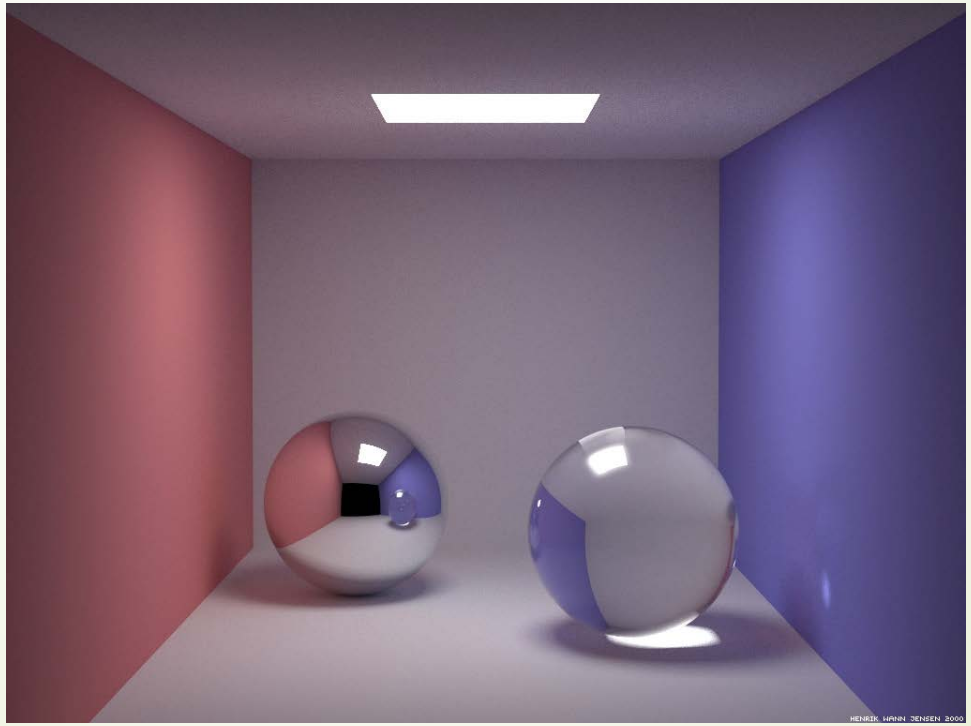
- What do we do with all these?
- Think about path tracing
  - A photon comes out from a light source
    - With certain wave length, direction, and energy
    - Hit a surface in direction k_i
    - Leaves the surface in direction k_o
    - $\rho(k_i, k_o)$ is applied to determine the new properties of the photon
    - The photon continues to hit surfaces until it hits the film (near camera plane)



http://blender3d.cz/others/tnt/

Path Tracing

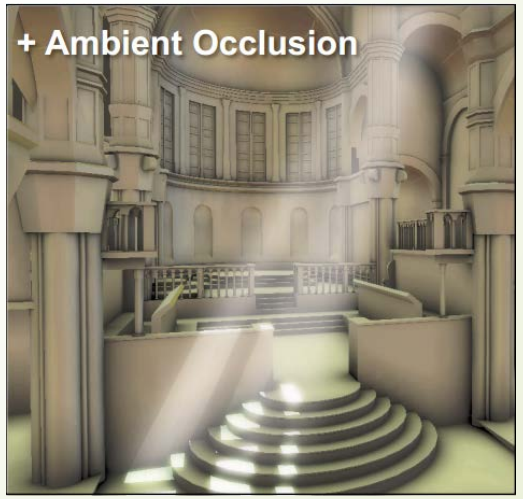
- What is the difference between your ray tracing and this path traced image?



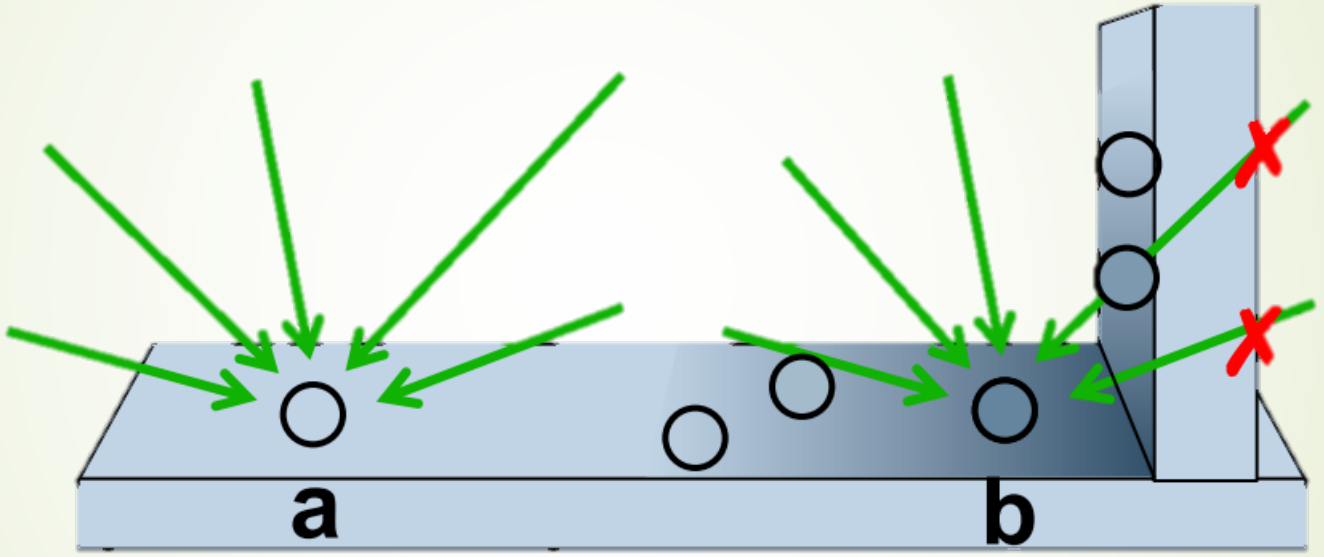
http://www.thepolygoners.com/tutorials/GIIntro/GIIntro.htm

Ambient Occlusion

- So far, our ambient term is merely a constant
- Ambient occlusion is a global illumination method that allows us better estimate the ambient term
  - Render objects as if place them in a cloudy day



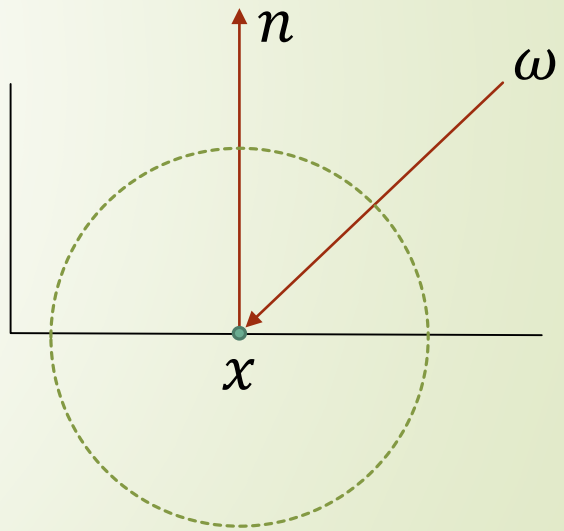
Basic idea of Ambient Occlusion



Less occluded More occluded

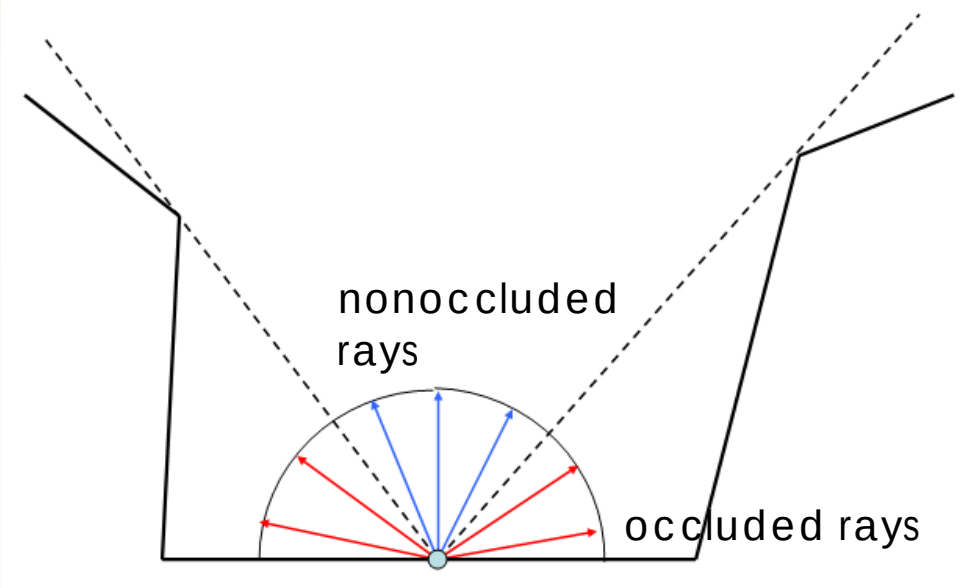
Ambient Occlusion

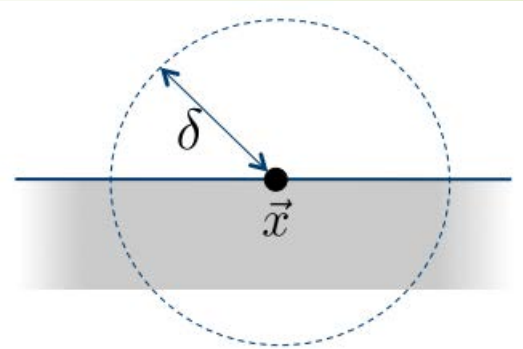
- Formulation
  - Ambient = $\frac{1}{\pi}\int L(\omega)\cdot V\cdot(\omega\cdot n)d\omega$
  - Recall that $L(\omega)$ is radiance from the direction of ω
    - $L(\omega)$ is usually assumed to be a constant
  - V is an indicator function
    - 0 if the steradiance ω is blocked
    - 1 otherwise



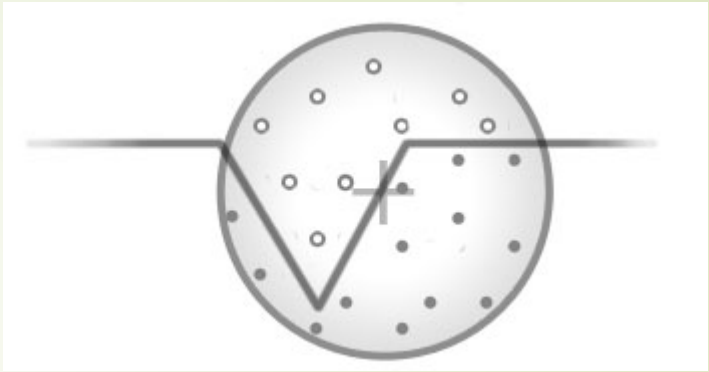
Ambient Occlusion

- Approximate using ray tracing
  - Shoot N rays in the open direction
  - Detect if a ray can see the sky
  - Occlusion is then $\frac{n}{N}$ if n rays are blocked
  - Practically, we should define a range δ as the influence range
    - If the ray hits something in the ball of radius δ then the ray is blocked
    - Otherwise the ray is free





Variants of AO Approximations



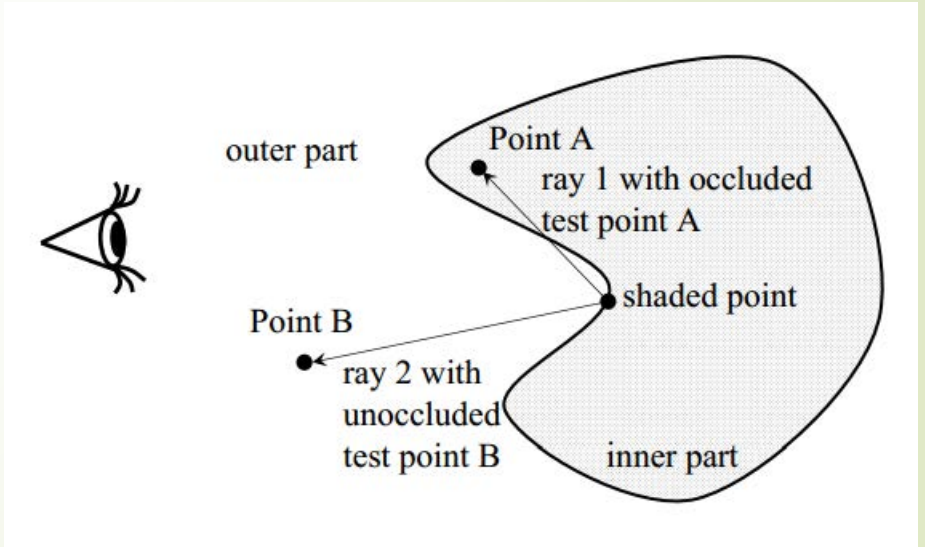
http://john-chapman-graphics.blogspot.com/2013/01/ssao-tutorial.html

- Ray traced AO
- Crytek SSAO (used in Crysis)
  - Use fragment shader per-pixel depth information
    - Sample in sphere around the given point
    - Project each sample to screen space to get the coordinates into the depth buffer
    - If the sample is behind the depth in the buffer, it contributes to the occlusion factor

Screen-Space Ambient Occlusion (SSAO)

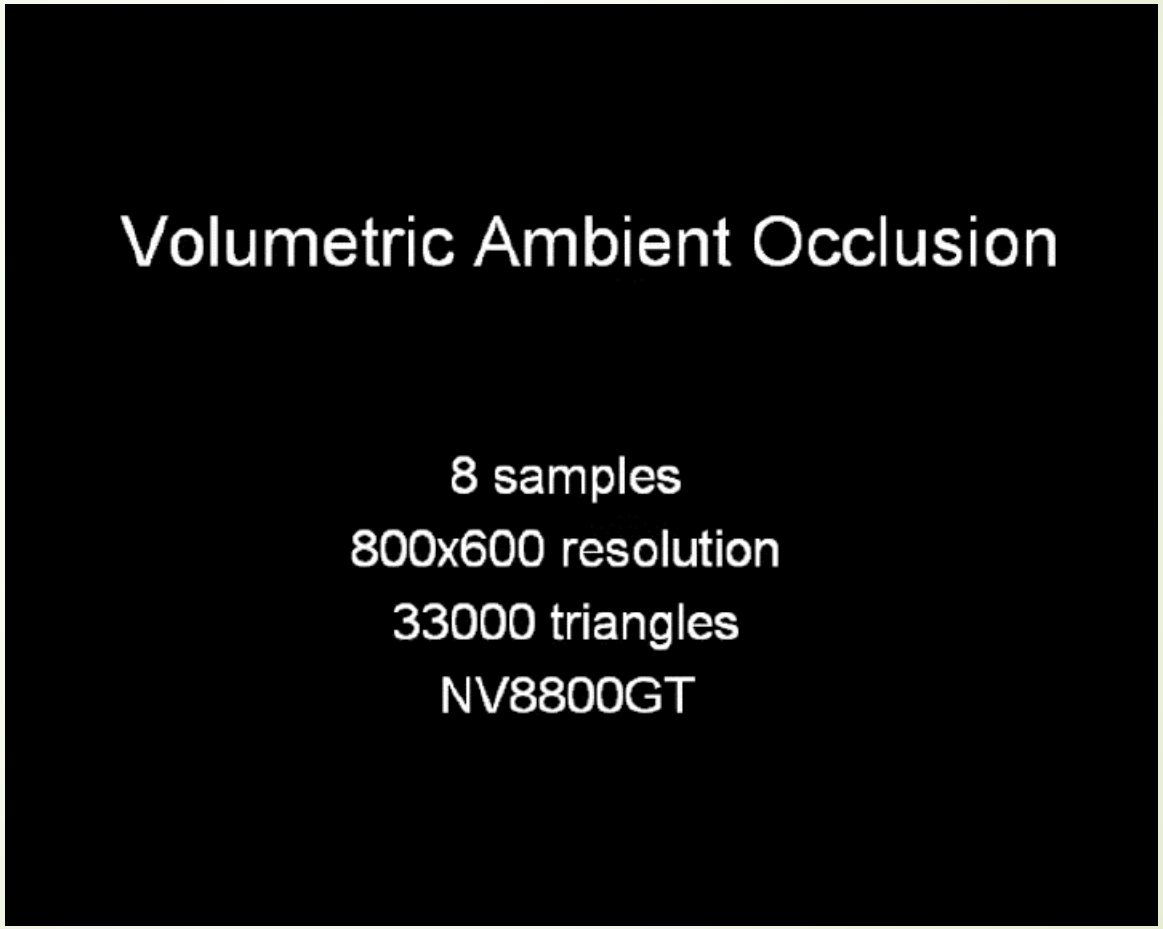
Variants of AO Approximations

- Volumetric AO
  - measures how big portion of the tangent sphere of the surface belongs to the set of occluded points
  - Fastest screen-space method



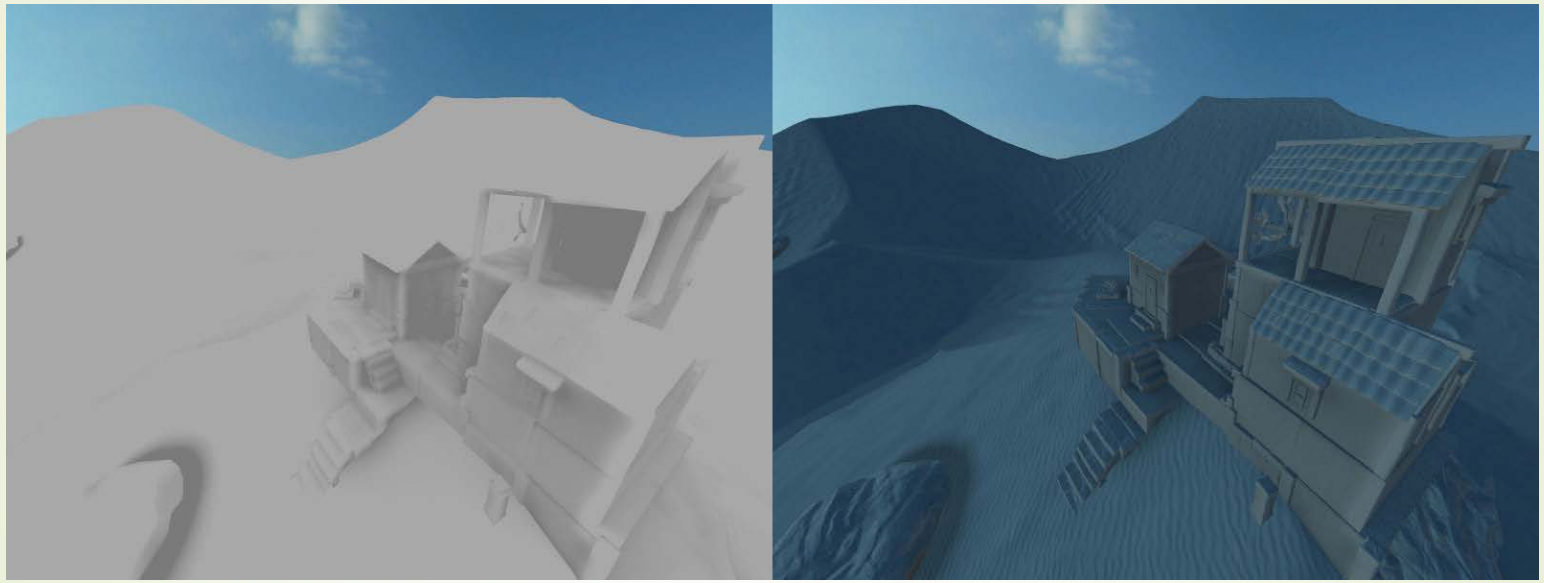
Replacing ray tracing by contain ment tests

Volumetric Ambient Occlusion

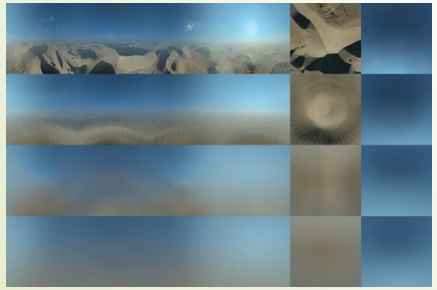


Variants of AO Approximations

- Image-based ambient light
  - Using cube-map, environment map, etc, to determine $L(\omega)$



By David Rosen



Blur image to reduce alias

Conclusion

- We briefly introduced and reviewed the global illumination
- We go over the basic ideas of ambient occlusion
- There are many variants for ambient occlusion approximation
  - Ray tracing (slow but most realistic)
  - Image-space ambient occlusion (fast but has artifacts)
  - ambient occlusion with cube map
  - ....