Advances in Real-Time Voxel-Based GI

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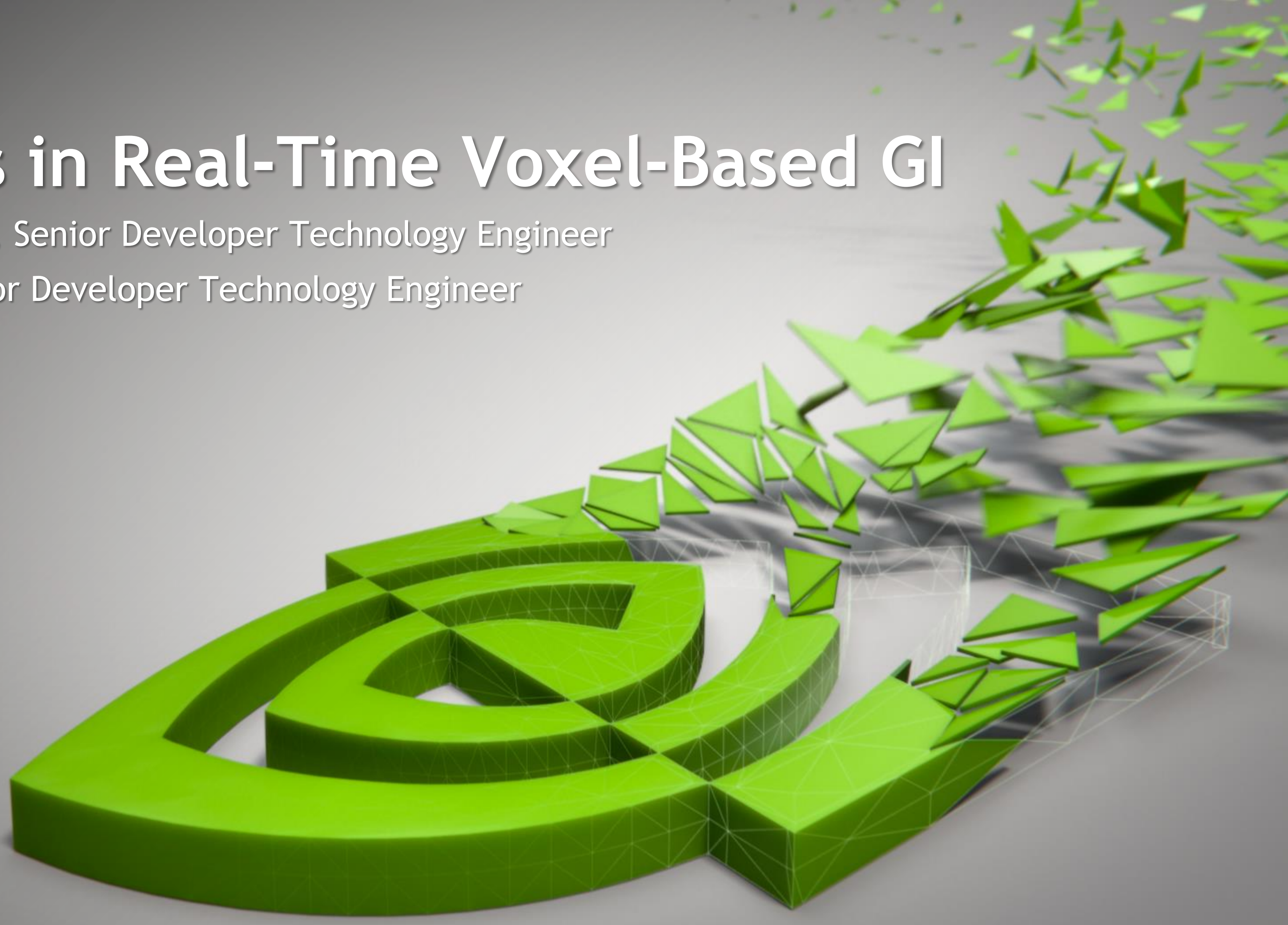
NVIDIA



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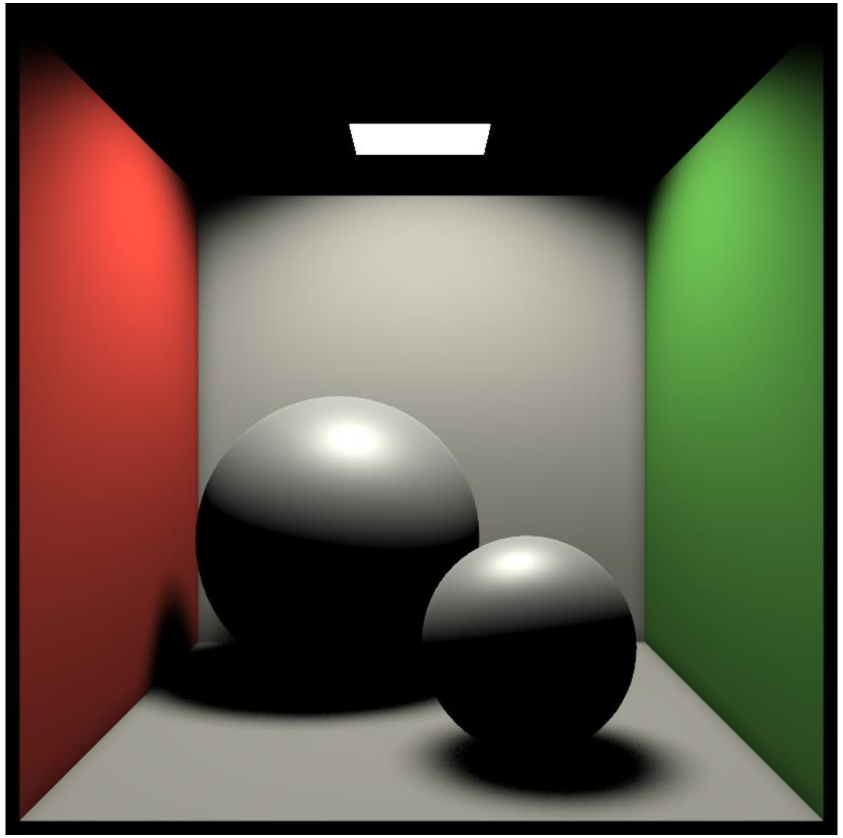
Recap on VXGI

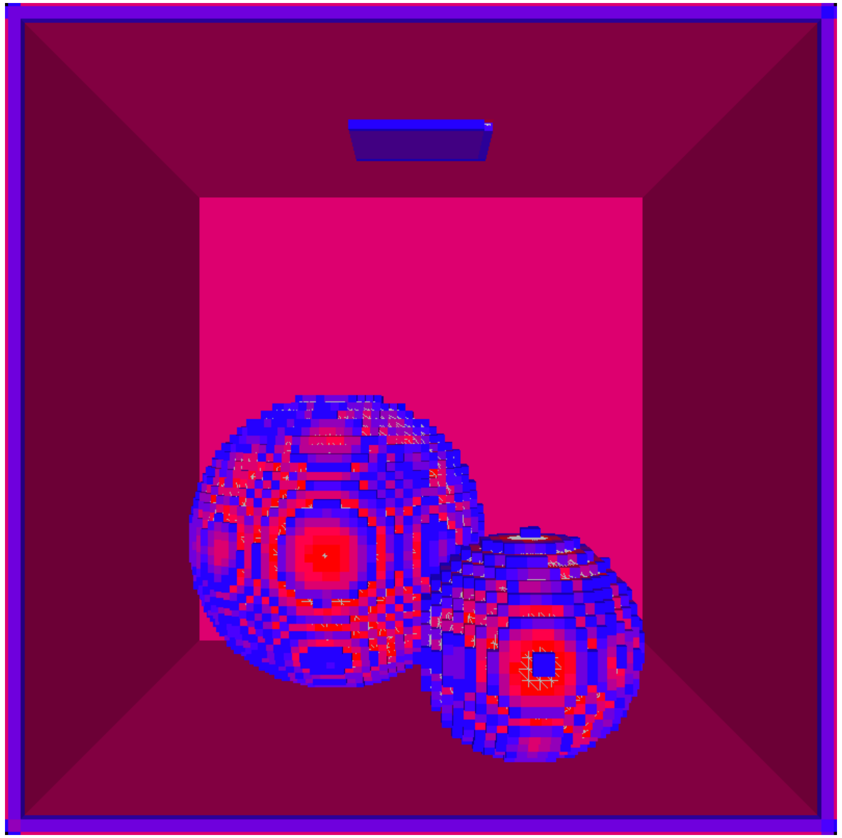
- Voxel Global Illumination
  - Inspired by Sparse Voxel Octree Global Illumination (SVOGI)
  - Clip-map used instead of octree

- Fully dynamic scene support
  - Voxelizing a game-like scene from scratch takes only a few ms
  - Supports multi-bounce GI through a temporal feedback loop on irradiance

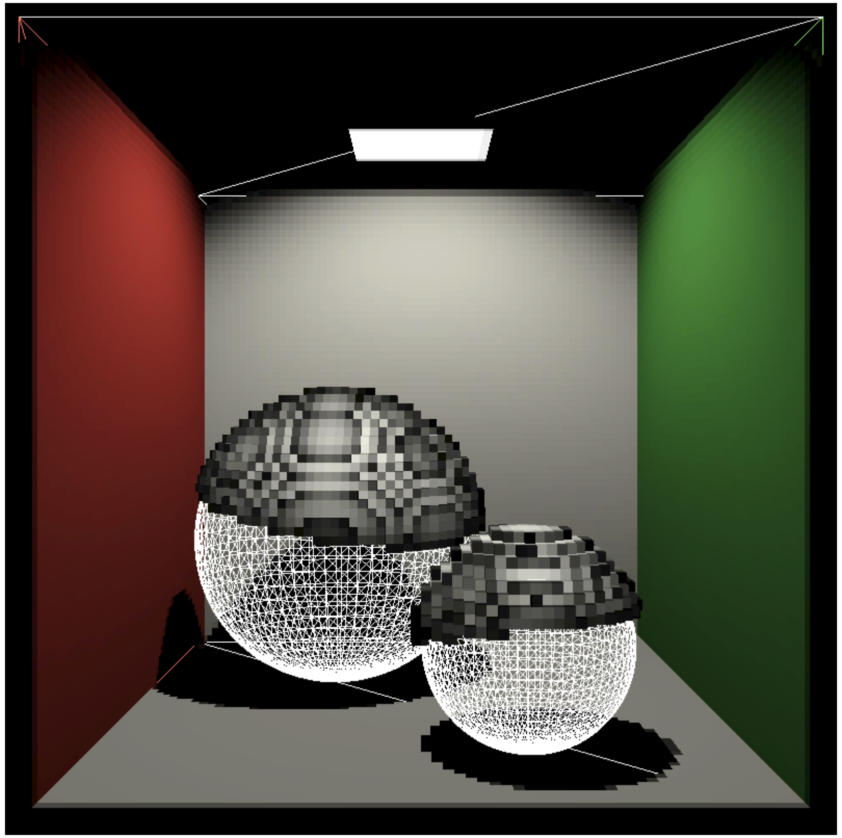
Cornell Box Scene



VXGI Algorithm: Voxelization



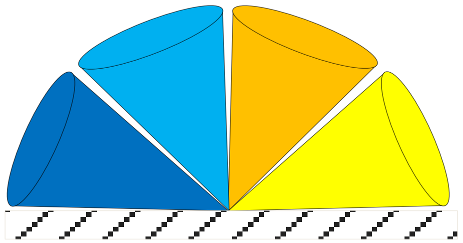
Opacity



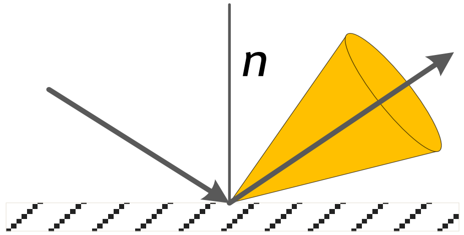
Emittance / Light

VXGI Algorithm: Tracing

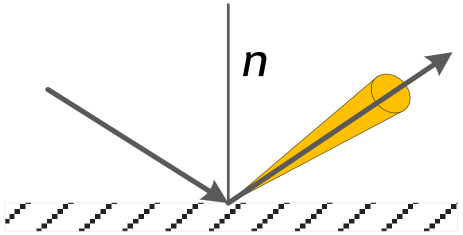
Diffuse

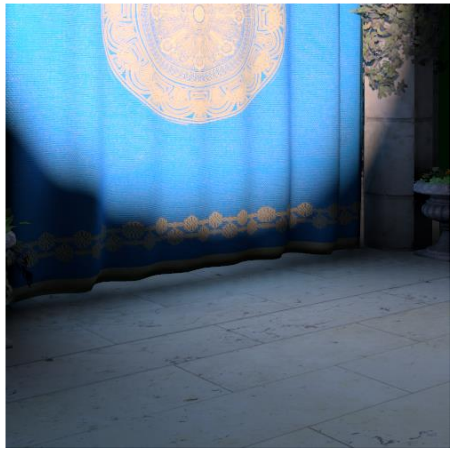


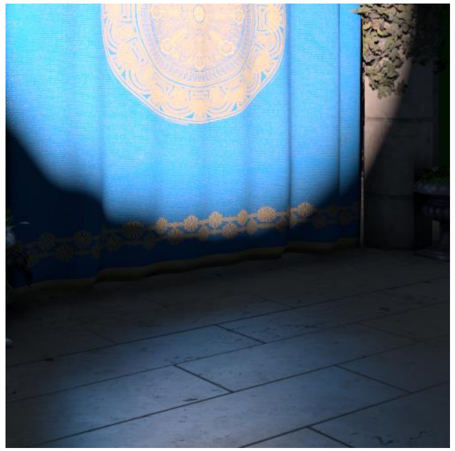
Rough Specular

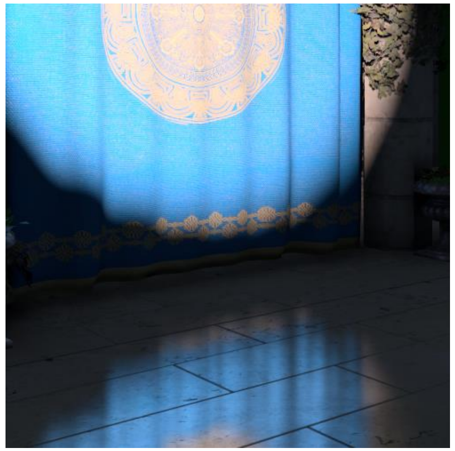


Fine Specular

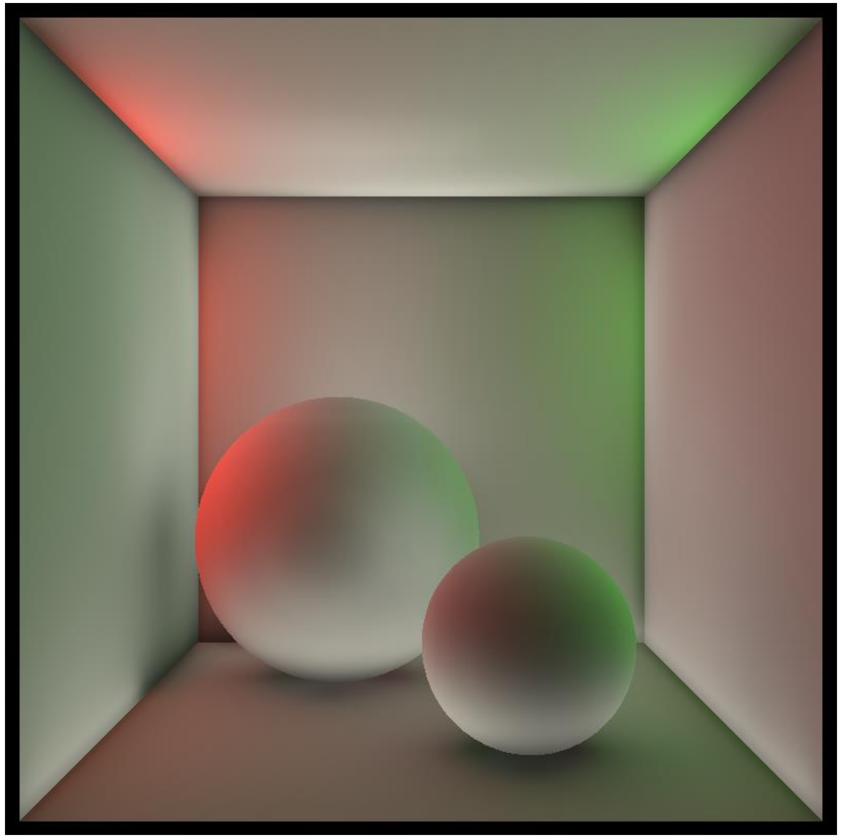


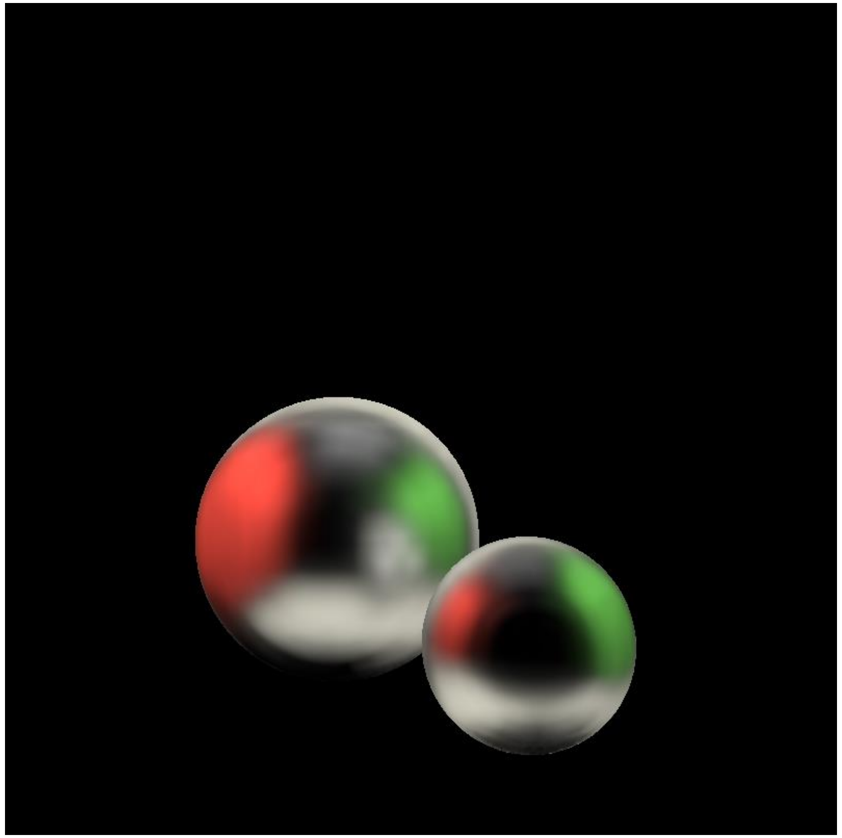




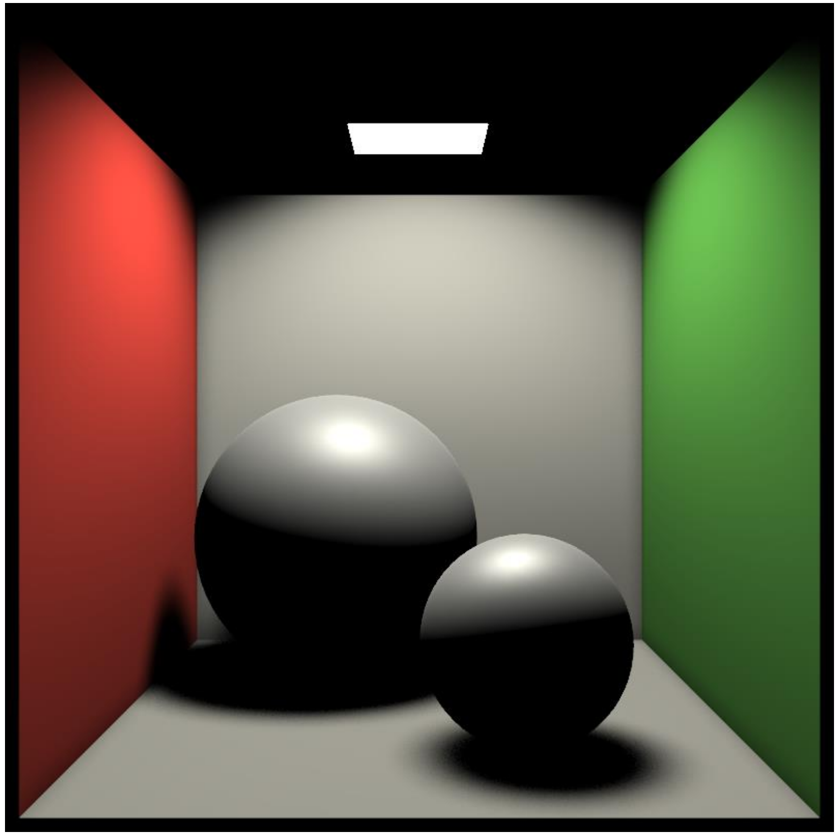


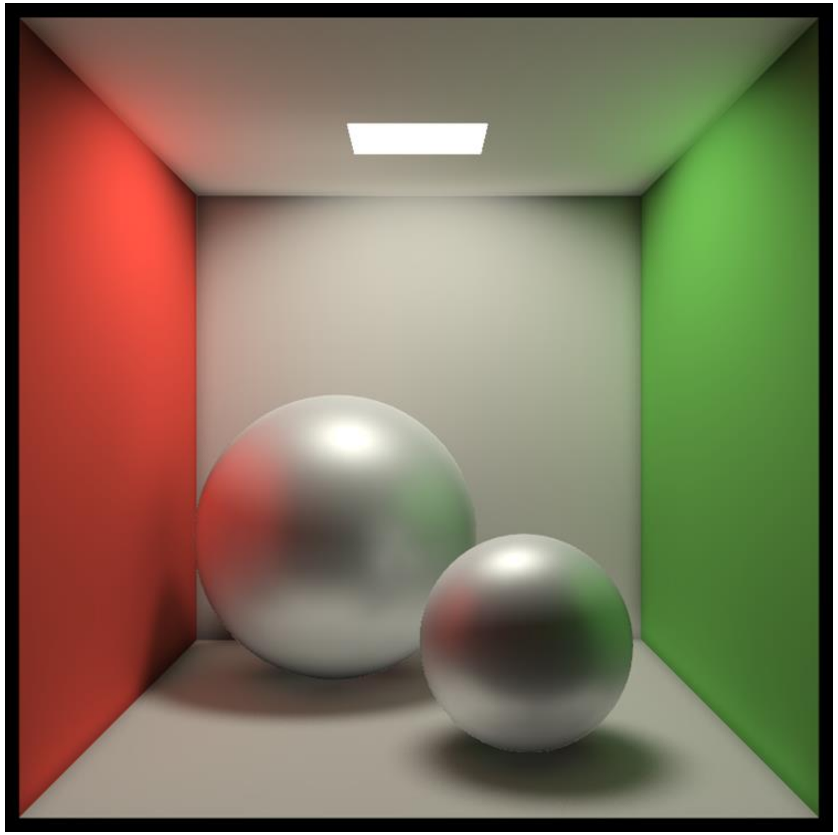
Results of Cone Tracing


Indirect Diffuse


Indirect Specular

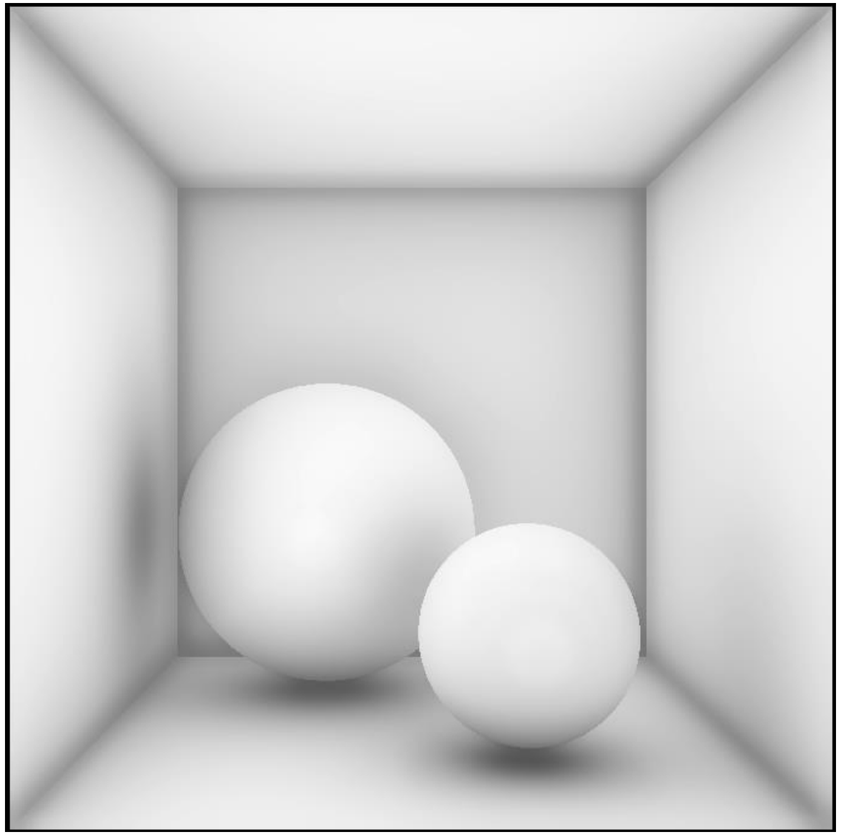
Final Result


Direct Lighting Only

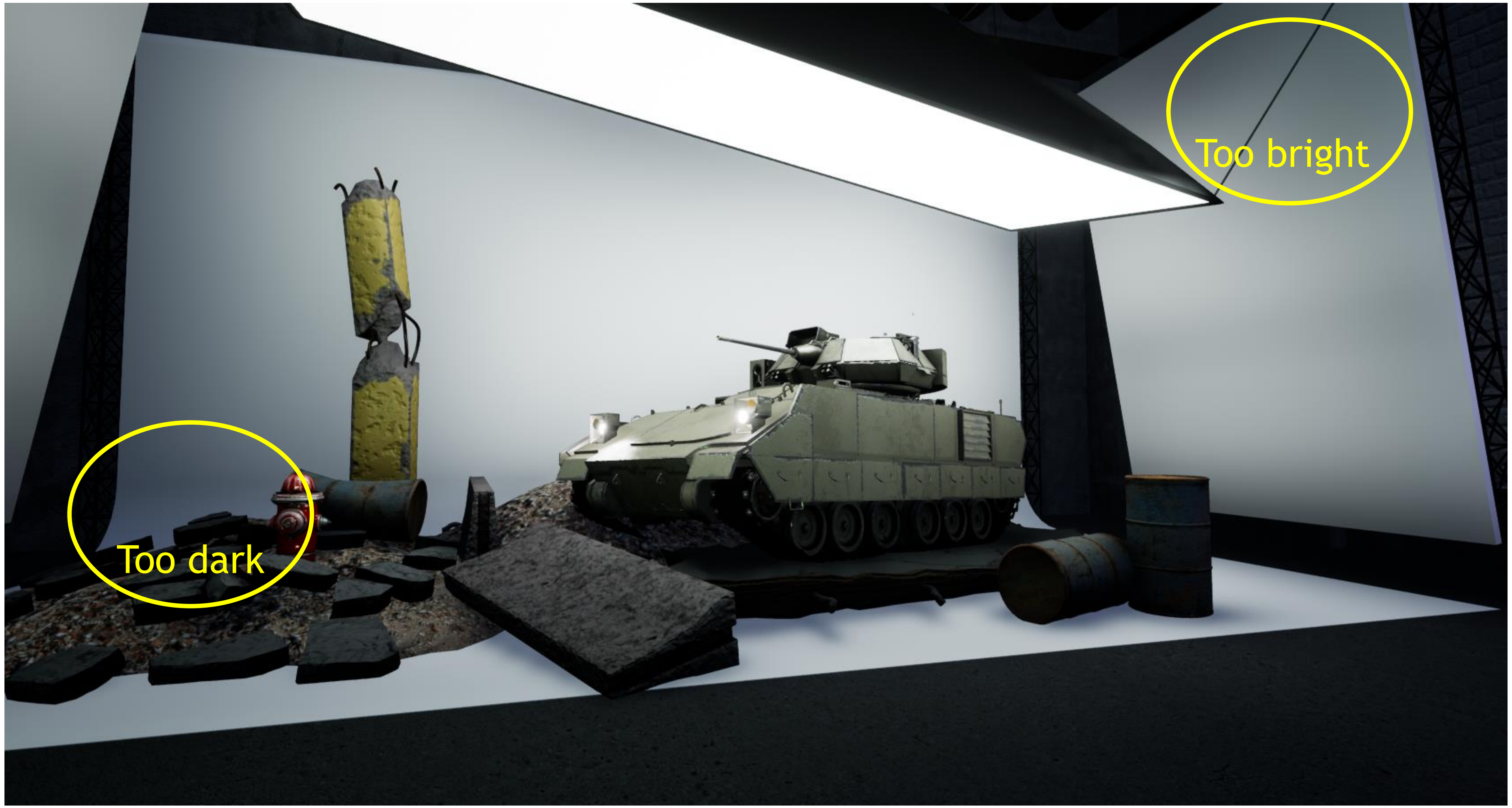

Direct and Indirect

Voxel Ambient Occlusion

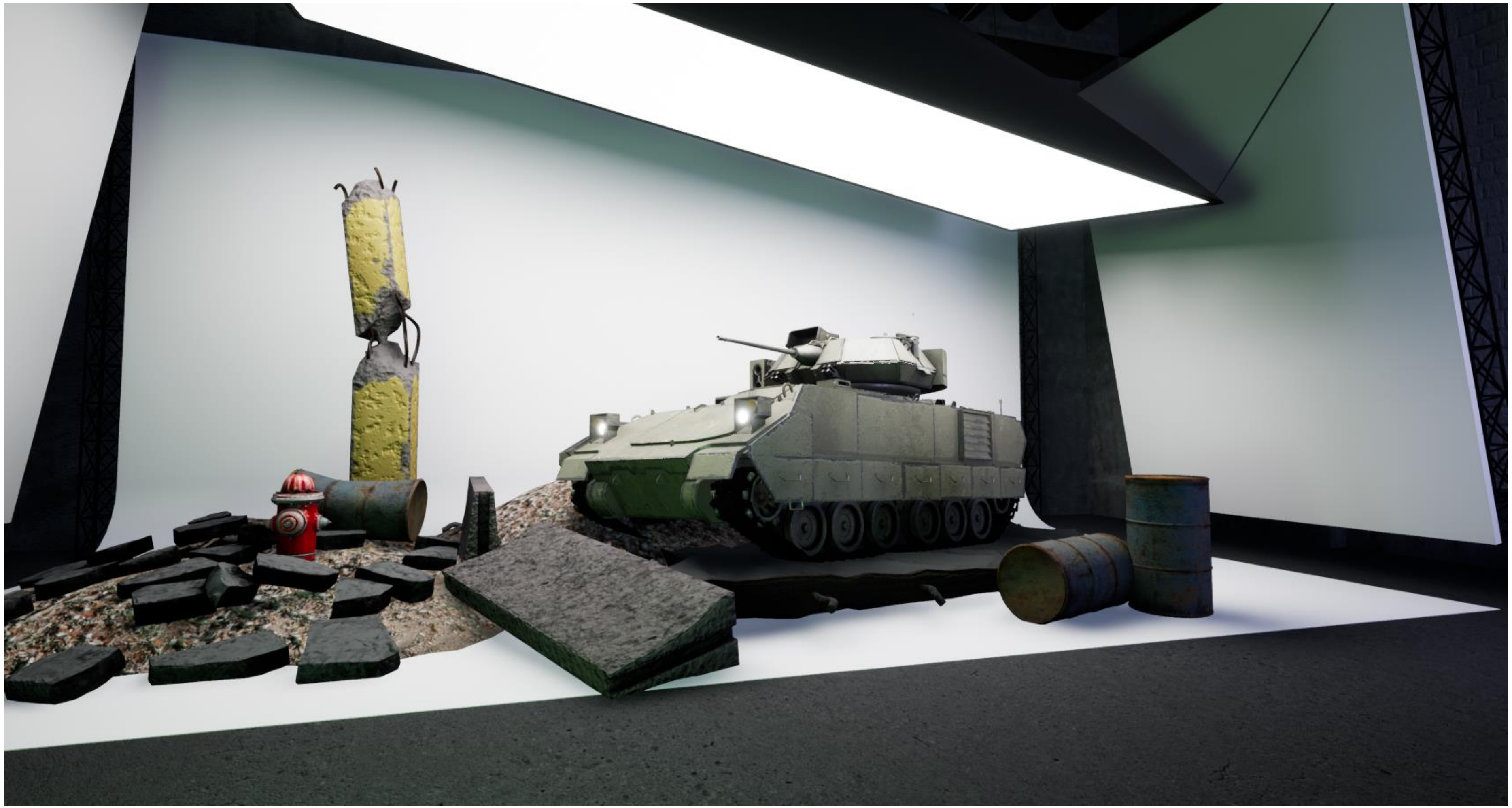
- VXAO
- Easier to compute than full global illumination
  - No light processing, only opacity
- Easier to integrate into engines
  - No materials or lights during voxelization
- Looks better than screen-space techniques
  - World-space, not screen-space
  - Best if combined with small-scale SSAO



Area Lights with VXGI



Better Area Lights with VXGI 2.0



Voxel Area Lighting

Area Lighting

- A hot topic of interest in the industry and academia

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  - Impressive lighting for area lights
  - Complexity is O(n)
    - n is # of edges

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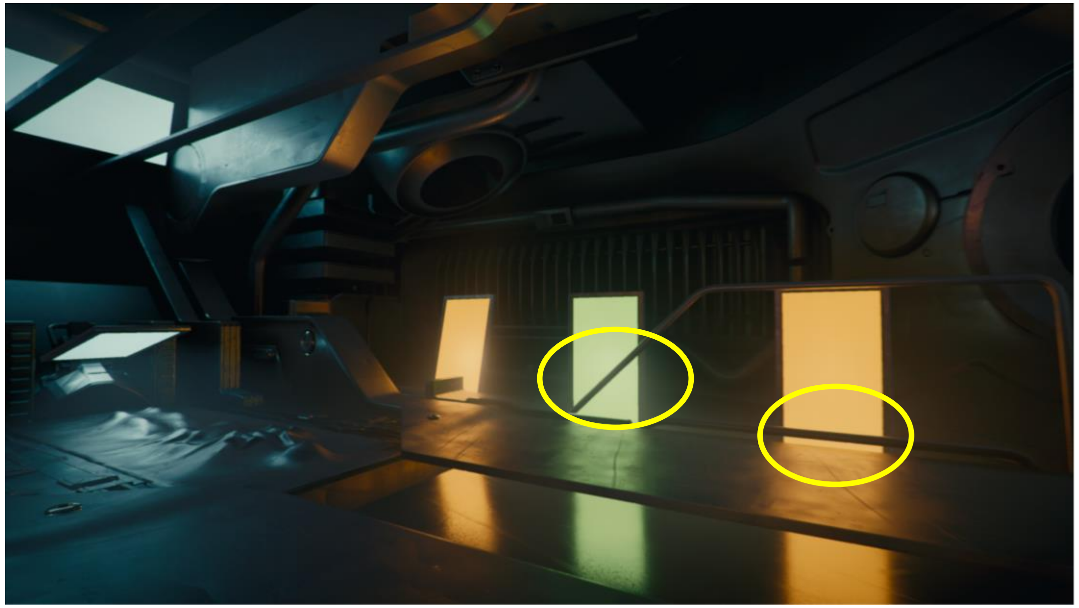
- Linearly Transformed Cosines
  - A new technique invented in 2016
  - Impressive lighting for area lights
  - Complexity is O(n)
    - n is # of edges
- But the occlusion is missing



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Voxel Area Lighting

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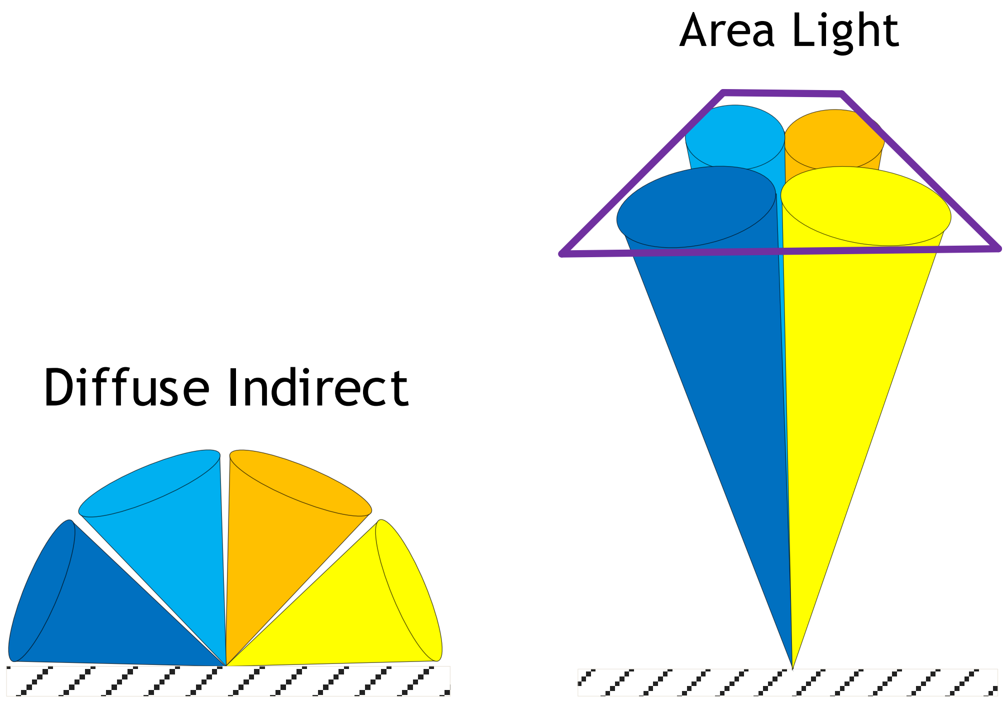
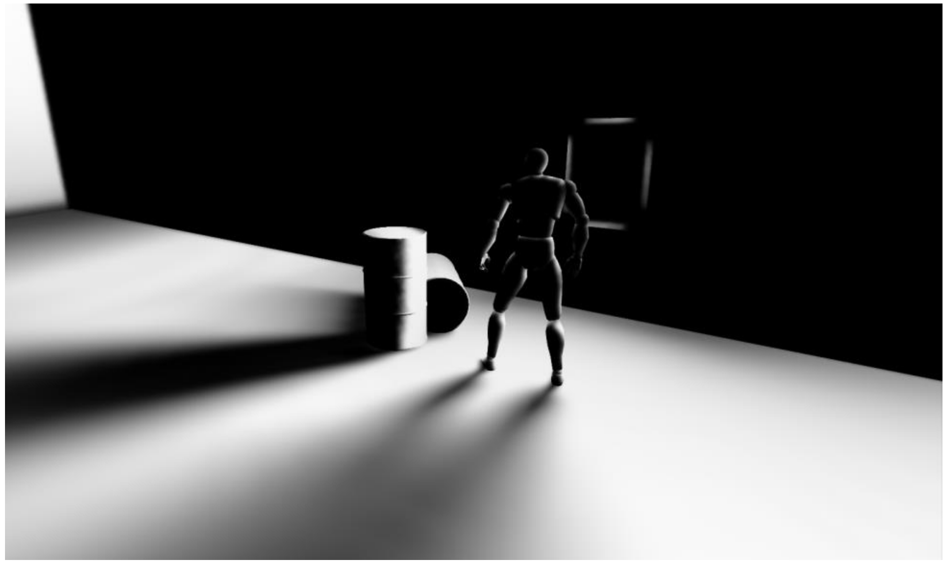


Voxel Area Lighting

- VXAL
- Distribute cones over the area light
- Occlusion
  - Large Scale: Cone tracing similar to VXAO
  - Small Scale: Screen space shadows



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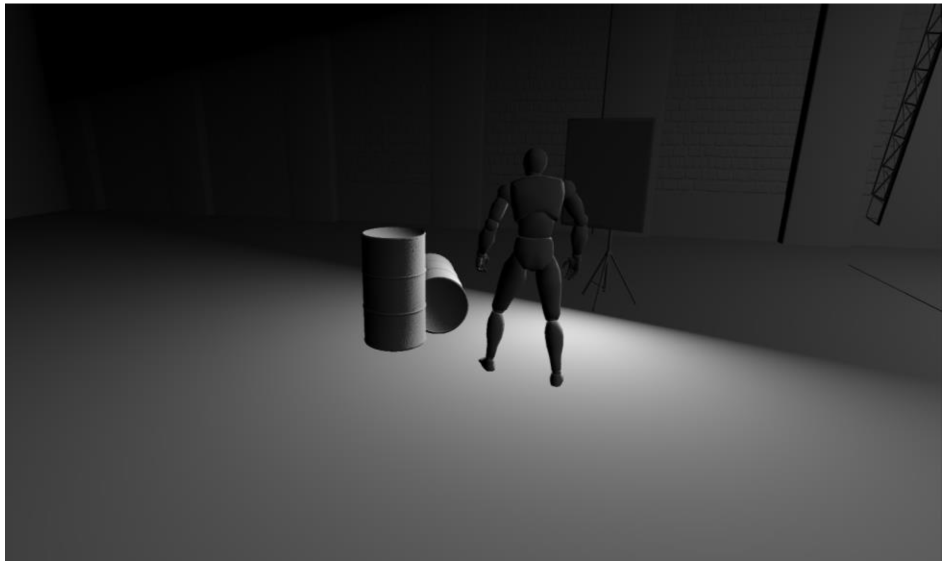
- Irradiance
  - Diffuse and Specular
  - Linearly Transformed Cosines



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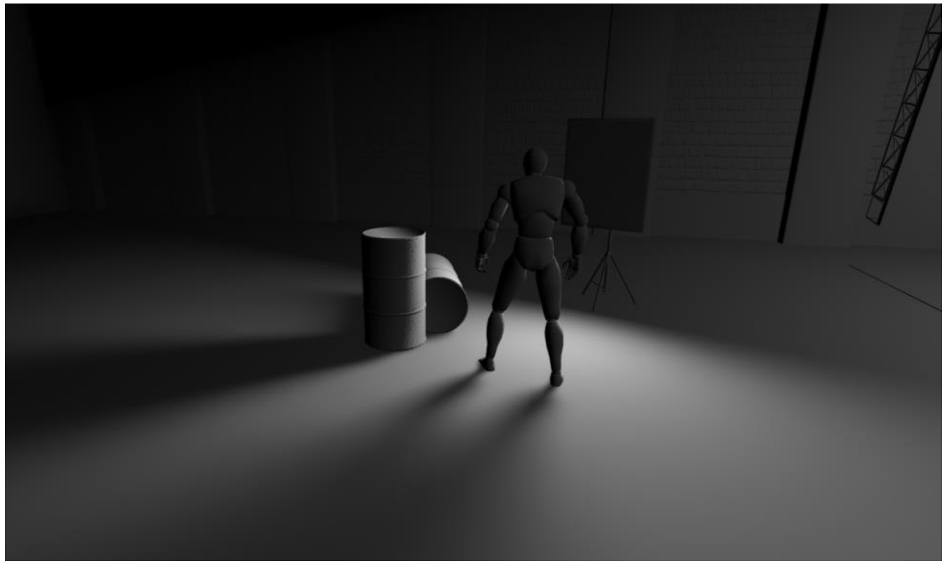

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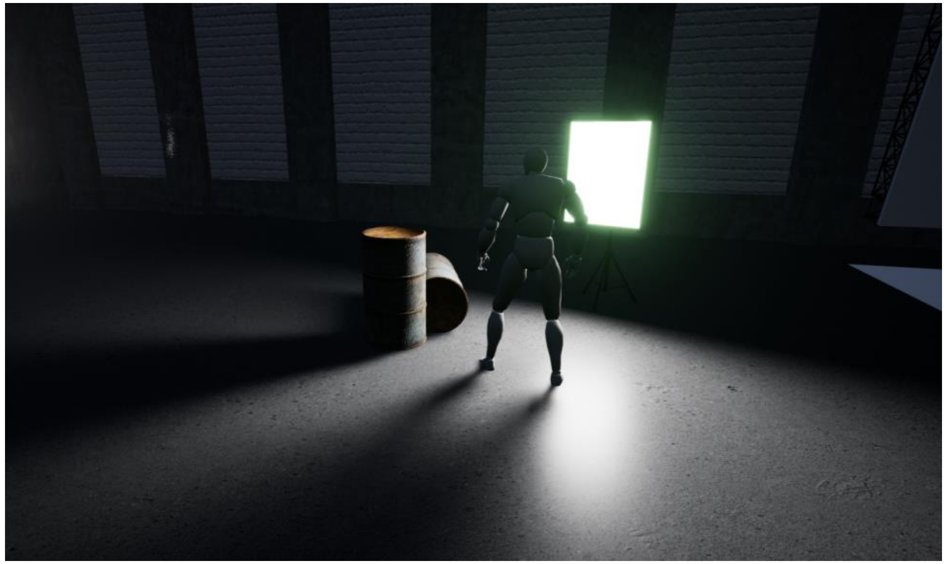
- Modulate irradiance with occlusion
- Apply material parameters like albedo, composite into the final view



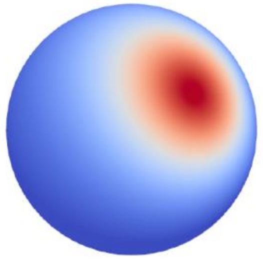
Area Lights

- Multiple area lights supported
  - Rectangular in shape
  - Textured or Solid color
  - Each light has some rendering cost
  - Dynamic textures are not free

- Wide range of quality settings
  - Tracing resolution: half-res to quarter-res
  - Occlusion quality: use more or fewer cones per unit angle
    - Actual number of cones is adaptive and varies per pixel

Linearly Transformed Cosines

- BRDF
  - How much light transfers from incoming directions to outgoing directions



BRDF

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Linearly Transformed Cosines

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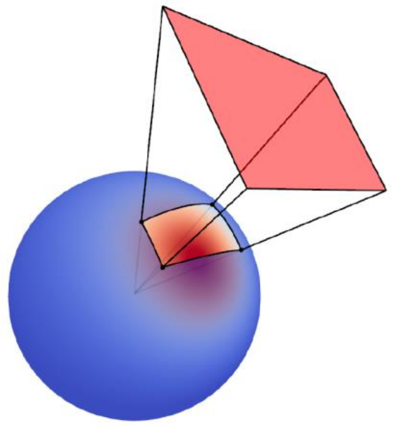
- Shading:
  - Integrate BRDF over the light’s spherical projection



Distribution D

Polygon P

$$\int_P D(\omega)\, d\omega = ?$$

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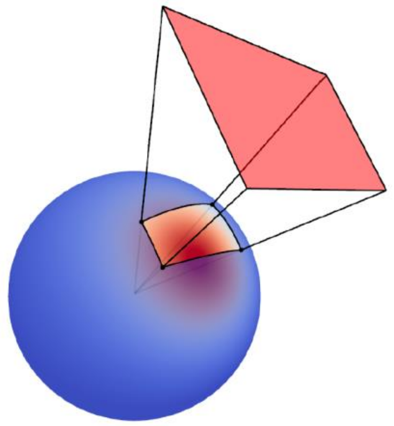
Linearly Transformed Cosines

- BRDF
  - How much light transfers from incoming directions to outgoing directions
- Shading:
  - Integrate BRDF over the light's spherical projection
- Analytic solutions exist, but only for simple BRDFs
  - e.g. Phong, but very expensive



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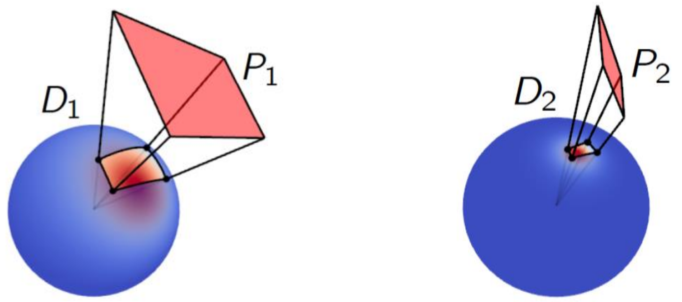
Linearly Transformed Cosines

- Integrals invariant under linear transformations
  - Transform to the distribution
  - Transform to the polygon
  - Results are same



$$\int_{P_1} D_1(\omega)\, d\omega = E[I] \qquad \int_{P_2} D_2(\omega)\, d\omega = E[I]$$

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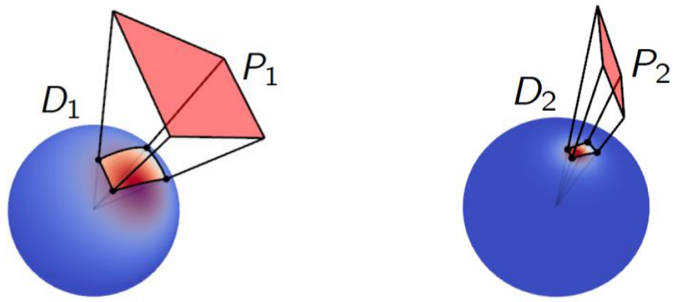
- Parameterized linear transforms
  - View Angle & Roughness
  - Pre-computed and stored in textures



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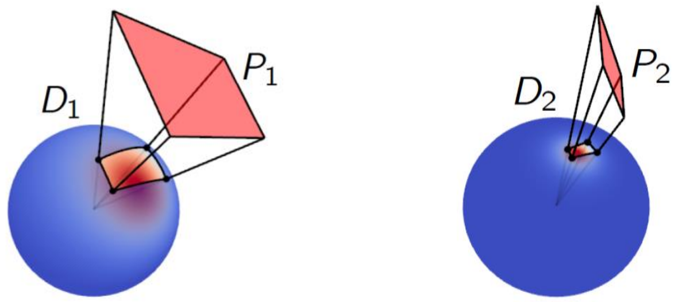
  - Pre-computed and stored in textures
- Prefiltered textures for textured lights



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VXAL API

- Set the area lights
  - Position, orientation, size, color, texture, etc.

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- Set the view information
  - Projection matrices, viewports, etc.
  - Provide G-buffer channels

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- Set the view information
  - Projection matrices, viewports, etc.
  - Provide G-buffer channels
- Returns
  - Diffuse Irradiance channel
  - Specular Irradiance channel

Future Work

- Support other types of area lights
  - Maybe disk or line lights
- Improve image quality
  - Near-field occlusion
  - Flickering in low-res modes

References

- “Realtime polygonal-light shading with linearly transformed cosines” by Heitz, E., Dupuy, J., Hill, S., and Neubelt, D. 2016, Transactions on Graphics 35

VXAL DEMO

VXGI 2.0 New Features

(besides VXAL)

One-Pass Voxelization

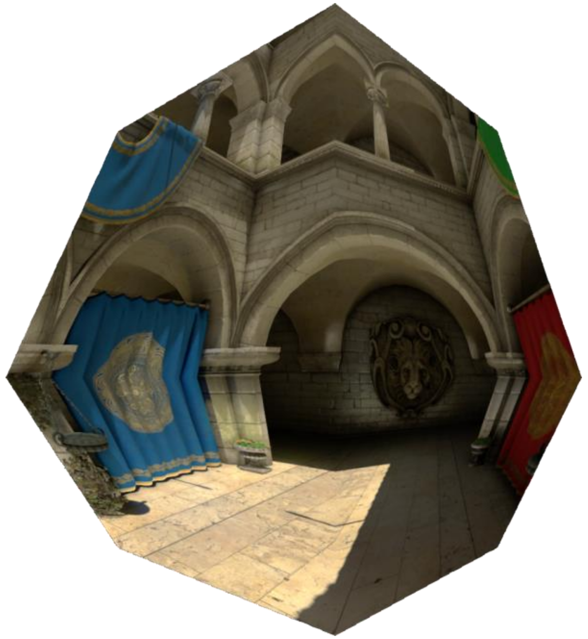
- VXGI 1.0:
  - Separate voxelization passes for opacity and emittance
  - Twice the CPU cost, almost twice the GPU cost – on top of other rendering passes

- VXGI 2.0:
  - Can do everything in one pass
  - Or multiple, up to the application
  - Each pass adds some opacity and emittance to the voxel volume

Custom G-Buffer Layouts

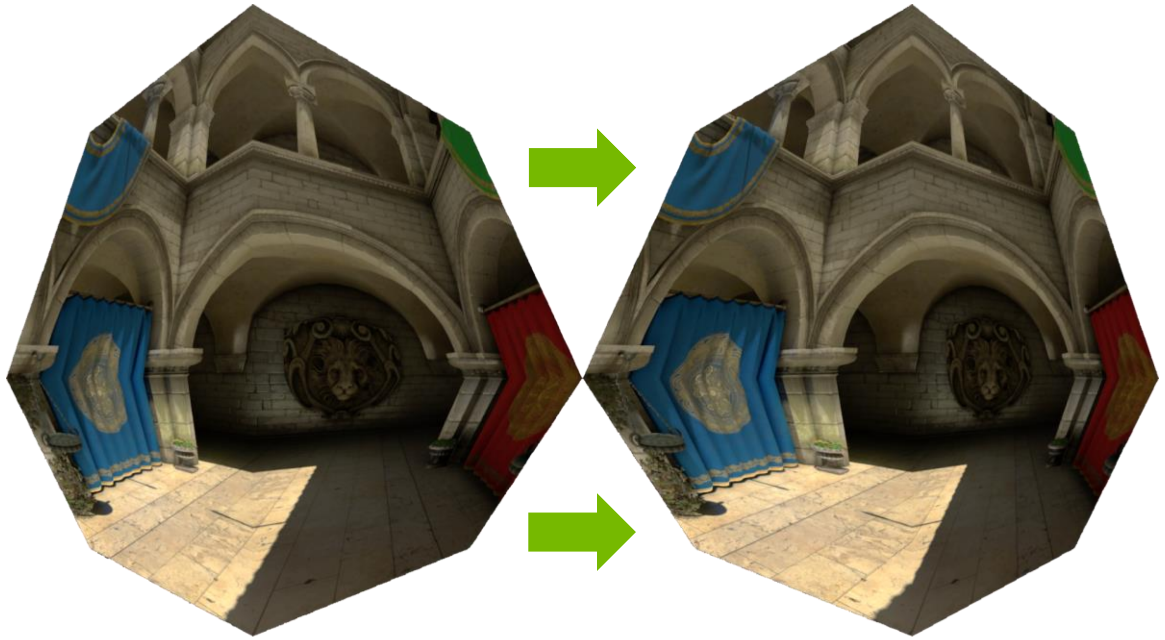
- VXGI 1.0 requires a specific data layout and projection
  - Hardware depth, linear normals, roughness in normal.w
  - Planar projection only
- VXGI 2.0 takes HLSL code to load geometry info for a pixel
  - Anything that resolves to a position and normal will do
  - VRWorks MRS and LMS projections, or anything else
  - Many tracing settings can vary per-pixel

Lens-Matched Shading



View Reprojection

- VXGI 1.0 supports reusing lighting information from the previous frame
  - Temporal reprojection or temporal filtering
- VXGI 2.0 adds reuse between views in the same frame
  - Compute lighting for the left eye
  - Reproject matching surfaces to the right eye
  - Fill the holes
  - No limits on the number of views



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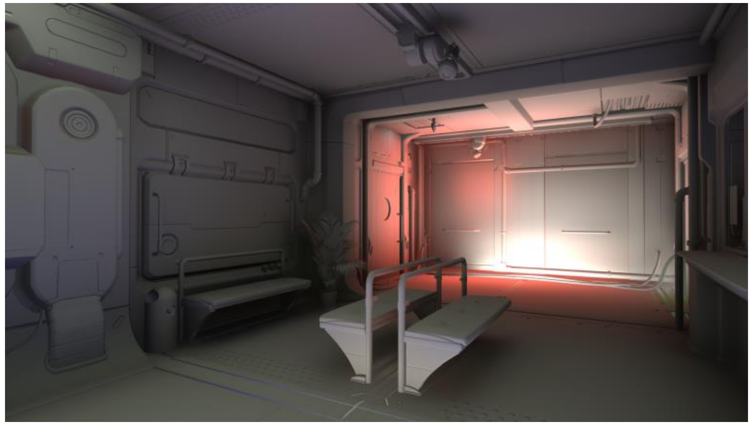
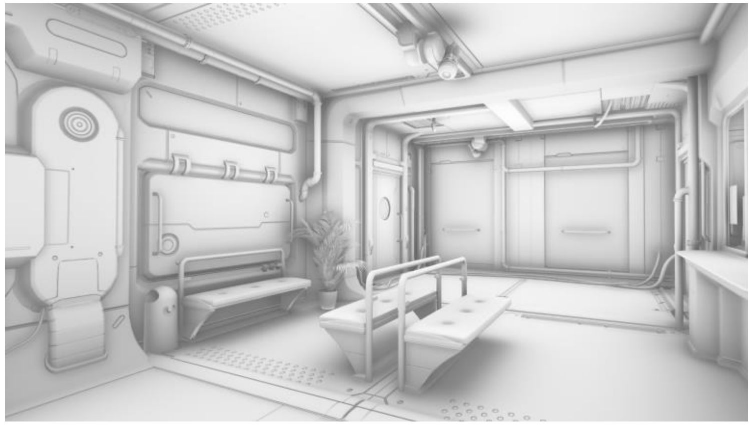
Simultaneous VXGI, VXAO, and VXAL

- VXGI 1.0 had two modes
  - AO mode: ambient occlusion channel is produced
  - GI mode: diffuse channel is produced with ambient lighting added
- VXGI 2.0 changes how the GI mode behaves
  - Diffuse channel has AO in the alpha component
  - Can compose as necessary on the application side
- VXAL is independent
  - Separate API
  - Same behavior in GI and AO modes





Other Improvements

Simpler Voxel Formats

- 3D or 6D opacity replaced by scalar
  - Same quality, better performance
  - Can do fractional opacity materials now

- Multiple emittance formats replaced by single FLOAT16
  - With a functional detour for GPUs which do not support FP16 atomics
  - Occlusion-only mode with no emittance can still be enabled

Simpler and More Flexible Materials

- Fewer controls from the CPU side
  - Most of MaterialInfo members removed
  - Only Adaptive Material Sampling Rate is still there

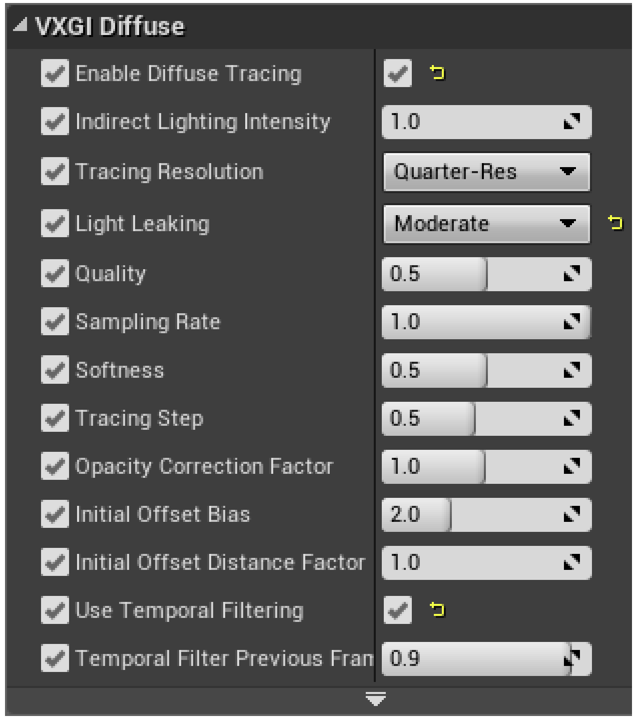
- More powerful on the shader side
  - Fractional opacity, variable per-voxel
  - Two-sided materials with different reflected colors

Opacity Scale = 0.25

Adjusting plant opacity
(animated)

Simpler Tracing Controls

- VXGI 1.0:
  - numCones, coneAngle, normalGroupingFactor, …, …
- VXGI 2.0:
  - quality, softness, directionalSamplingRate, …
  - Adjust Quality and Softness to get an acceptable look
  - Then adjust the sampling rate and temporal filtering to get a usable noise level


VXGI Diffuse

✓ Enable Diffuse Tracing	✓
✓ Indirect Lighting Intensity	1.0
✓ Tracing Resolution	Quarter-Res
✓ Light Leaking	Moderate
✓ Quality	0.5
✓ Sampling Rate	1.0
✓ Softness	0.5
✓ Tracing Step	0.5
✓ Opacity Correction Factor	1.0
✓ Initial Offset Bias	2.0
✓ Initial Offset Distance Factor	1.0
✓ Use Temporal Filtering	✓
✓ Temporal Filter Previous Fran	0.9

There’s More...

- Separate SSAO pass
- Support for pre-view translation
- Improved upscaling and temporal filters
- Non-cubic voxel volumes
- Reduced light leaking
- Fine control over D3D extensions
- Improved NVRHI

Summary

Summary

- New version: VXGI 2.0

- VXAL: High-quality area lighting with shadows
- Lots of smaller new features
- Better performance than VXGI 1.0

- Available soon
  - Mid-April 2018
  - SDK and Unreal Engine 4 integration

VXGI 2.0

Now with VXAL

Thank you!

- Questions?

- Contact us:
  - alpanteleev@nvidia.com
  - rsathe@nvidia.com

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