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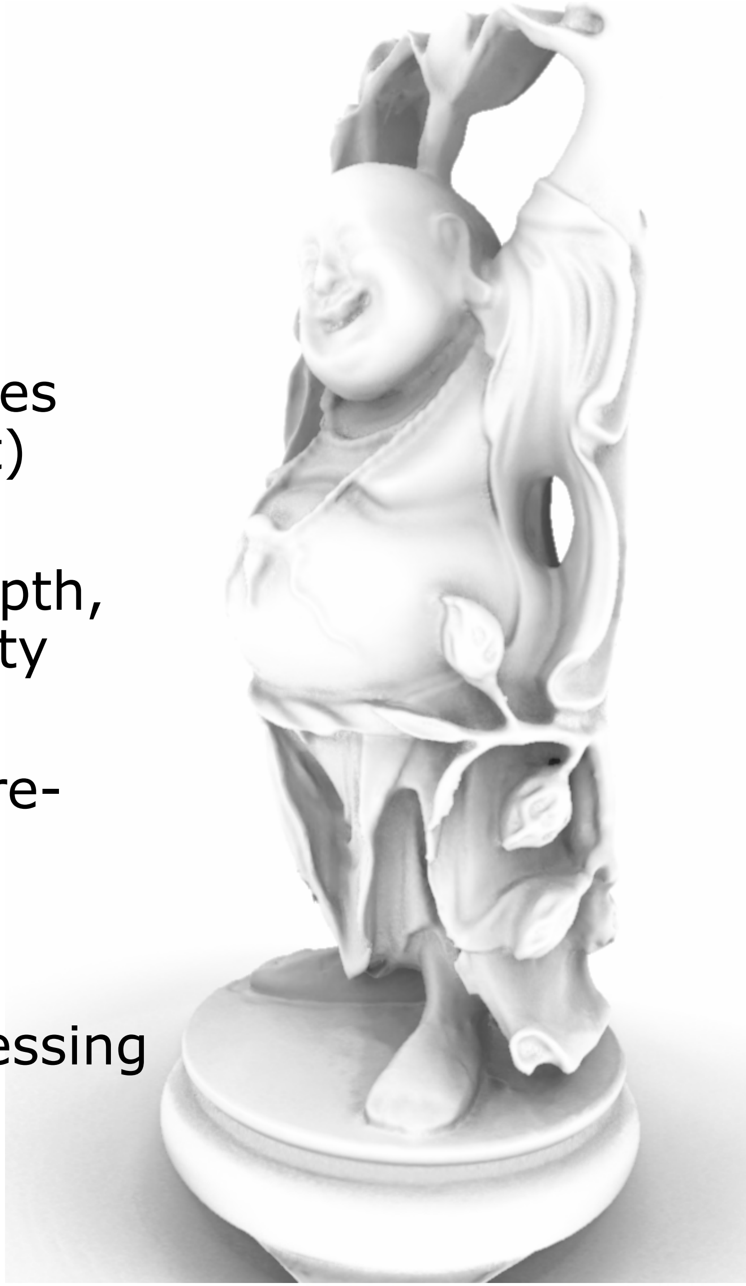
Real-Time Depth Buffer Based Ambient Occlusion

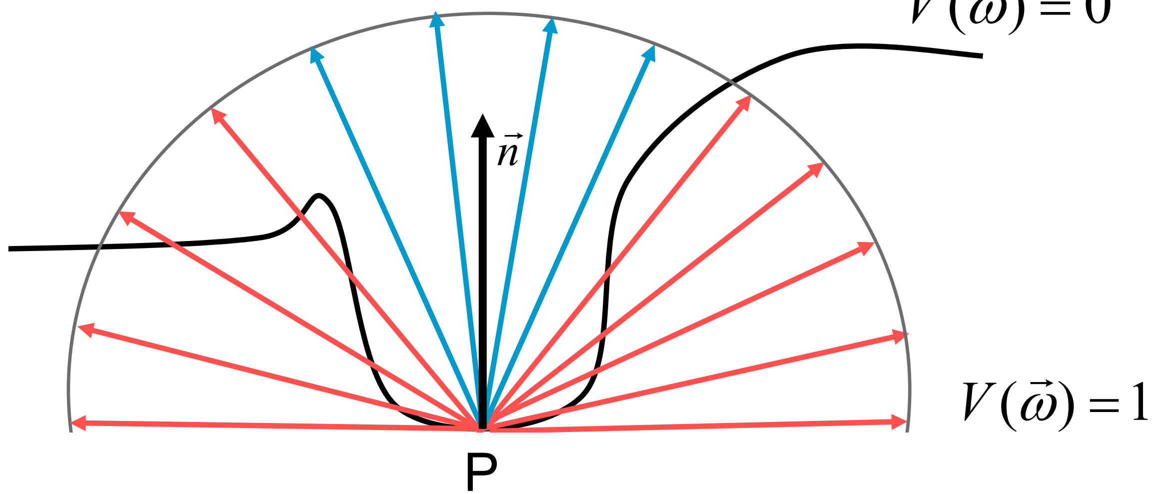
Miguel Sainz – NVIDIA
msainz@nvidia.com

Motivation

- Ambient occlusion approximates soft outdoor lighting (sky light)
- It gives perceptual clues of depth, curvature, and spatial proximity
- Traditional methods require pre-processing (bad for dynamic scenes)
- It can be done as a post-processing pass



Ambient occlusion



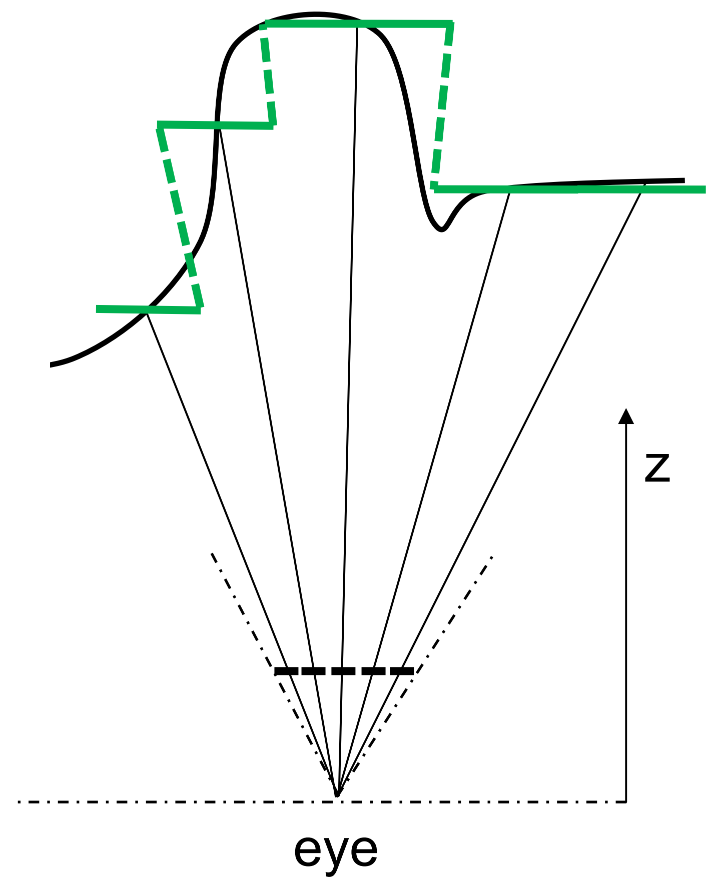
- Integral over the hemisphere Ω of radius R

$$A_P(\vec{n}) = 1 - \frac{1}{\pi}\int_{\Omega} V_P(\vec{\omega})(\vec{n}.\vec{\omega})d\omega$$

- Weighted by cosine term for diffuse shading
- V($\vec{\omega}$) typically attenuated with distance to P

Why screen space?

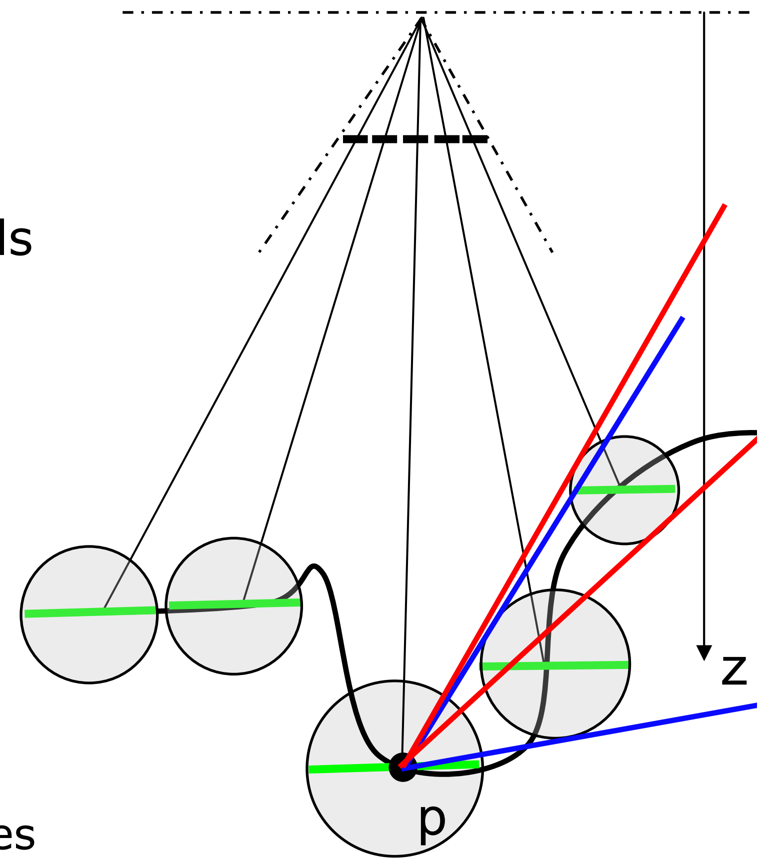
- Depth buffer is an approximation of the scene
- Depth buffer is available as part of normal rendering
- No dependency on primitive count
- No pre-calculation of any kind



Related work

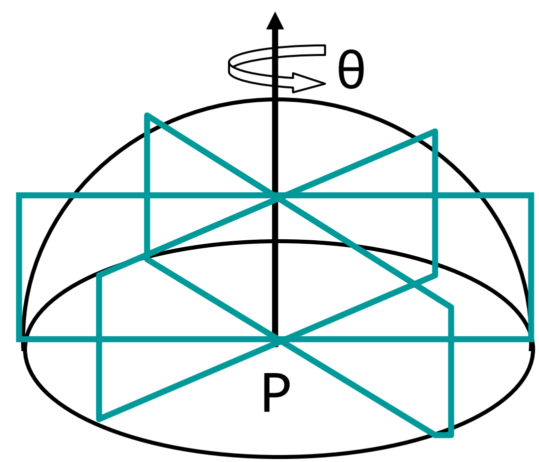
[Shanmugam and Okan 07]

- Approximate eye-space pixels by micro spheres
- Accumulate occlusion of spheres in a kernel
- Over-occlusion artifacts
  (multiple neighboring spheres contribute to the same pixel)



Horizon Split AO

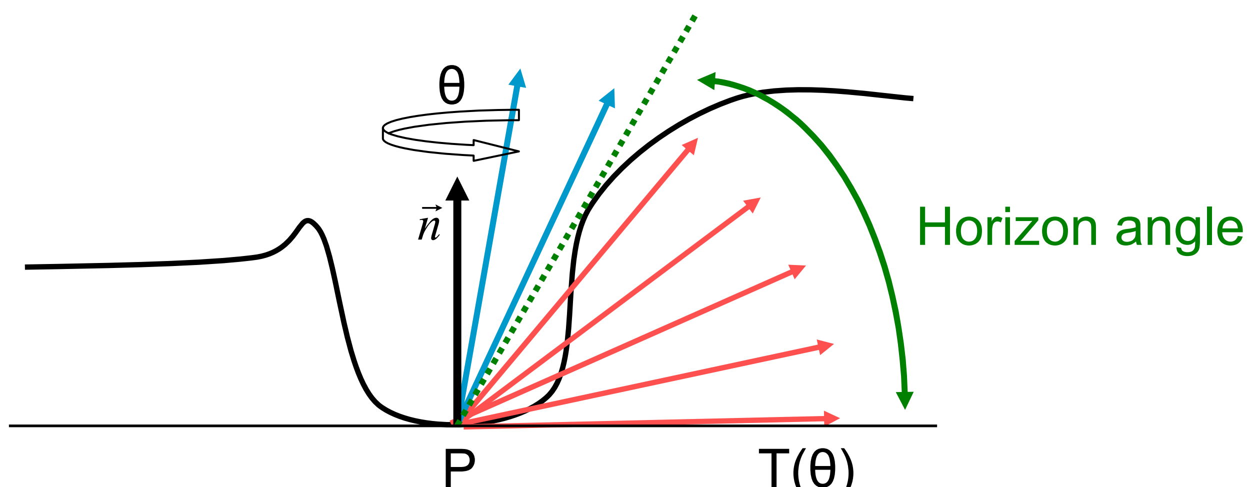
- Treat depth buffer as a height field and process each pixel
- Sample a set of directions over the hemisphere
    - Evaluate a fan of slices around the normal on each surface pixel
    - Use randomization
- Split AO integral in two parts for each slice



HSAO - Intuition

- The hemisphere can be partitioned in two parts based on the “horizon” around P

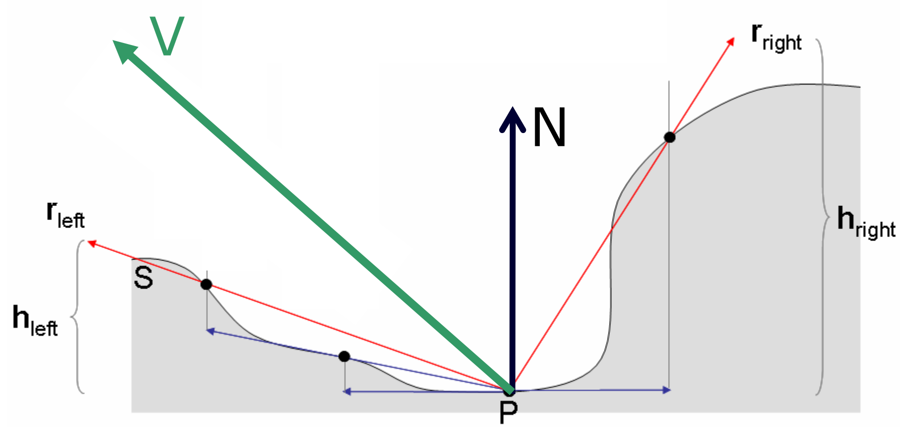
  - Red rays are always occluded
  - Blue rays are undetermined and need to be traced



- The horizon angle can be found by stepping along the tangent T(θ)

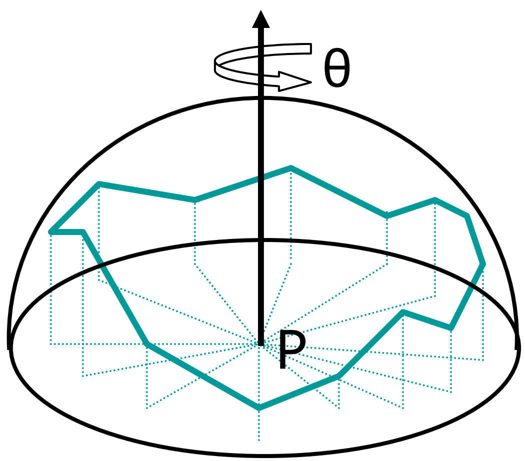
Horizon determination

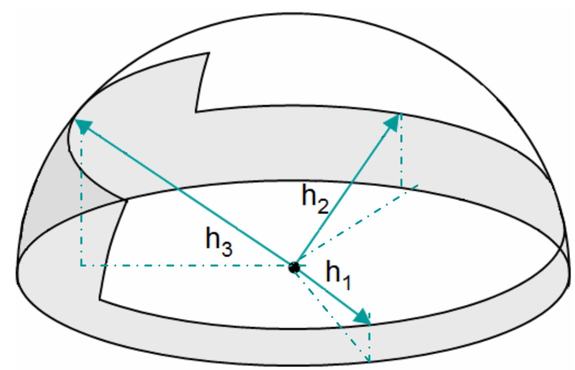
On a given slice around the normal, iterate N steps while deflecting the tangent ray in the normal direction



Horizon integration

- Piece-wise linear approximation of the horizon



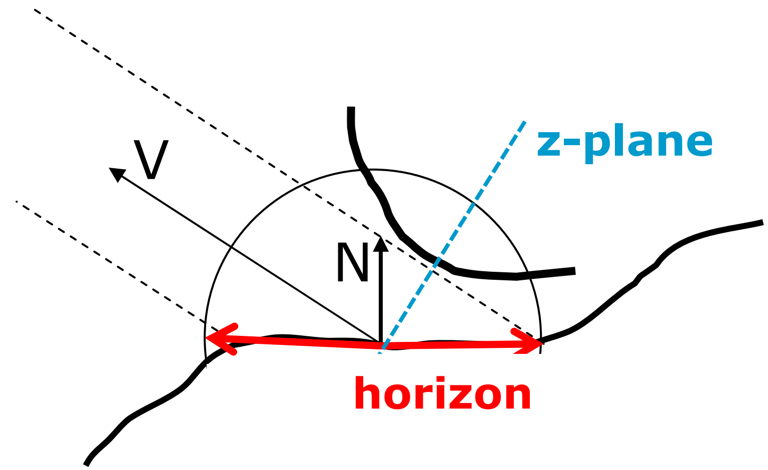


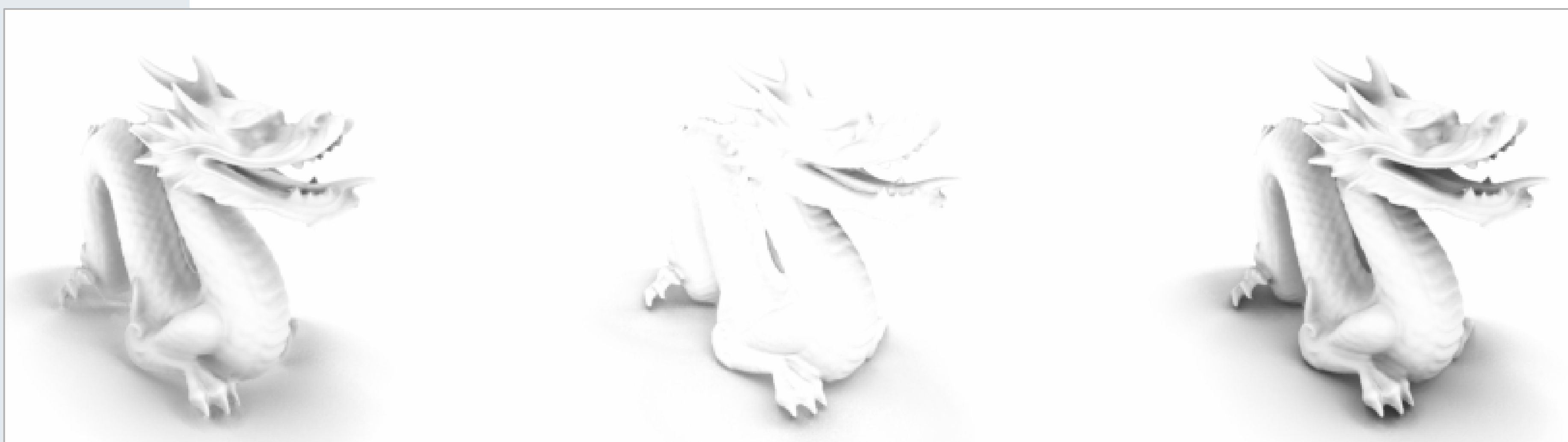
$$O_T = \frac{1}{N_d} \sum_{i=1}^{N_d} H^2(\theta_i) dz$$

- Efficient integral of occlusion contribution

Normal occluders - intuition

- For some surface orientations the tangent tracing will not hit any surface



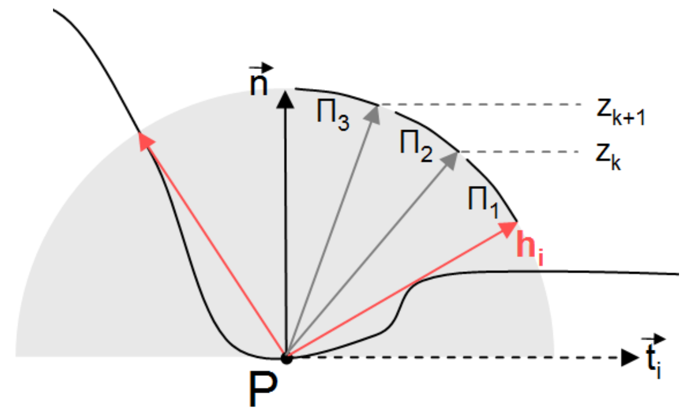


Horizon component

Normal component

Normal occluders

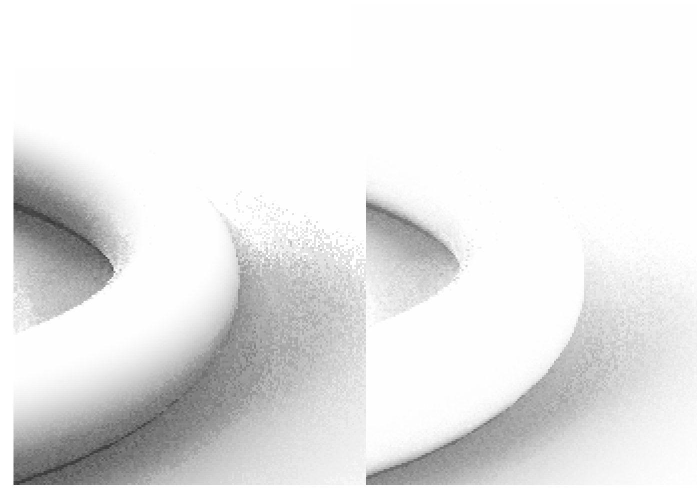
- Evaluated by ray marching
- Angle range constrained by the horizon and the normal
- Lambertian distribution of rays
- Simple AO contribution

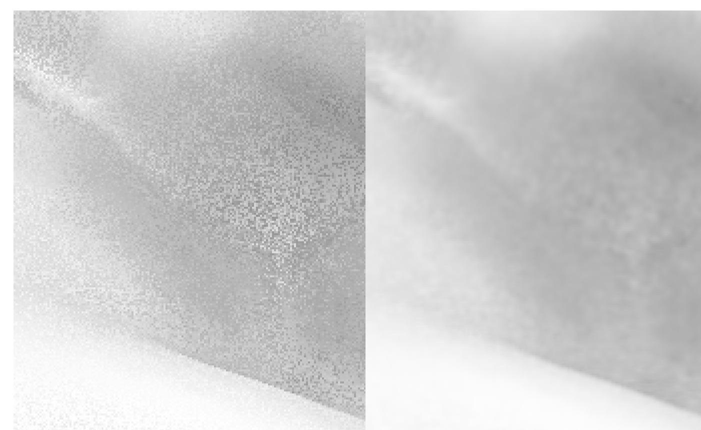


$$O_{N,i(z_k)} = \frac{1}{N_d}\left(z_{k+1}^2 - z_k^2\right)\cdot V(\vec{\omega})$$

Additional Tweaks

- Linear attenuation
  - Remove banding discontinuities at the boundaries
- Smart Blur
  - Remove the noise artifacts
  - Use depth information to avoid edge leaking
- Final compositing
  - Add as an ambient term





Dragon

Resolution: 800x600

AO Render Time: 7.9ms

Trace Radius: 1/4 Model's Width

Horizon Rays: 8

Number of steps: 8

Normal Rays per Direction: 1

Dragon

Resolution: 800x600

AO Render Time: 26.9 ms

Trace Radius: 1/4 Model's Width

Horizon Rays: 16

Number of steps: 16

Normal Rays per Direction: 1

Optimizations

- New formulation - Done
  - Improved integration space and math
  - No need for marching additional normal rays. 1.5x faster

- Use previous frame(s) information
- Downscale ND buffers

…

Demo time!

For more information

Contact me at msainz@nvidia.com

Slides, code and whitepaper will be soon available at **developer.nvidia.com**

(Co-authors: Rouslan Dimitrov and Louis Bavoil)

Questions?