CS354R

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GLOBAL ILLUMINATION

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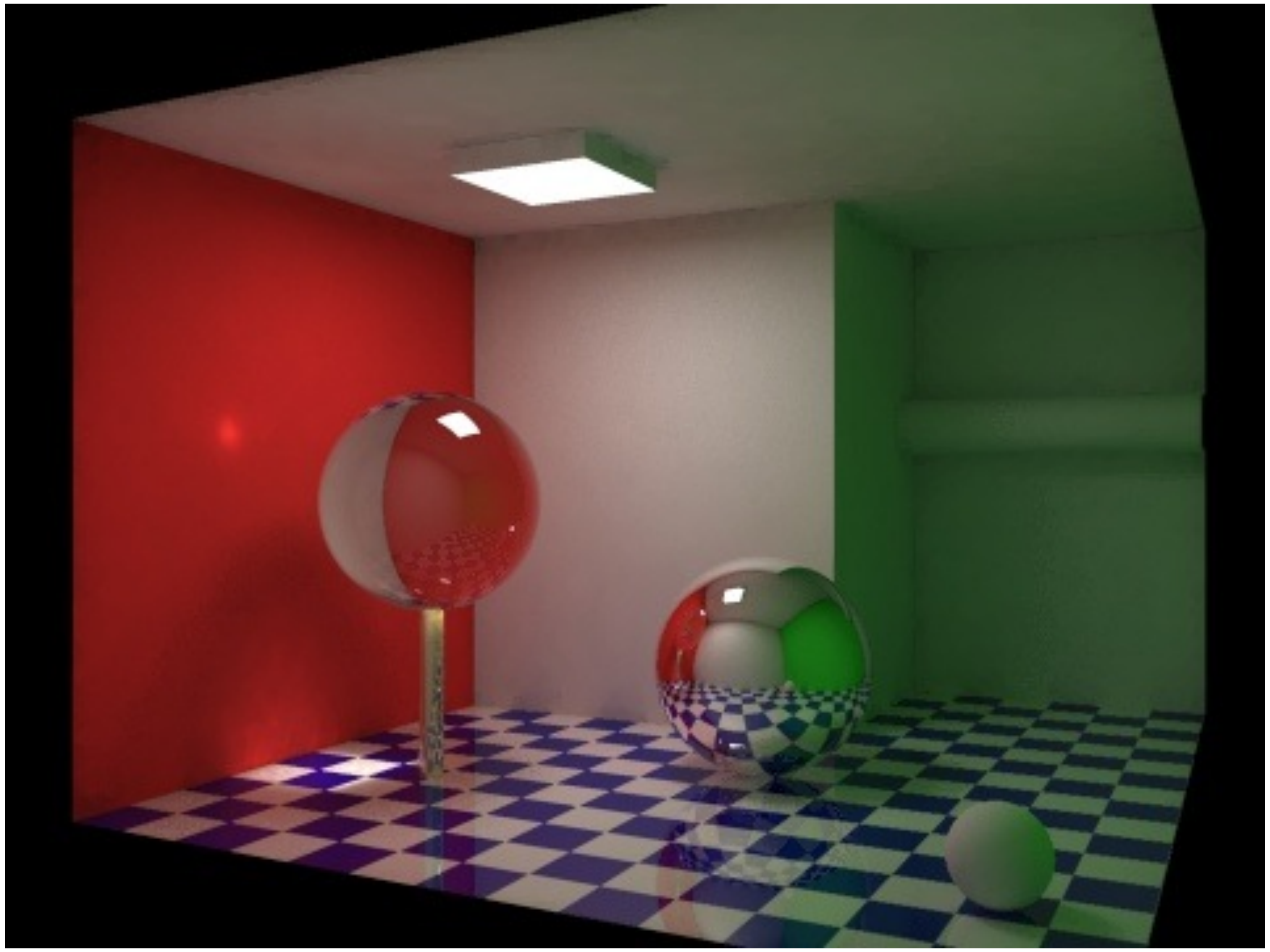
Mirror's Edge (2008)

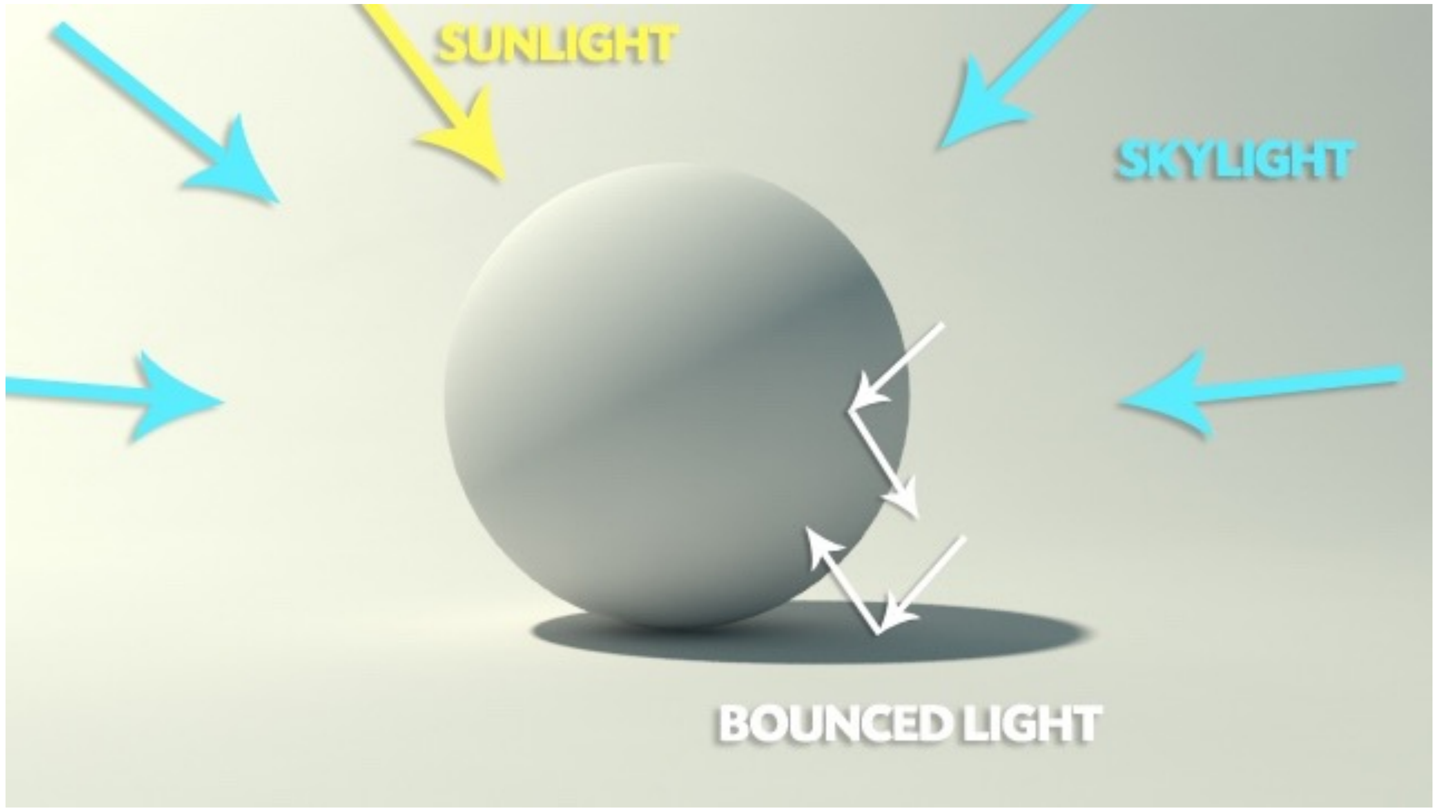
WHAT IS GLOBAL ILLUMINATION?

- Scene recreates feel of physically-based lighting models
- All objects affect rendering of individual objects
- Desirable effects include:
  - Shadows
  - Reflection
  - Refraction
  - Diffuse inter-reflection
  - Caustics



THE PHYSICS OF GI

- Must model photon interactions (i.e. light bounce) with world objects based on position and material
    - Light sources
    - Illuminated objects
    - Object materials
    - Viewing properties



DISCUSS

- What are some of the challenges of making a real-time lighting model?
- What parts of the system can be optimized and how?

PRE-BAKED LIGHTING

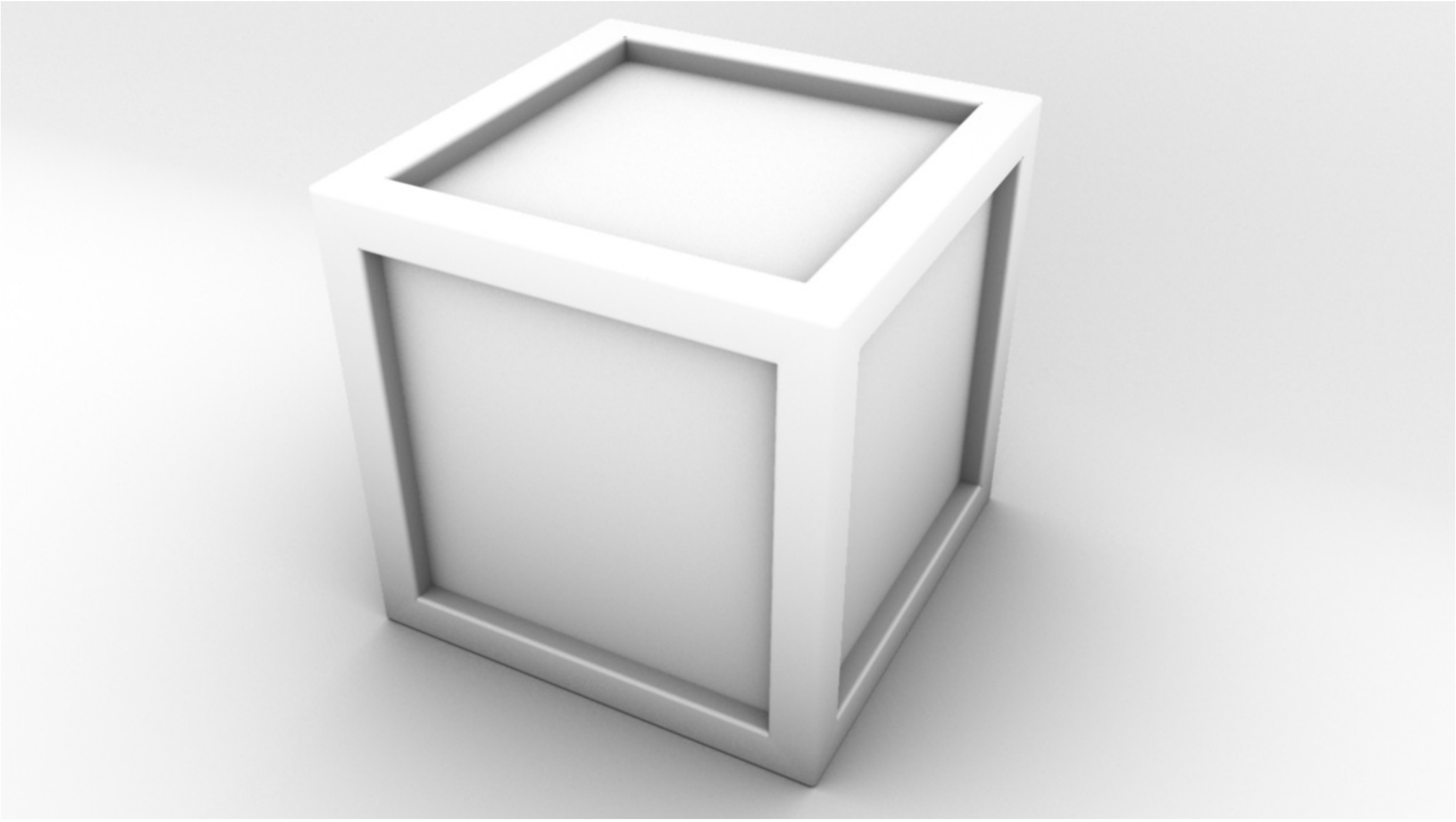
- Compute lighting offline
- Good-looking effects without limitations of real-time rendering
  - Diffuse inter-reflection (color bleed)
  - Ambient occlusion (indirect shadows)
  - Translucent shadows
- True dynamic lighting not possible

SCREEN SPACE TECHNIQUES

- Screen space techniques only use information within the rasterization pass (pixels)
    - Fragment depths
    - Positions
    - Normals
    - Tangent spaces
- **Deferred shading** technique breaks down rendering pass into multiple computations
    - Render lighting information into individual textures
    - Combine these textures into single screen texture
    - Compute lighting based on this texture

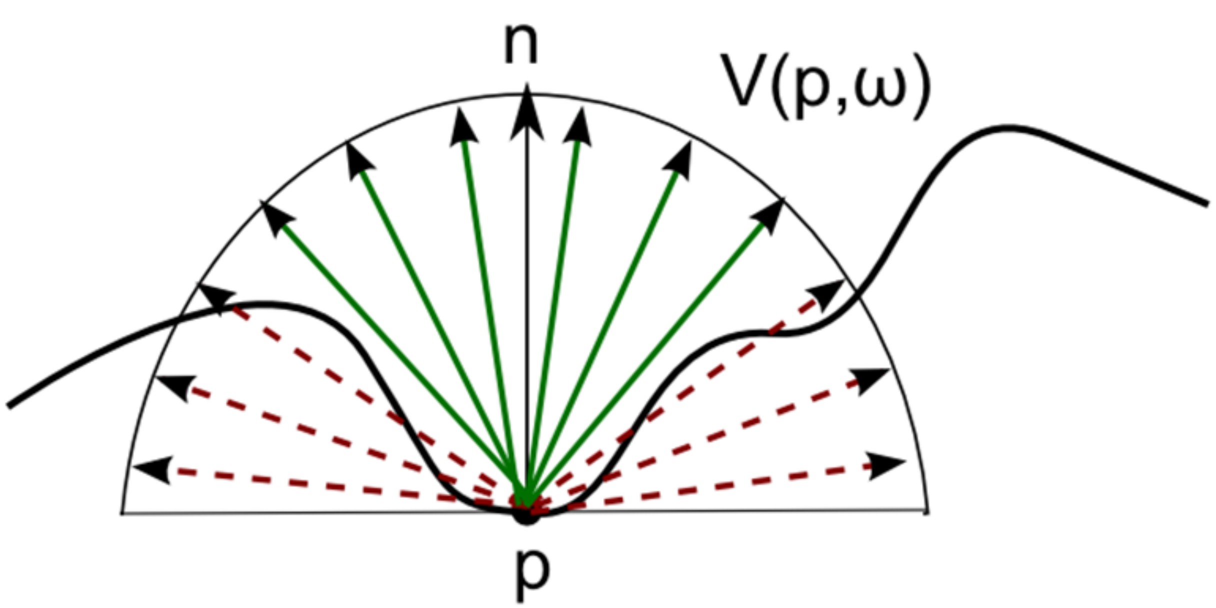
EXAMPLE: SCREEN SPACE AMBIENT OCCLUSION

- Ambient occlusion provides soft shadows as if seen with a highly diffuse light source (e.g. an overcast day)



CALCULATING AO IN REAL-TIME

- Calculate visibility function V for integral over hemisphere
- Depth buffer is a discrete approximation of frontmost scene geometry
- Crytek method generates random points then approximates visibility and distance attenuation



$$AO(\mathbf{p},\mathbf{n}) = \frac{1}{\pi}\int_{\Omega} V(\mathbf{p},\omega)\,\mathbf{n}\cdot\omega\,d\omega,$$

SSAO ADVANTAGES AND DISADVANTAGES

- Advantages
  - Provides better self-shadowing on objects
  - Simple to implement
  - Not affected by scene complexity
  - Works on dynamic scenes
- Disadvantages
  - Coarse approximation
  - Halo artifacts can appear where depth buffer has sharp discontinuities
  - No directionality in lighting
  - Incorrect shadow color

SSAO'S WANING POPULARITY

- Many SSAO variants:
  - HBAO (Horizon-based Ambient Occlusion)
  - HDAO (High-definition Ambient Occlusion)
  - SSDO (Screen-space Directional Occlusion)
- All have same, fundamental visual artifacting issues
- Screen space techniques also becoming less performant as monitors/TVs become higher resolution

VXAO AND RTAO

- Voxel Ambient Occlusion (VXAO) introduced by NVidia within VXGI pipeline
  - Not a screen space technique
  - Uses information from world space voxel information to calculate AO
- Ray-traced Ambient Occlusion (RTAO) introduced by NVidia with RTX hardware support
  - Not a screen space technique
  - Uses ray-traced information from world space to calculate AO

VXAO TO HBAO COMPARISON


Fig 1. HBAO+ channel


Fig 2. VXAO channel

SHADOW MAPS

- Pre-render scene from point of view of light to compute distance to scene objects in depth buffer
- During actual render, check if fragment is occluded by object in shadow map
  - Fragment is farther from light than the shadow map depth
- Soft shadows achieved by imitating shadow's penumbra and blurring

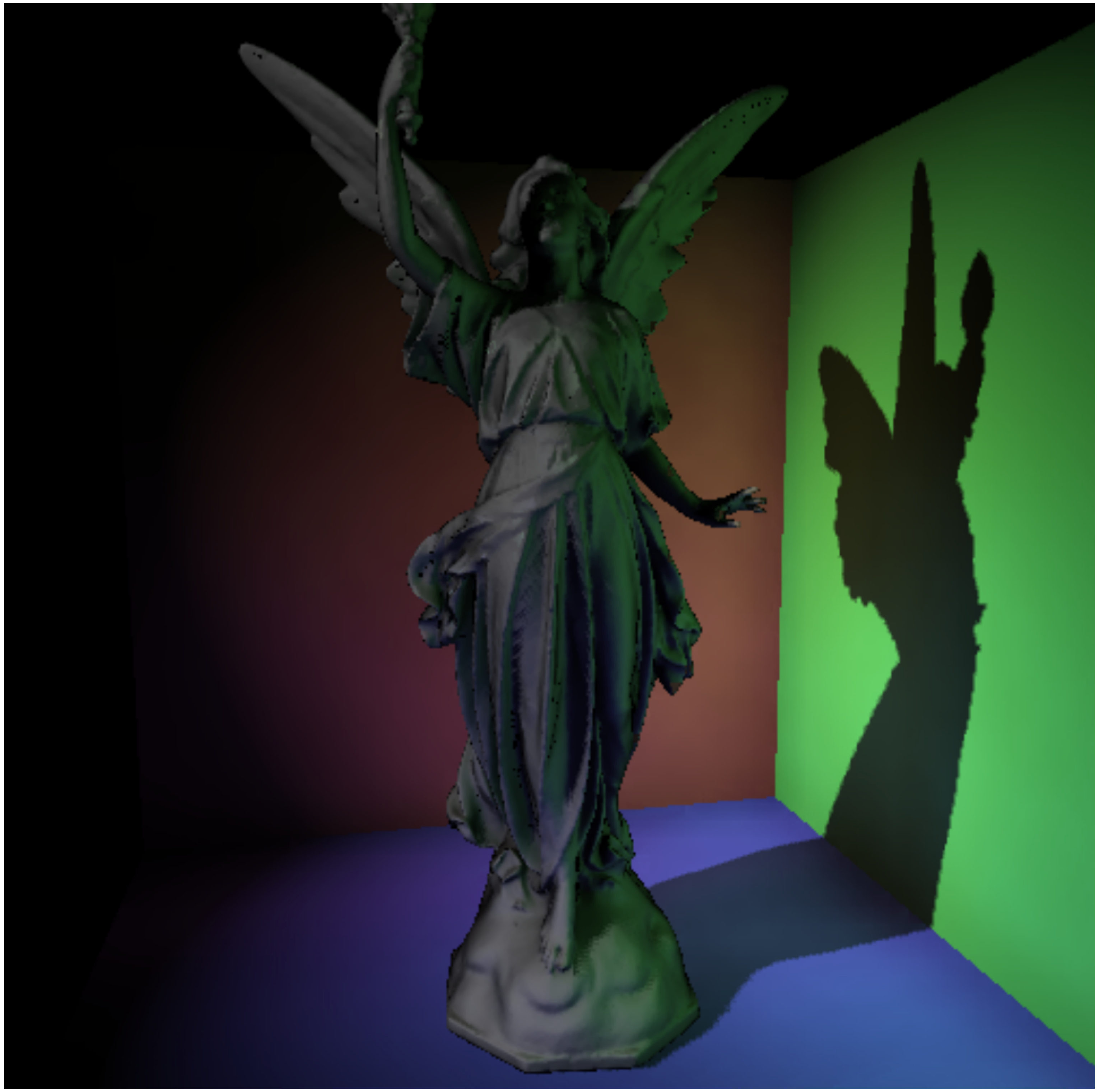
SHADOW MAPS

Variance Shadow Maps (Donnelly & Lauritzen)

REFLECTIVE SHADOW MAPS

- Treat all fragments of shadow map as indirect light sources
- Use these light sources to approximate the indirect illumination on each pixel
    - Imitates an extra bounce of lighting
- Infeasible to consider all pixels, so pixels ranked by importance
- Results in indirect lighting on pixel that may come from occluded light
    - Not physically accurate but plausible

REFLECTIVE SHADOW MAPS



CALCULATING GI IN WORLDSPACE

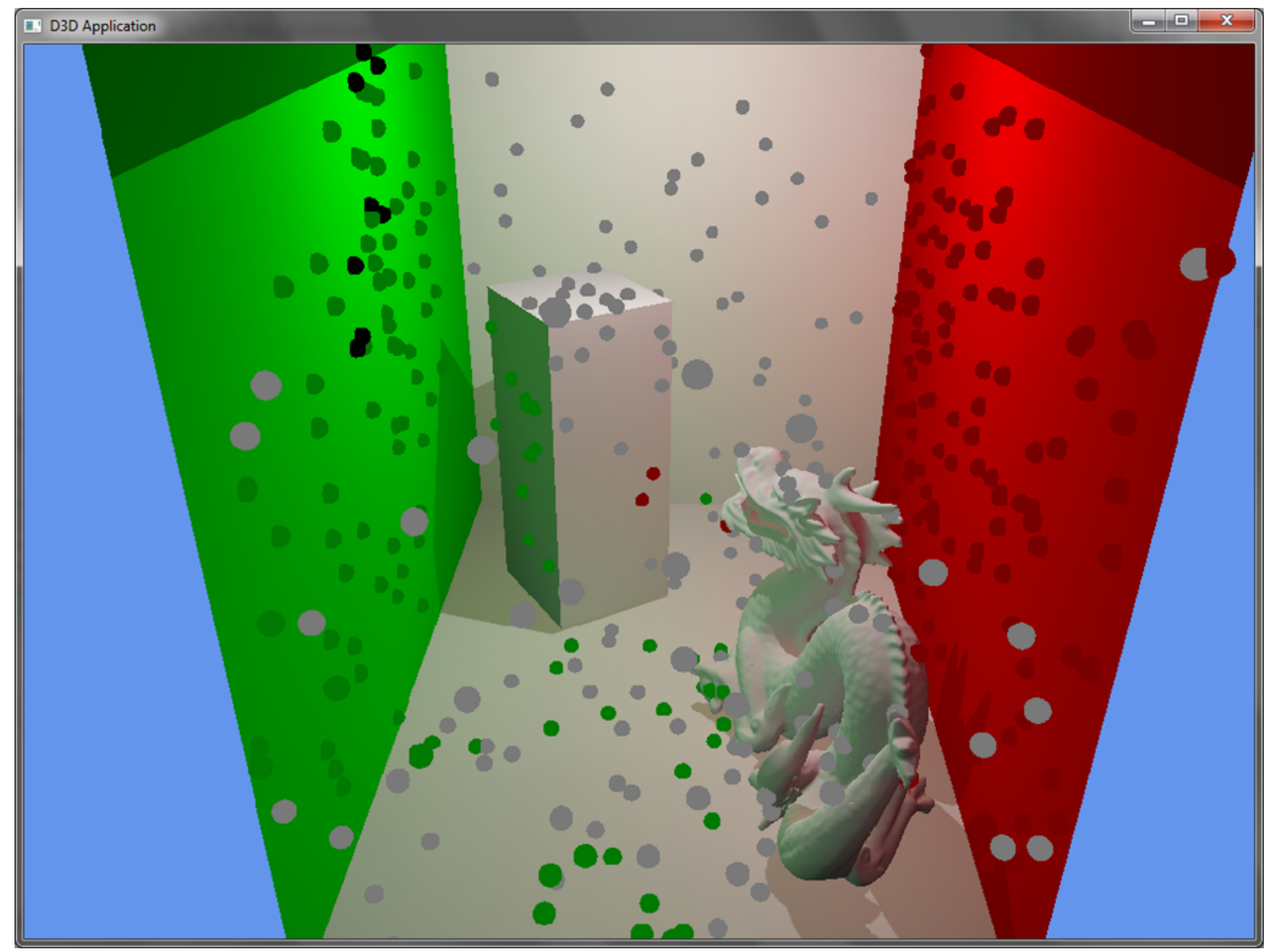
- To accurately depict global illumination, we need to simulate light bounce in the actual scene
  - Expensive and time-consuming
  - Not generally feasible in realtime
- Use precomputes, acceleration structures and simplifications to compensate

RADIOSITY

- Accounts for transfer of energy from both light sources and surfaces
- Models diffuse lighting with fewer calculations than ray-tracing based techniques
- View independent
- Color-bleed artifacts
- Distorts specular highlights

VIRTUAL POINT LIGHTS

- Used in radiosity-based renderers
- VPLs approximate direct and indirect lights in scene to reduce light bounce calculations



http://graphicsrunner.blogspot./201com1/03/instant-radiosity-using-optix-and.html

INSTANT RADIOSITY

- Add VPLs into scene by tracing photons shot out from the light source
- Treat VPLs as point lights
- Gather light from all VPLs in scene to compute indirect illumination
- Take dynamic visibility into account using shadow maps
- Use imperfect shadow maps for greater efficiency

CASCADING LIGHT PROPAGATION VOLUMES

- Used for low-frequency (indirect) lighting
- Built using 3-D nested lattices for efficient light transport
- Used in Cryengine in 2010 for both PC and console

SPARSE VOXEL CONE TRACING (SVOGI)

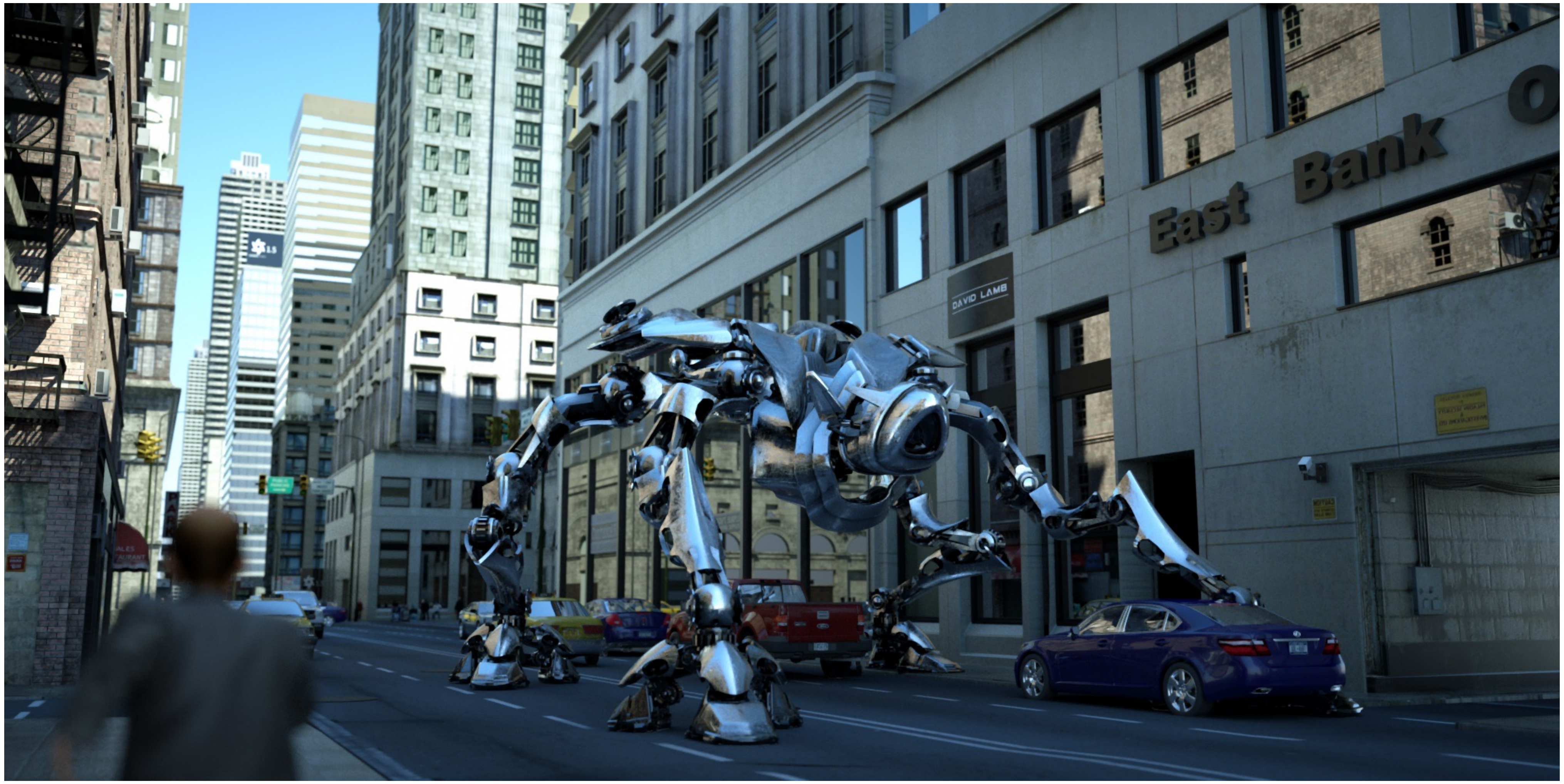
- Computes indirect illumination and ambient occlusion
- GPU-based
- Octree-based
- Stores voxels as 3D textures
- Rasterize primary rays
- Cone-trace secondary rays through octree
- Works for forward and deferred rendering

VXGI

- Built into UE4 (NVIDIA only)
- https://www.youtube.com/watch?v=O9y_AVYMEUs

BRIGADE PATH TRACER

- Optimized BHV, work queue, and convergence algorithm
- https://www.youtube.com/watch?v=FbGm66DCWok



DENOISING

- Bi-directional path tracers populate the scene with photon information emitted from the source lights then bounce rays from the camera to calculate final light
- Uses Monte Carlo method to perform unbiased sampling to converge on lighting integration
  - Requires a large number of samples to reduce noise
- Denoising is process of reducing noise without a large number of samples
  - Historically done with image processing techniques but machine learning works extremely well

RAYTRACING HARDWARE

- Hardware solutions can allow for faster calculations and interactions but doesn't fundamentally solve the problem

https://www.youtube.com/watch?v=7Yn09UHWYFY

FURTHER READING/VIEWING

- Real-Time Global Illumination Siggraph 2009 (http://www0.cs.ucl.ac.uk/staff/J.Kautz/RTGICourse/)
- VXAO (https://developer.nvidia.com/vxao-voxel-ambient-occlusion)
- Cascaded Light Propagation Volumes for Real Time Indirect Illumination (http://www.crytek.com/cryengine/cryengine3/presentations/cascaded-light-propagation-volumes-for-real-time-indirect-illumination)
- NVIDIA VXGI: Dynamic Global Illumination for Games (http://www.gdcvault.com/play/1022392/)
- Brigade Article (https://www.hindawi.com/journals/ijcgt/2013/578269/)