Computer Graphics
CS 543 – Lecture 13 (Part 2)
Advances in Graphics

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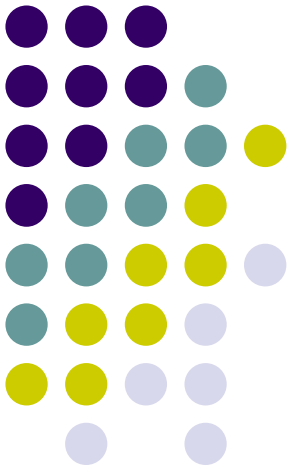
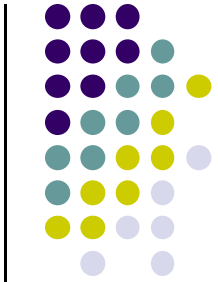
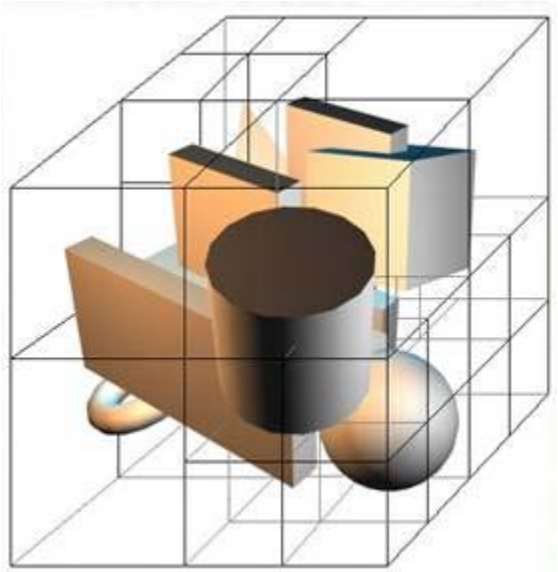


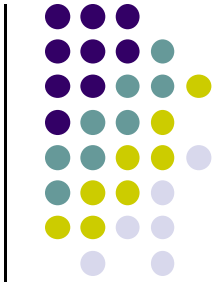
Recall: Accelerating Ray Tracing



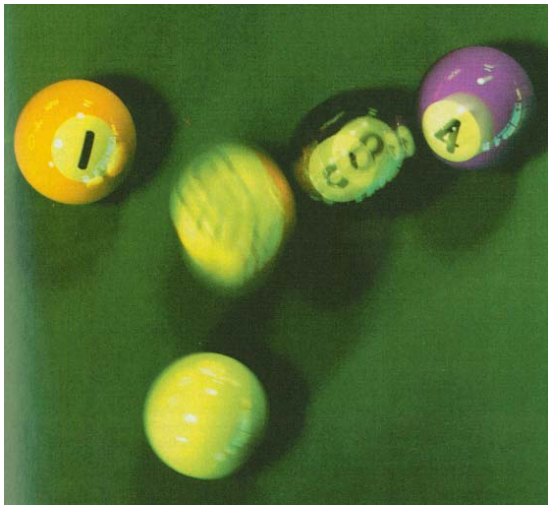
- To accelerate ray tracing, place grid over scene
- Test cells recursively
- Acceleration structures: BSP trees, kd trees, etc

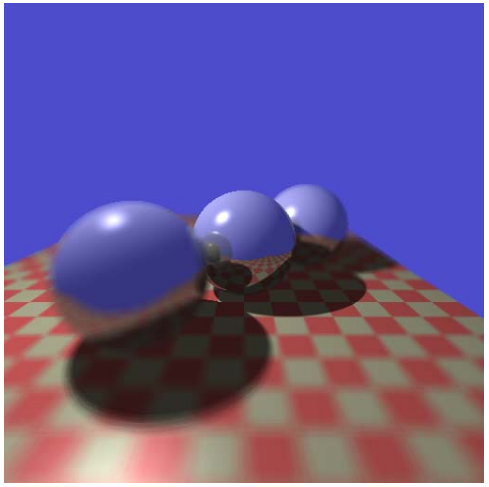


Making Ray Tracing Look Real

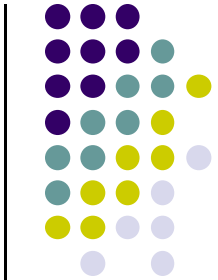


- **Antialiasing**
  - Cast multiple rays from eye through same point in each pixel
- **Motion blur**
  - Each of these rays intersects the scene at a different time
  - Reconstruction filter controls shutter speed, length
- **Depth of Field**
  - Simulate camera better
    - f-stop
    - focus
- **Other effects** (soft shadow, glossy, etc)

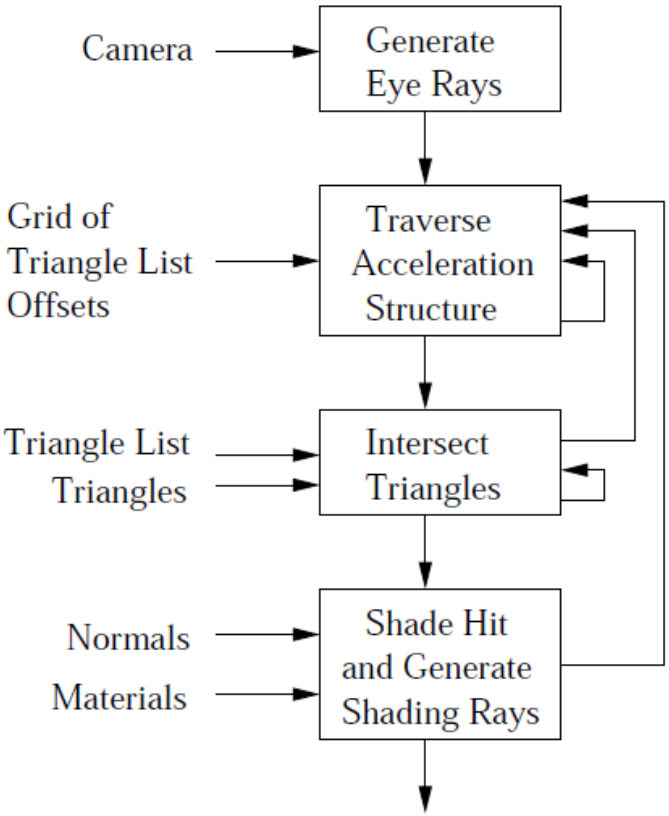




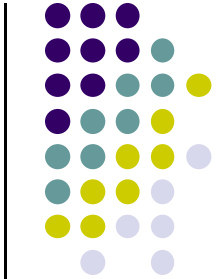
Real Time Ray Tracing



- Multi-pass rendering: Ray tracer using 4 shaders

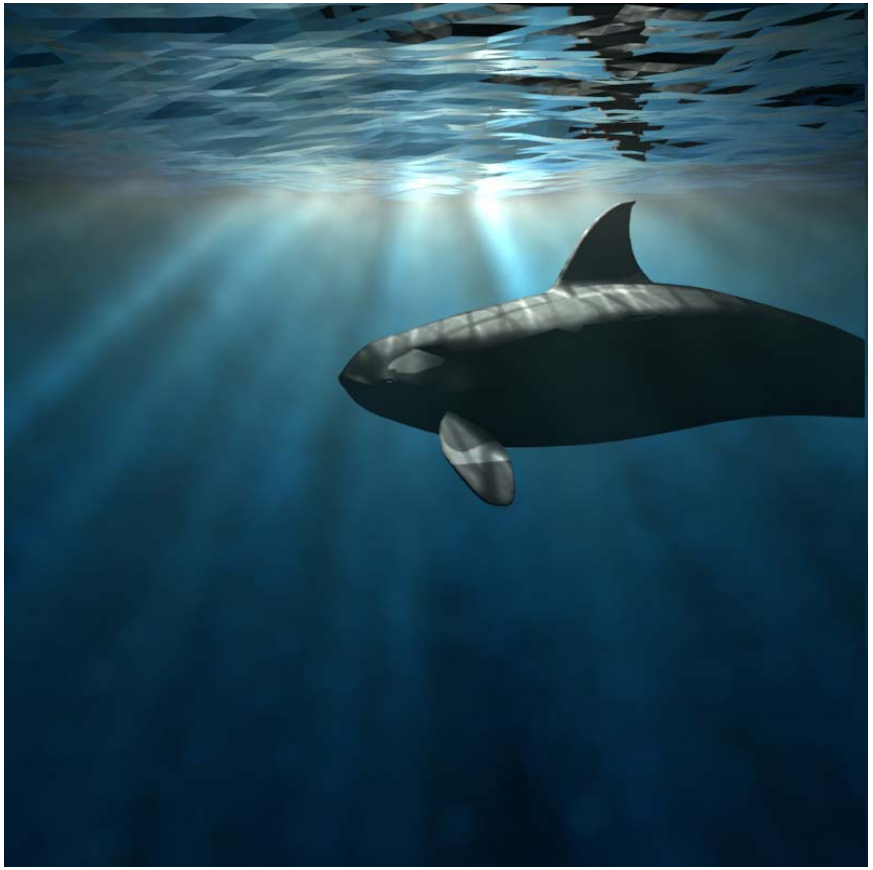


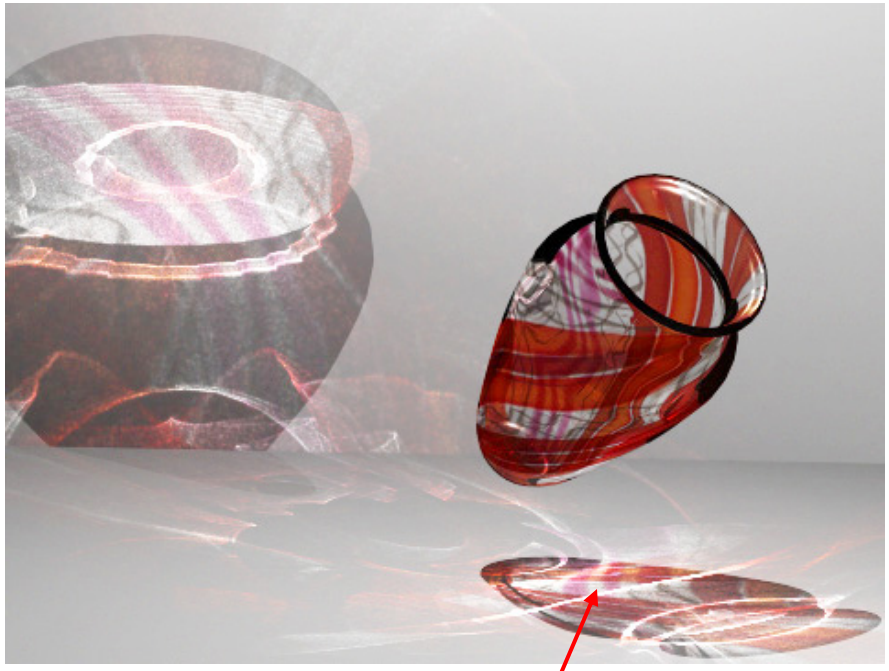
Real Time Ray Tracing



- Nvidia Optix ray tracer
- Needs high end Nvidia graphics card
- SDK is available on their website
- http://developer.nvidia.com/object/optix-home.html

Photon mapping examples

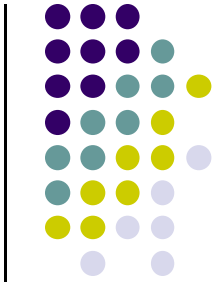




Caustics

Images: courtesy of Stanford rendering contest

Photon Mapping

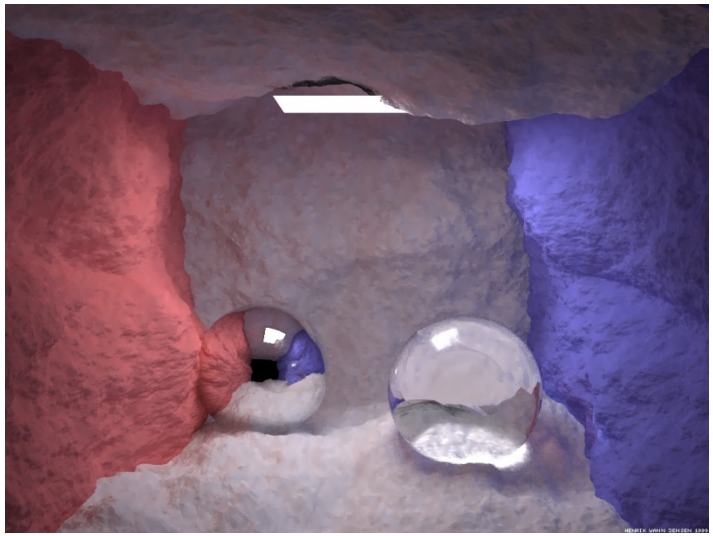


- Simulates the transport of individual photons (Jensen ’95-’96)

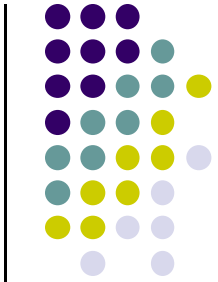
  Two pass algorithm
- Pass 1 - **Photon tracing**
  - Emit photons from lights
  - Trace photons through scene.
  - Store photons in kd-tree (photon maps)
- Pass 2 - **Rendering**
  - Render scene using information in the photon maps to estimate:
    - Reflected radiance at surfaces
    - Scattered radiance from volumes

      and translucent materials.
- Good for effects ray tracing can’t:
  - Caustics
  - Light through volumes (smoke,

    water, marble, clouds)



Photon Tracing



Photon scattering

- Emitted photons are probabilistically scattered through the scene and are eventually absorbed.
- Photon hits surface: can be reflected, refracted, or absorbed
- Photon hits volume: can be scattered or absorbed.

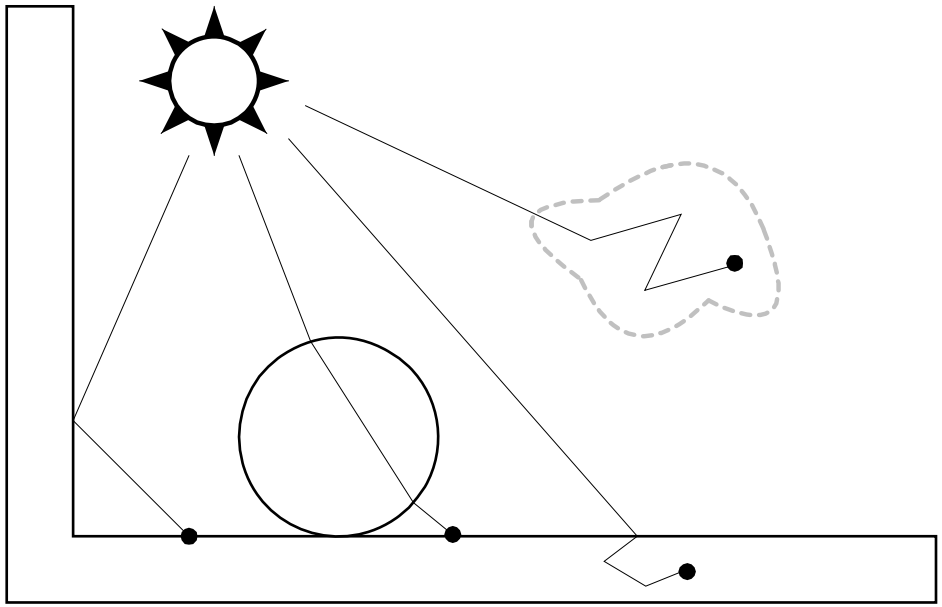
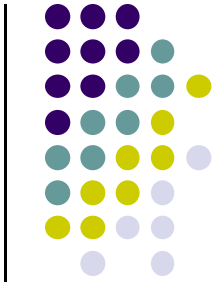
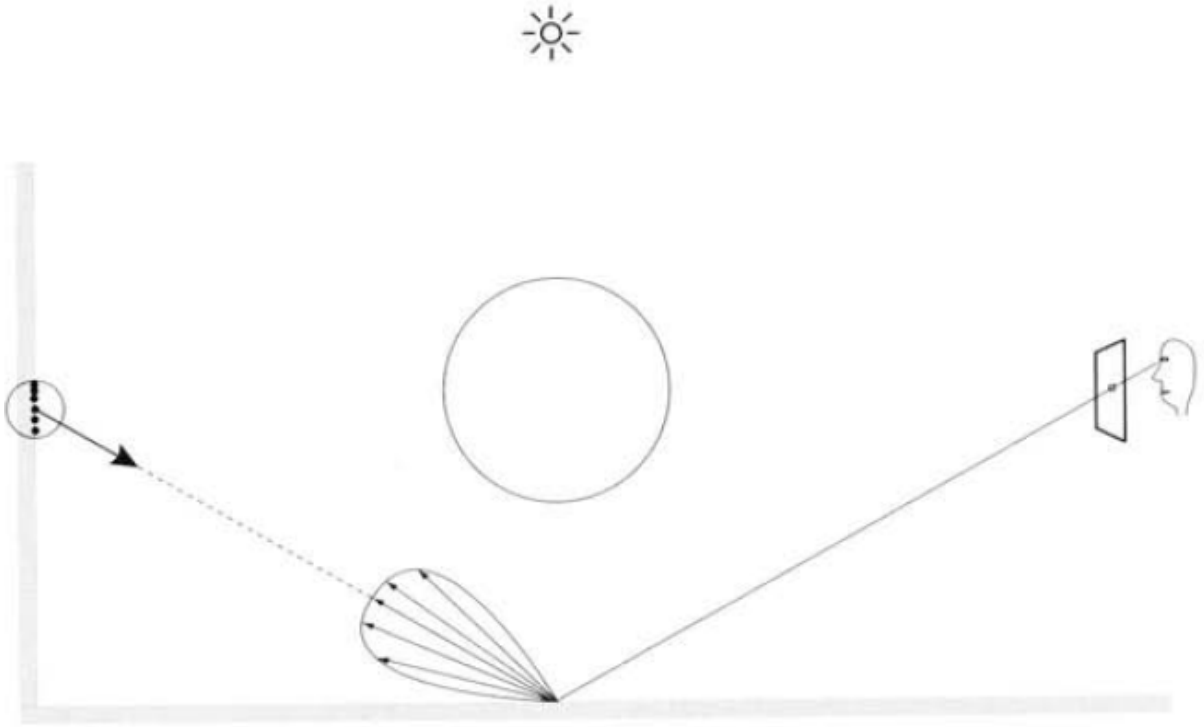


Illustration is based on figures from Jensen[1].

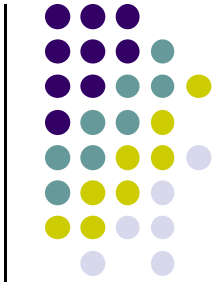
Photon mapping: Pass 2 - Rendering



- Indirect diffuse lighting: Use ray tracing
- Volumes, caustics: estimate illumination using photon map

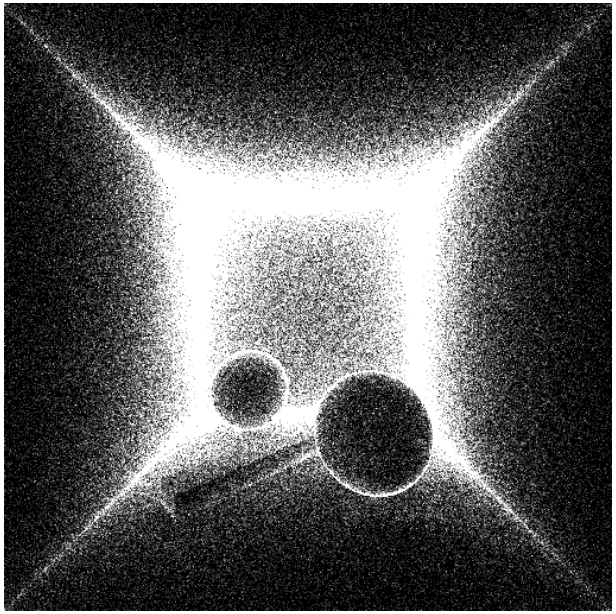


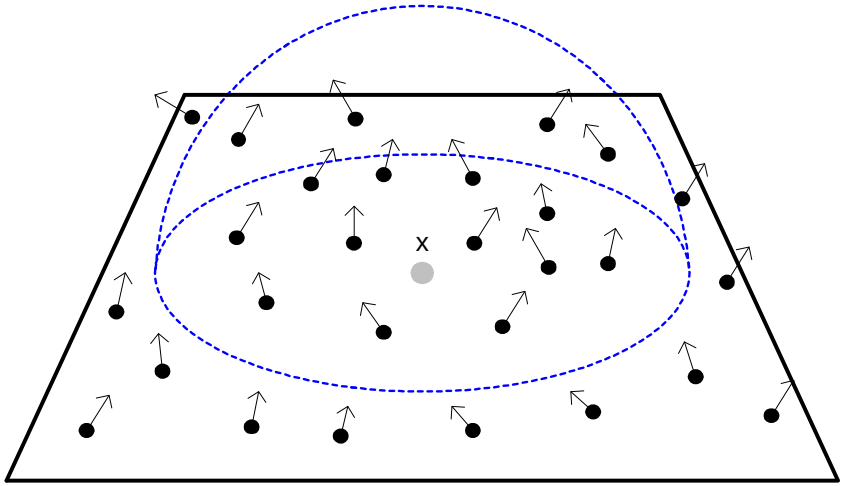
Photon Tracing



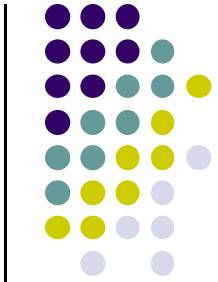
Pass 2 - Rendering

- Imagine ray tracing a hitpoint x
- Information from photon maps used to estimate radiance from x
- Radius of circle required to encountering N photons gives radiance estimate at x

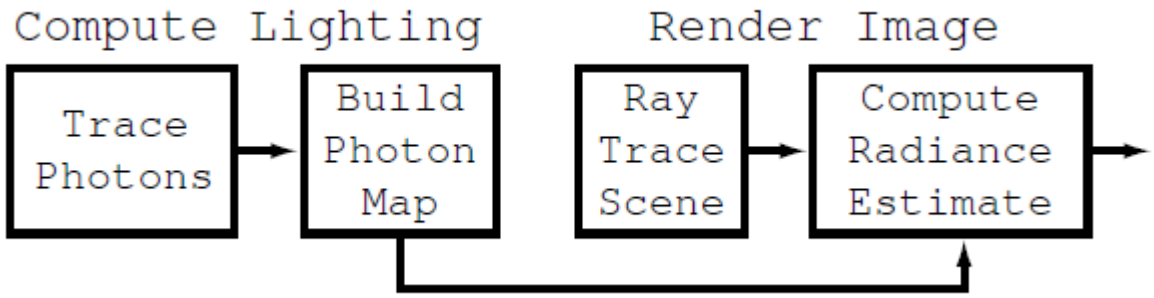




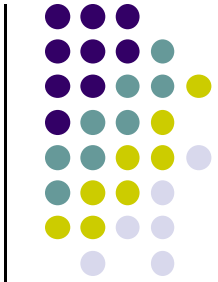
Real Time Photon mapping



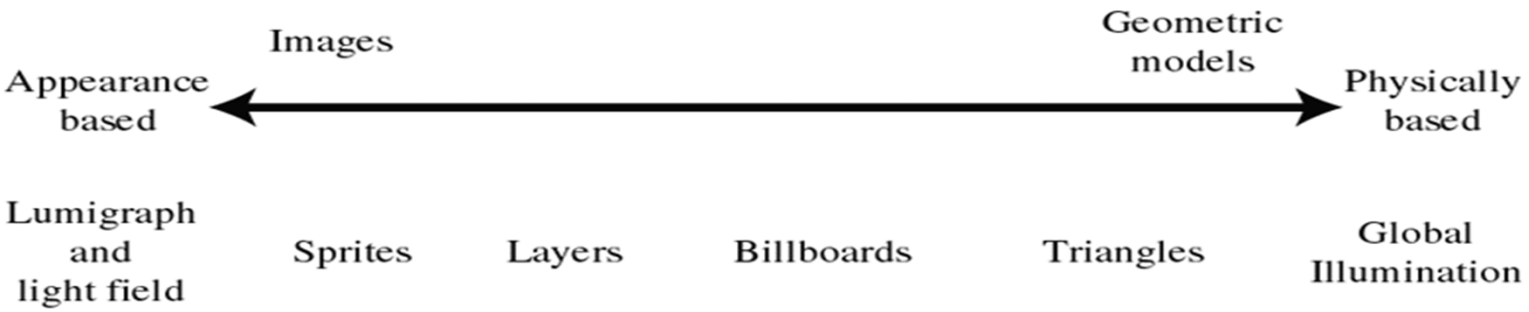
- Similar idea to real-time ray tracing.
- Photon mapping as multi-pass shading



Real-Time Rendering Techniques

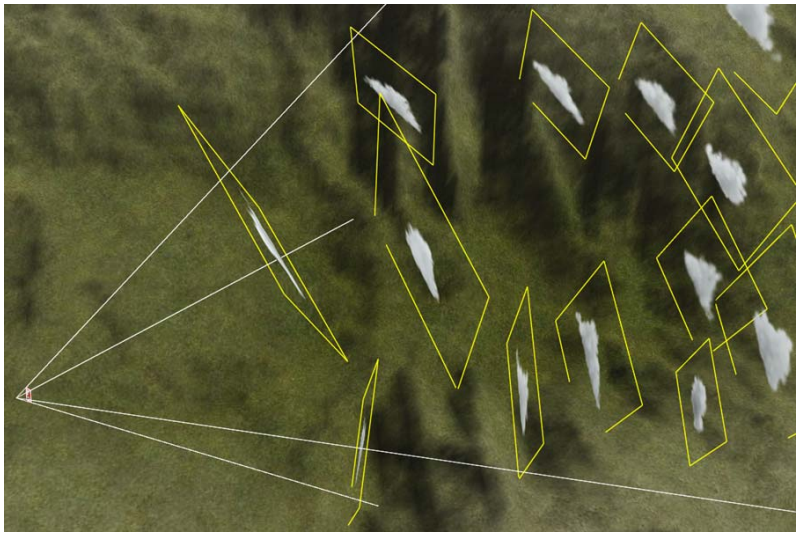


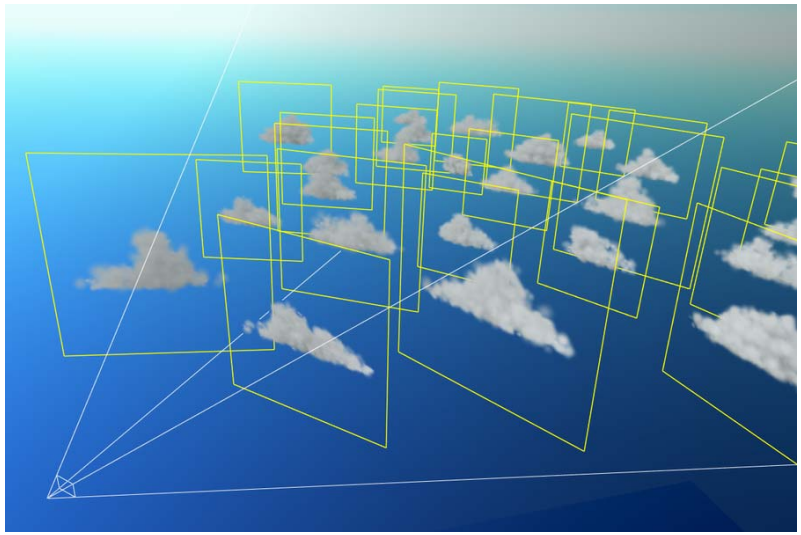
- Applications: game engines, virtual reality, simulators, etc
- Algorithms must run at min 30 FPS
- Polygonal techniques: OpenGL, DirectX
- Shaders: Pixel/vertex shading
- Level of detail management (simplification, tesselation)
- Texturing to improve RT performance
- Point-based rendering
- BRDF factorization, SH lighting
- Image-based rendering: Spectrum of IBR techniques



Billboards

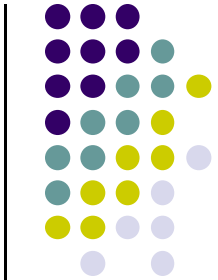
- IBR: pre-render geometry onto images/textures
- Rendering at runtime involves simple lookups, fast
- Similar technique used for crowds in NFL madden football



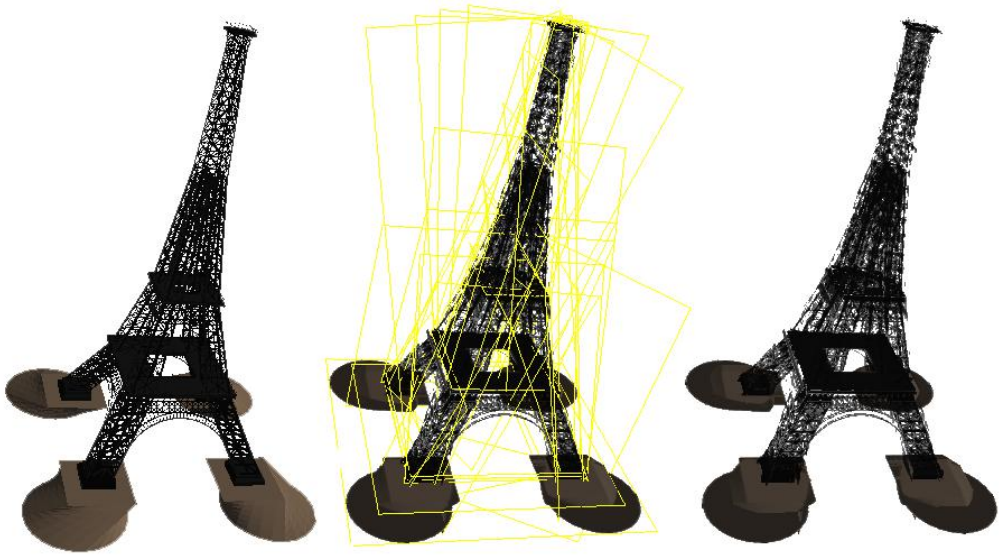


Real time cloud rendering, Mark J. Harris

Billboard Clouds

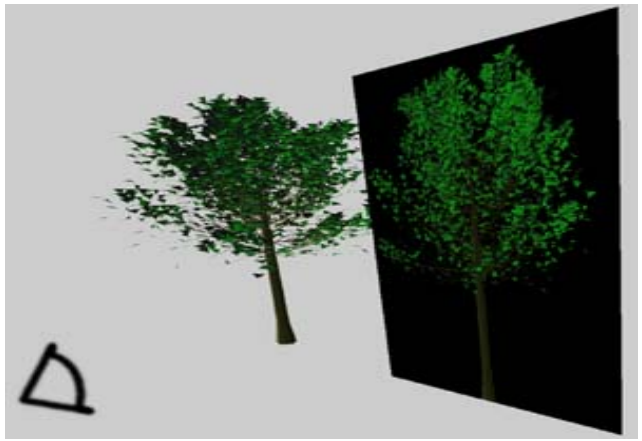


- **Billboard Clouds**, Decoret, Durand *et al* [SIGGRAPH'03]
- Render complex mesh onto cloud of billboards
- Billboard inclined at different viewpoints



Imposters

- Similar to billboards

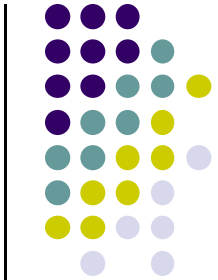


Impostors Made Easy – William Damon, Intel

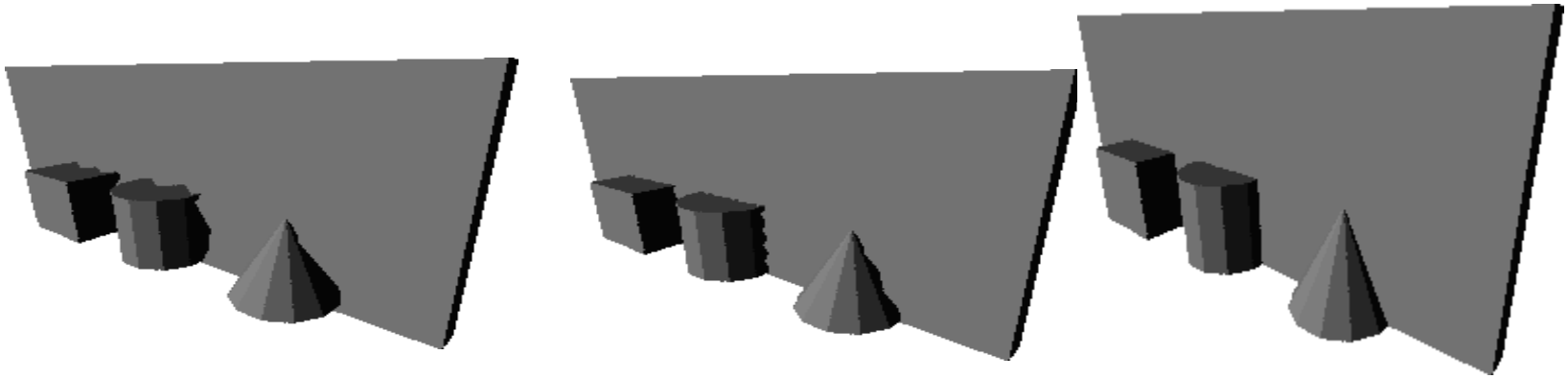
No Impostors

With Impostors

Depth Sprite aka Nailboard



- Give depth to image !
- RGBΔ - Δ (transparency) is depth parameter
- Set Δ based on depth of actual geometry
- Accuracy varies with no. of bits to represent Δ



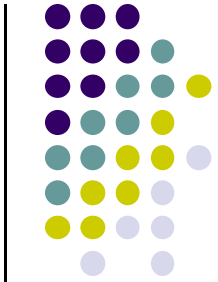
2 bits

4 bits

8 bits

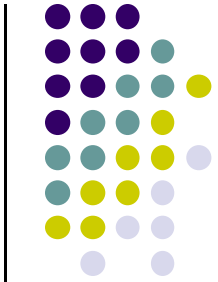
http://zeus.gup.uni-linz.ac.at/~gs/research/nailbord/

IBR: Pros and Cons



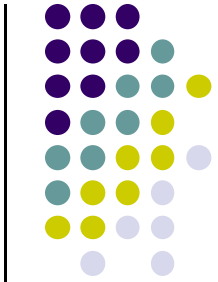
- Pros
  - Simplifies computation of complex scenes
  - Rendering cost independent of scene complexity
- Cons
  - Static scene geometry
  - Fixed lighting
  - Fixed look-from or look-at point

Recent Trends in Games

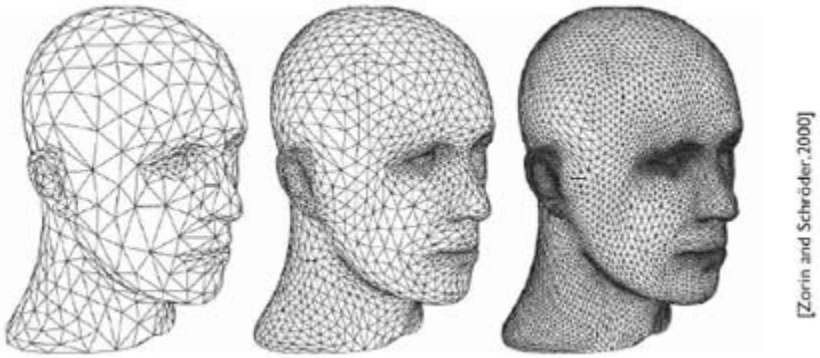


1. Real Time LoD Management
2. Capture rendering data
3. Pre-computation to speed up run-time
4. Screen Space GI techniques
5. Real Time Global Illumination
6. Hardware-accelerated physics engines

Recall: Trend 1: Real-Time LoD Management

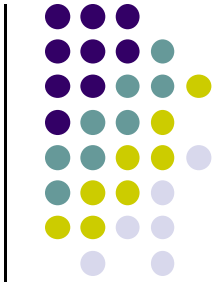


- Geometry shader unit, can generate new vertices, primitives from original set
- Tesselation and simplification algorithms on GPU
- Real-time change LoD in game



[Zorin and Schröder, 2000]

Trend 2: Capture Rendering Data

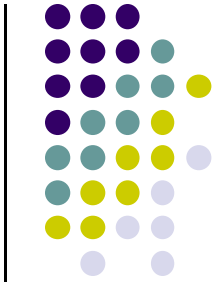


- Old way: use equations to model:
  - Object geometry, lighting (Phong), animation, etc
- New way: capture parameters from real world
- Example: motion in most sports games (e.g. NBA 2K live) is captured.
  - How? Put sensors on actors
  - Actors play game
  - Capture their motion into database
  - Player motion plays back

  database entries

Courtesy: Madden NFL game

Geometry Capture: 3D Scanning



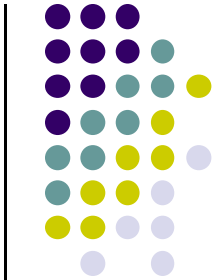
- **Capturing geometry trend:** Precise 3D scanning (Stanford, IBM,etc) produce very large polygonal models

Model: David

Largest dataset Size: 2 billion polygons, 7000 color images!!

Courtesy: Stanford Michael Angelo 3D scanning project

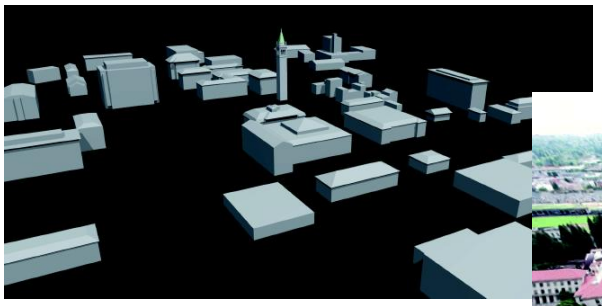
How is capture done?



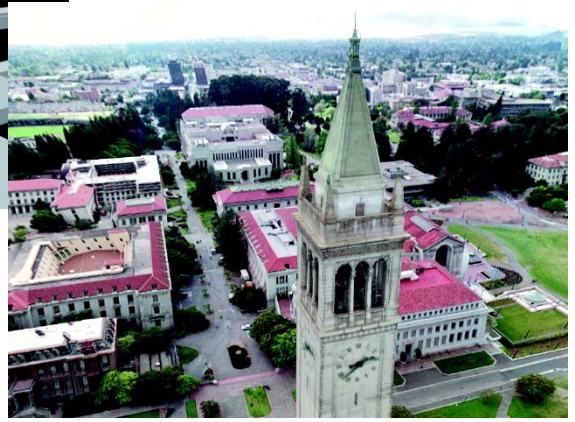
- **Capture:**
  - Digitize real object geometry and materials
  - Use cameras, computer vision techniques to capture rendering data
  - Put data in database, many people can re-use
- **Question:** What is computer vision?

Exactly What Can We Capture?

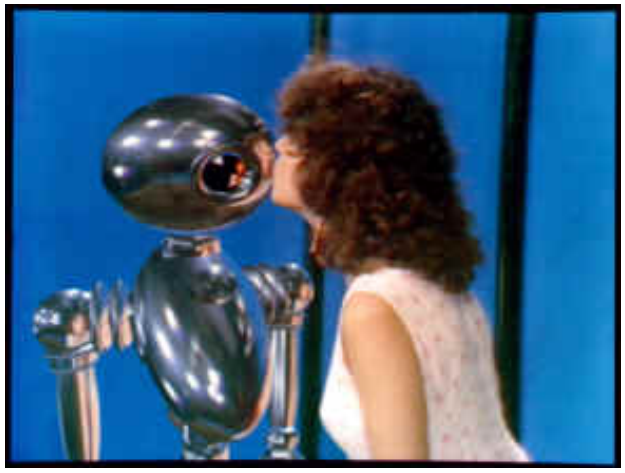
1. Appearance (volume, scattering, transparency, translucency, etc)



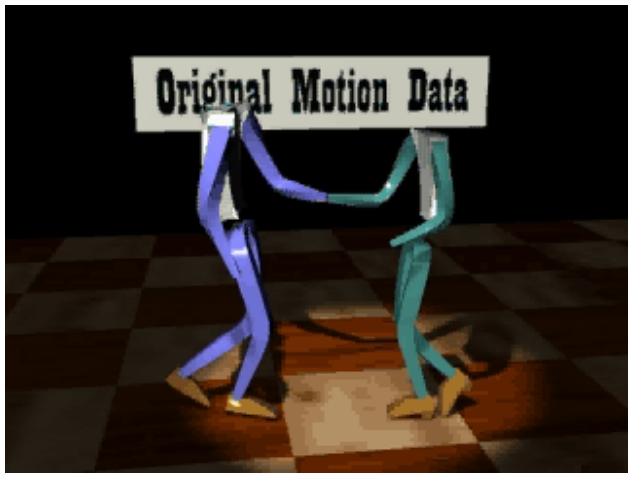
2. Geometry



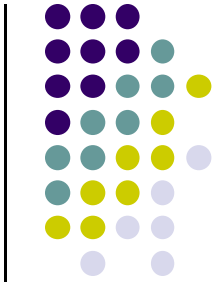
3. Reflectance & Illumination



4. Motion

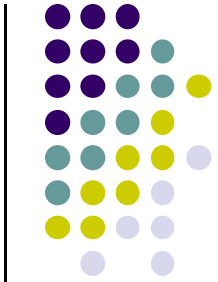


Light Probes: Capturing light

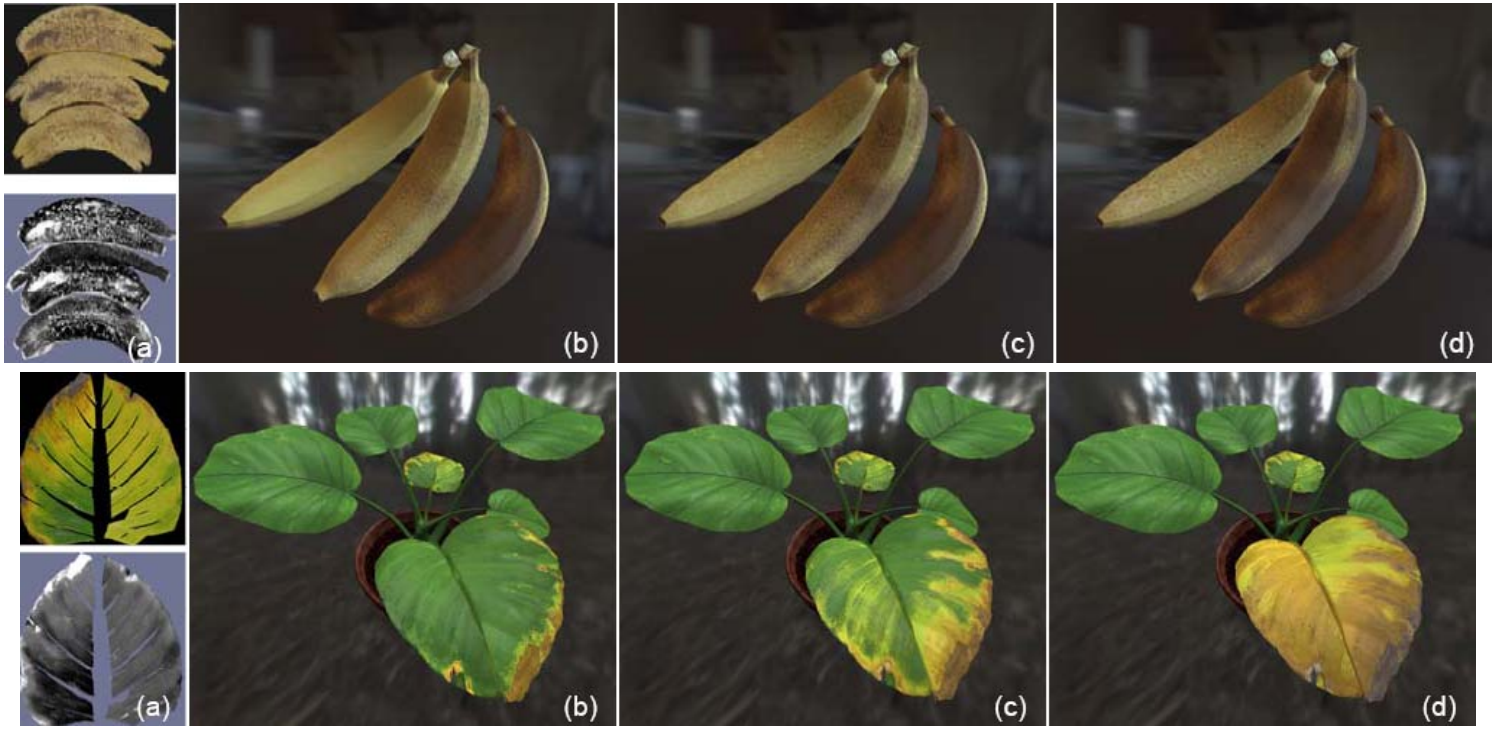


Amazing graphics, High Dynamic Range?

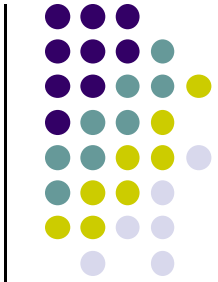
Recall: Capture Material Reflectance (BRDF)



- **BRDF:** How different materials reflect light
- **Examples:** cloth, wood, velvet, etc
- Time varying?: how reflectance changes over time
- TV examples: weathering, ripening fruits, rust, etc

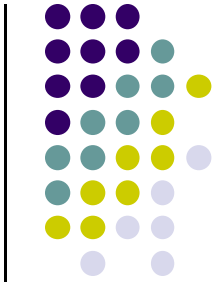


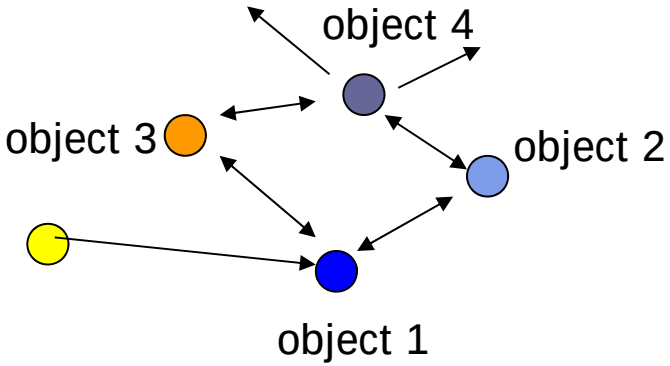
Why effort to capture?



- **Big question:** If we can capture real world parameters, is this really **computer graphics?**

Trend 3: Pre-computation to speed up run-time

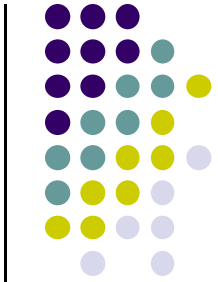




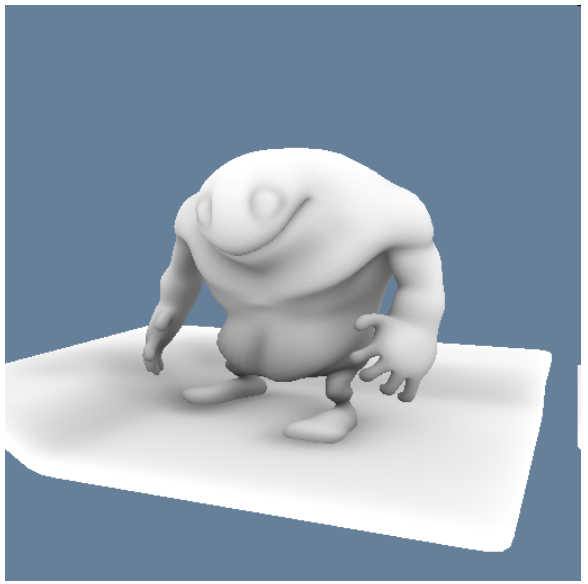
- Pre-compute **lighting**
  - Lights objects mostly static
  - Use GPU to pre-compute approximate lighting solutions
  - Speeds up run-time
- Pre-compute **Occlusion**
- Pre-compute **Radiance Transfer** (reflections)
  - Use spherical harmonics


Pre-computed Global Illumination
HALO 3
BUNGiE
SIGGRAPH2009

Pre-Compute Occlusion

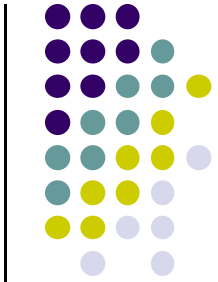


- Ambient occlusion
  - Each rendered point receives hemisphere of light
  - Estimate fraction of hemisphere above point that is blocked
  - Render ambient term as fraction of occlusion

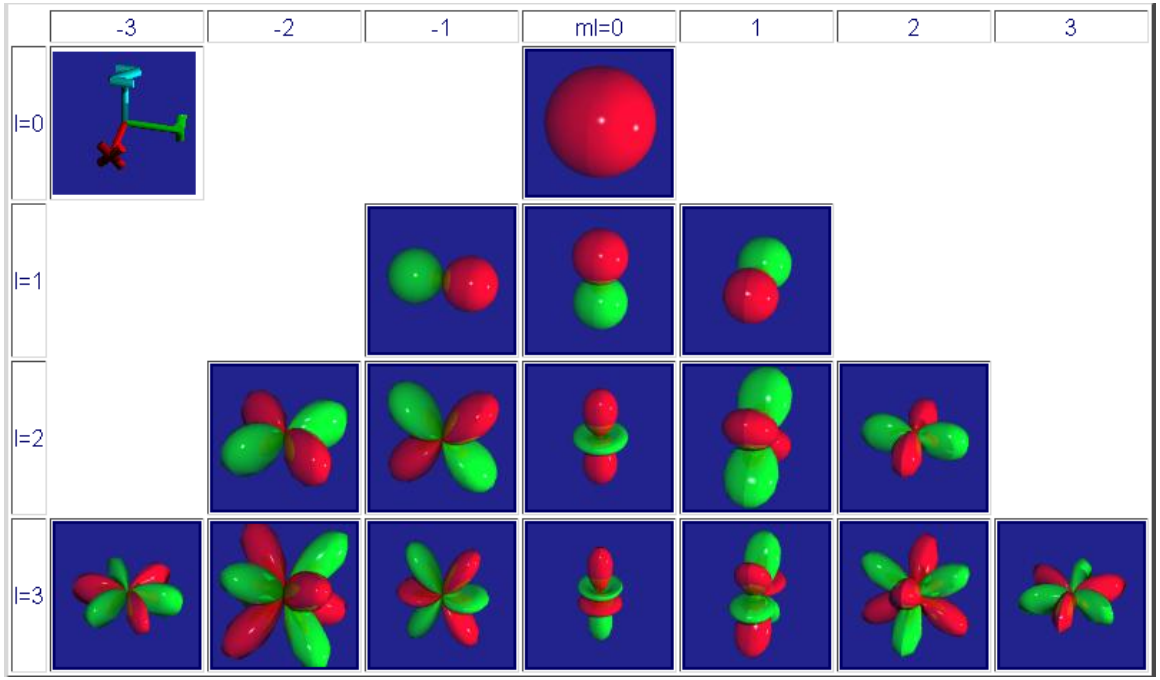


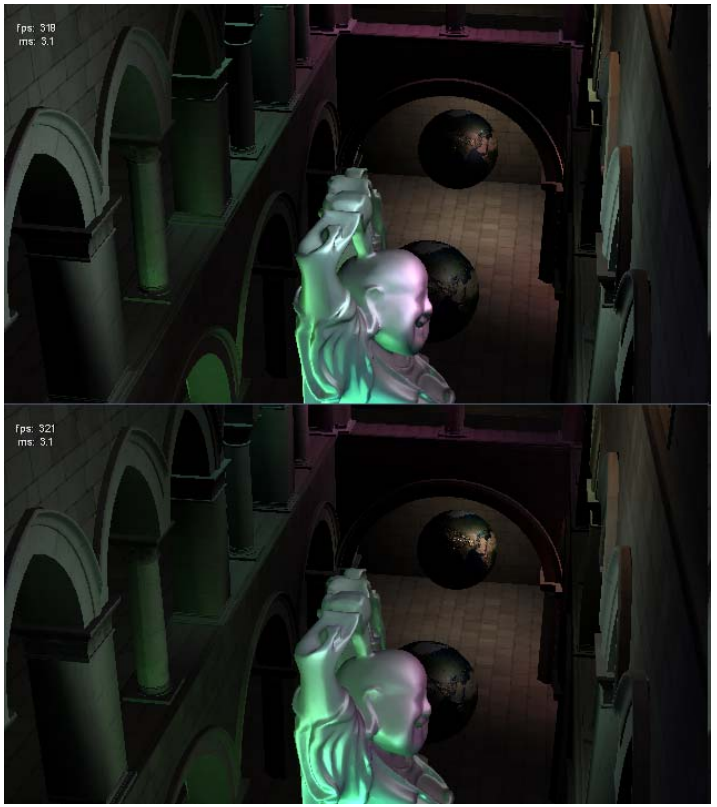
Courtesy Nvidia SDK 10

Precomputed Radiance Transfer



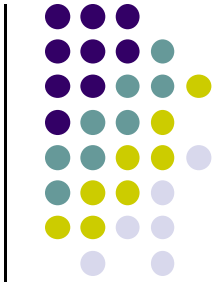
- Factorize and precompute light and material as **Spherical Harmonics**
- Run-time: Light reflection is dot product at run time (Fast)





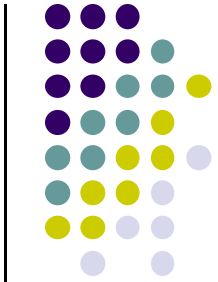
Sponza Atrium: Courtesy Marko Dabrovic

Trend 4: Real time Global Illumination



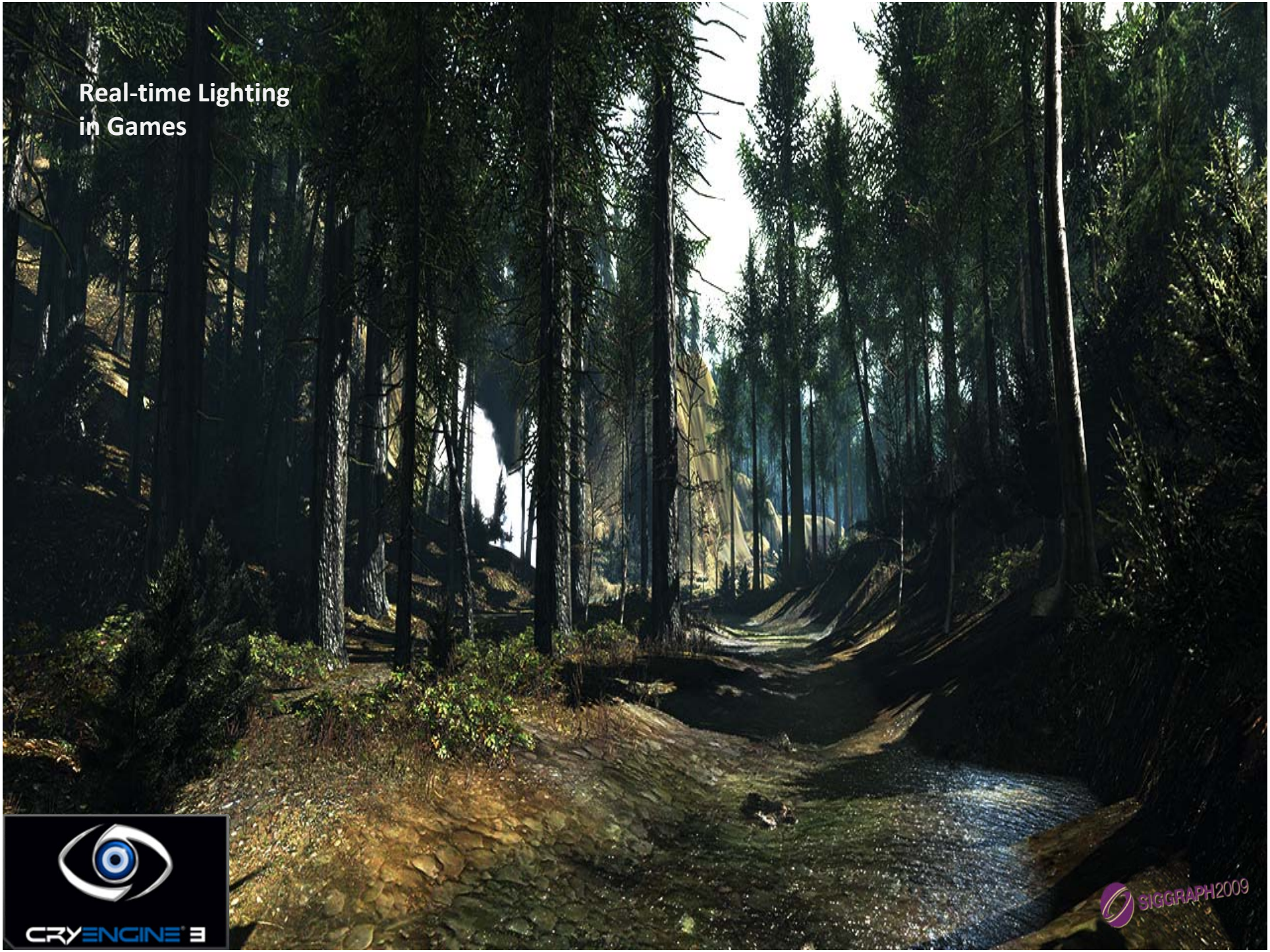
- What's the difference?
  - Pre-compute means lookup at run-time
  - Approximate representations (e.g Spherical Harmonics)
  - Fast, but not always accurate
- Real Time Global Illumination: state-of-the art
  - Calculate complex GI equations at run-time
  - Use GPU, hardware

Real Time Global Illumination



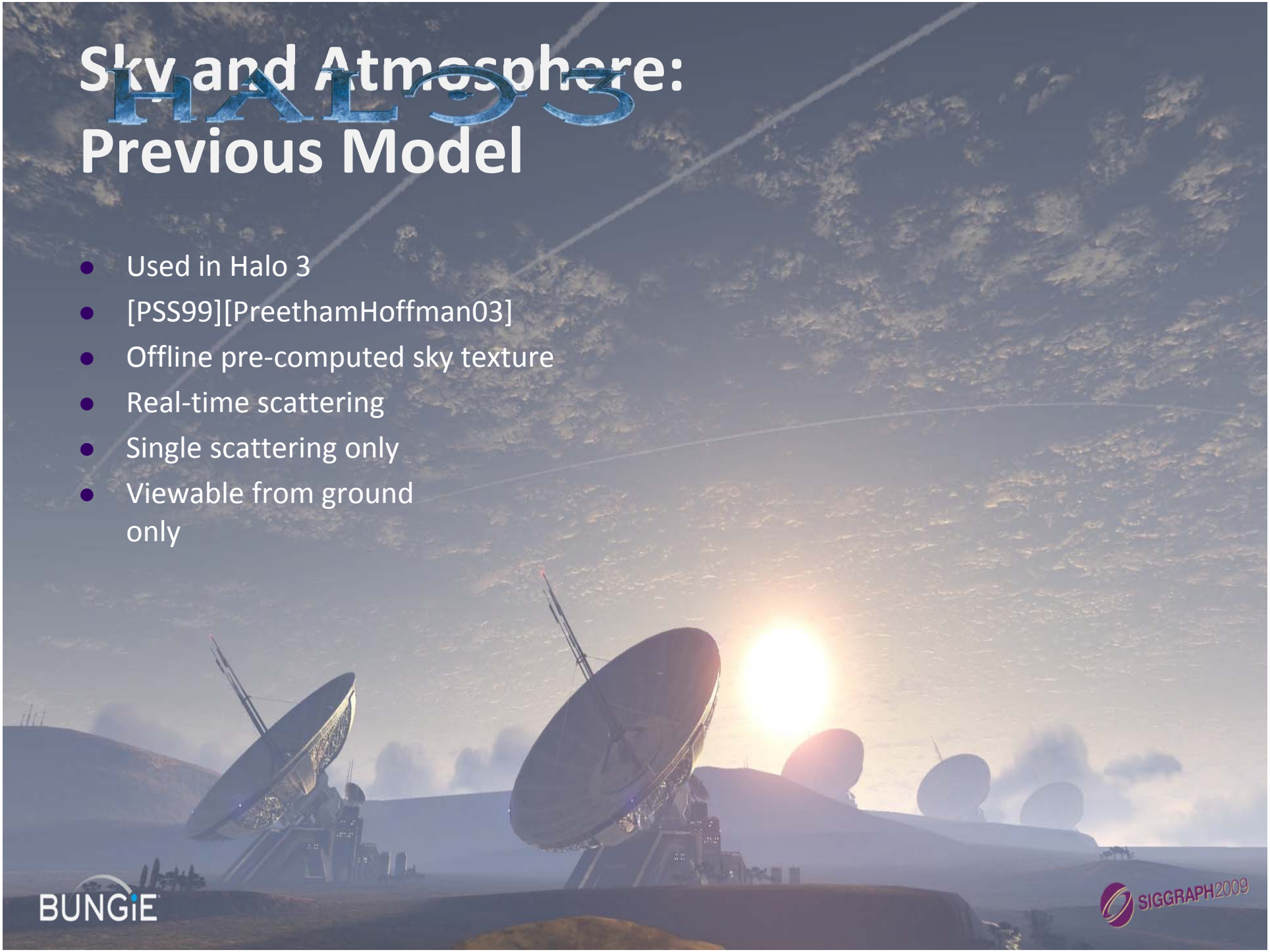
- Ray tracing enables global illumination
- Instead of billboards, imposters, images use physically-based appearance models
- Very cool effects:
  - Shadows
  - Ambient Occlusion
  - Reflections
  - Transmittance
  - Refractions
  - Caustics
  - Global subsurface scattering
  - What does it look like?

Real-time Lighting in Games



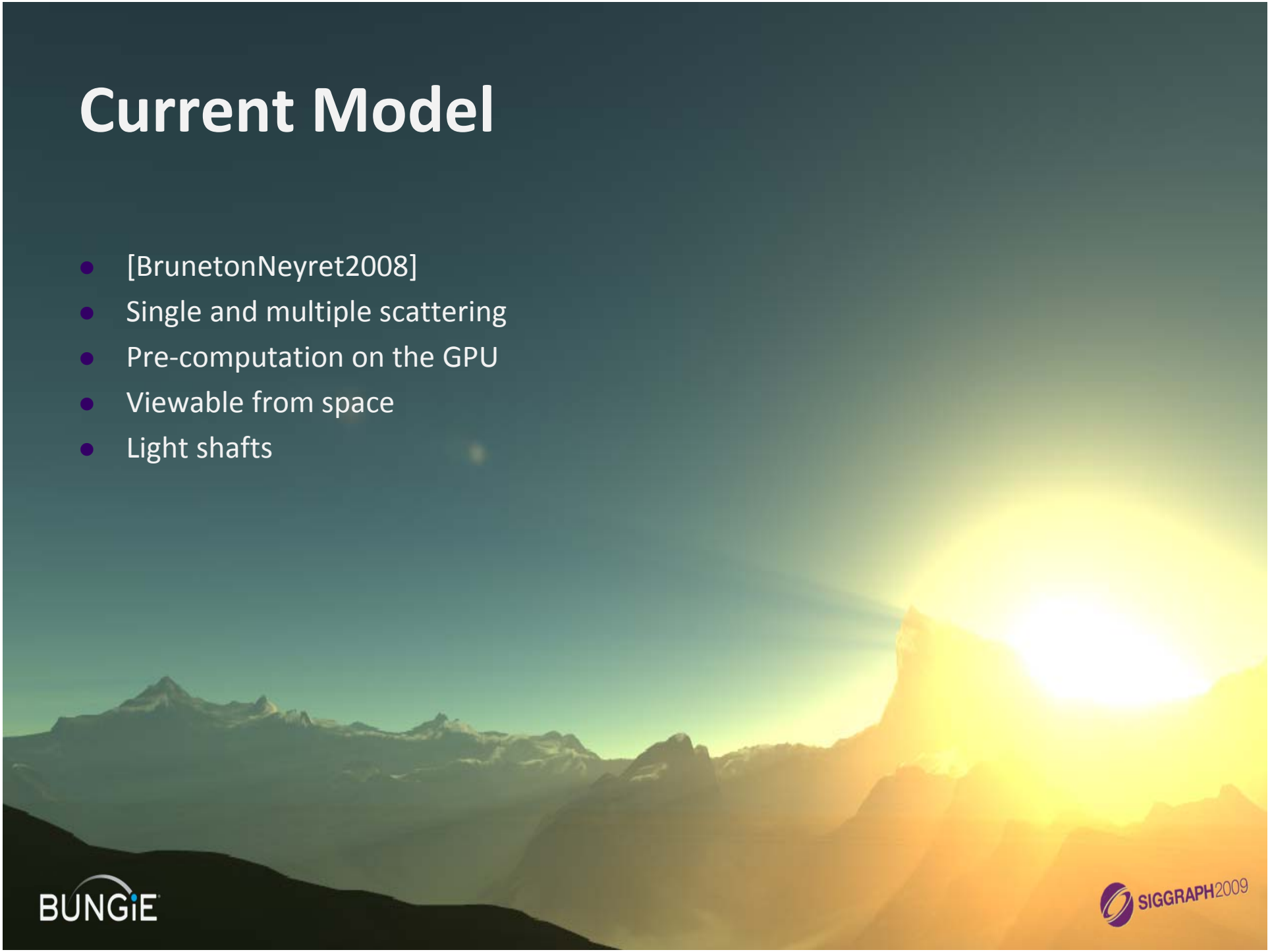
Sky and Atmosphere: Previous Model

- Used in Halo 3
- [PSS99][PreethamHoffman03]
- Offline pre-computed sky texture
- Real-time scattering
- Single scattering only
- Viewable from ground only

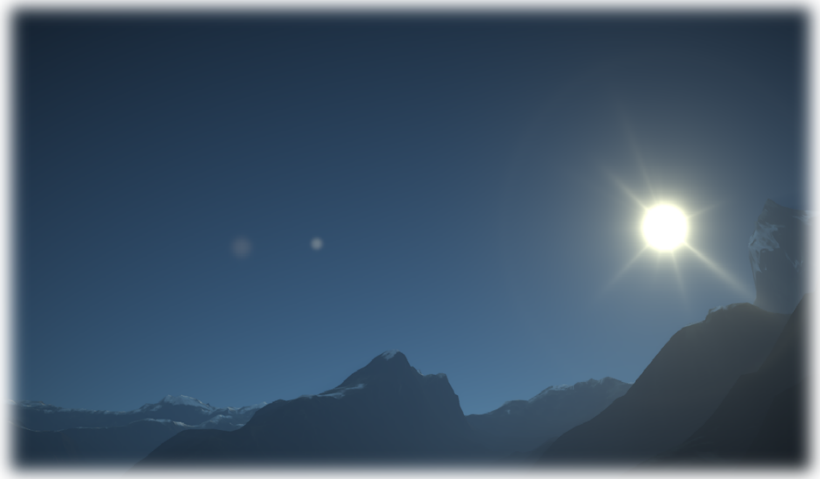


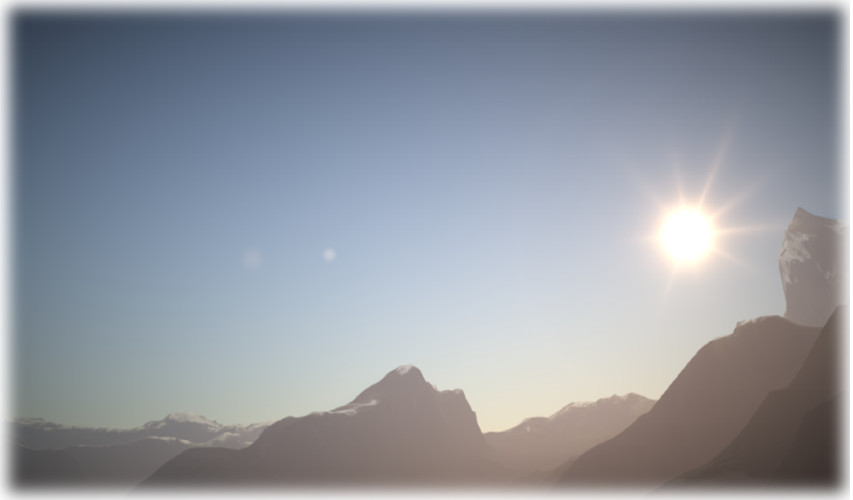
Current Model

- [BrunetonNeyret2008]
- Single and multiple scattering
- Pre-computation on the GPU
- Viewable from space
- Light shafts



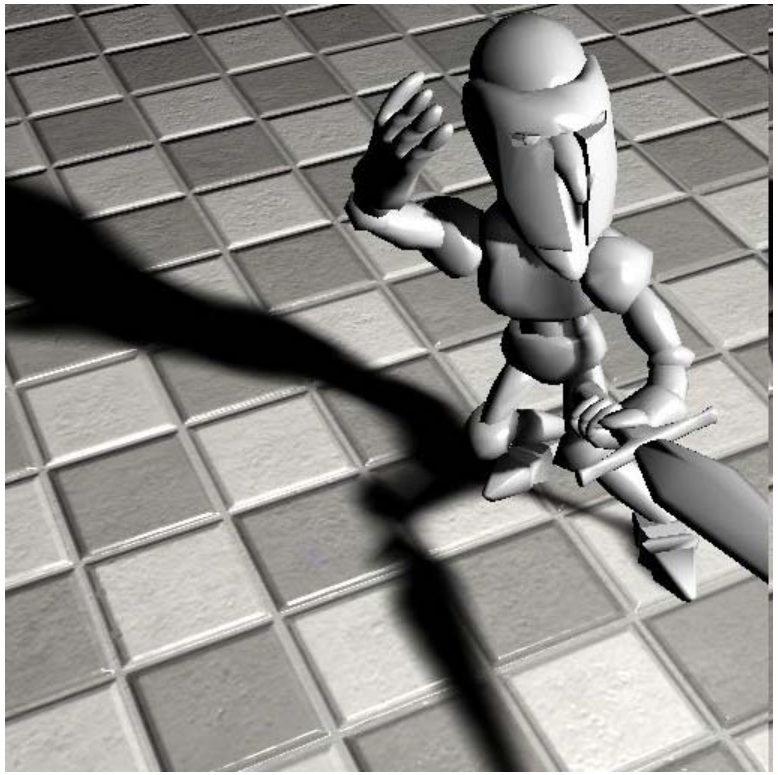
Different Atmospheres





Time Of Day

Shadows



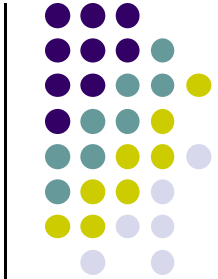
Variance shadow mapping
Courtesy Nvidia SDK 10

Courtesy Hellgate:London,
flagship studios inc

Caustics and Refraction

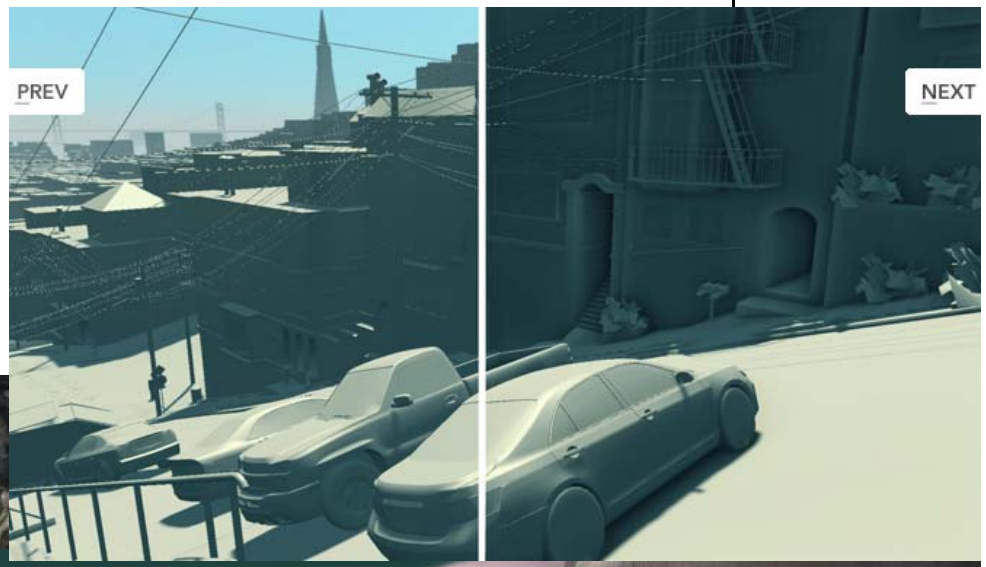
Courtesy Chris Wyman, Univ Iowa

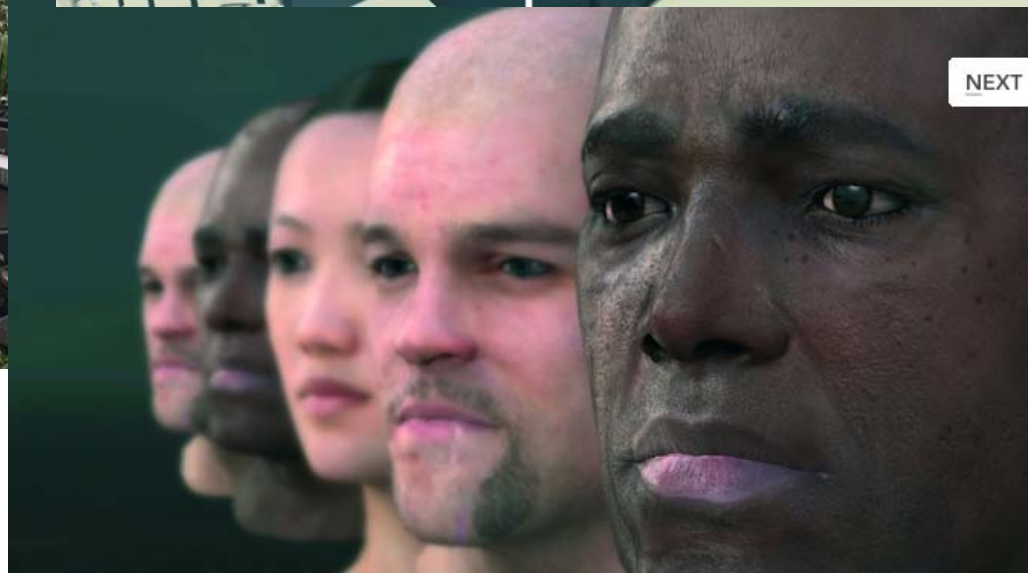
CryEngine 3:GI with Light Propagation Volumes



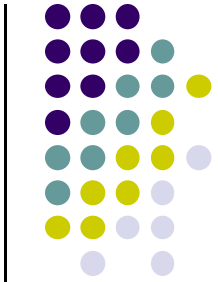
- State-of-the-art game engine
- Real-time simulation of massive,indirect physically-based lighting

Crytek Crisis Engine Screenshots





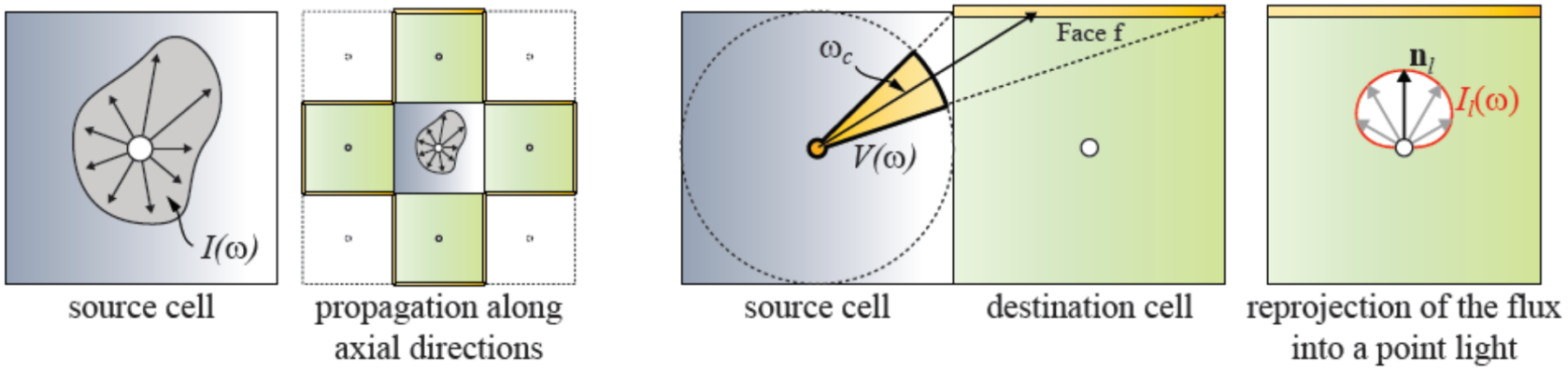
Demo

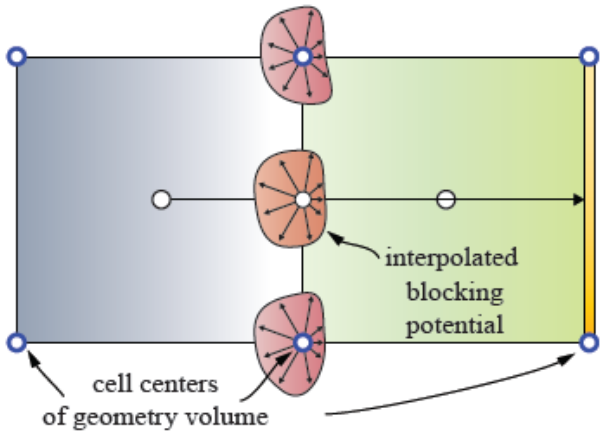


- Light Propagation Volumes Demo

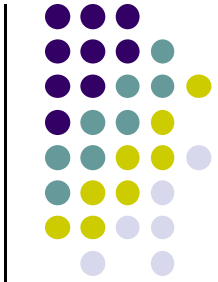
LPV Idea

Main idea: represent light propagation as Virtual Point Lights (VPL)
Re-project VPL into adjacent cells





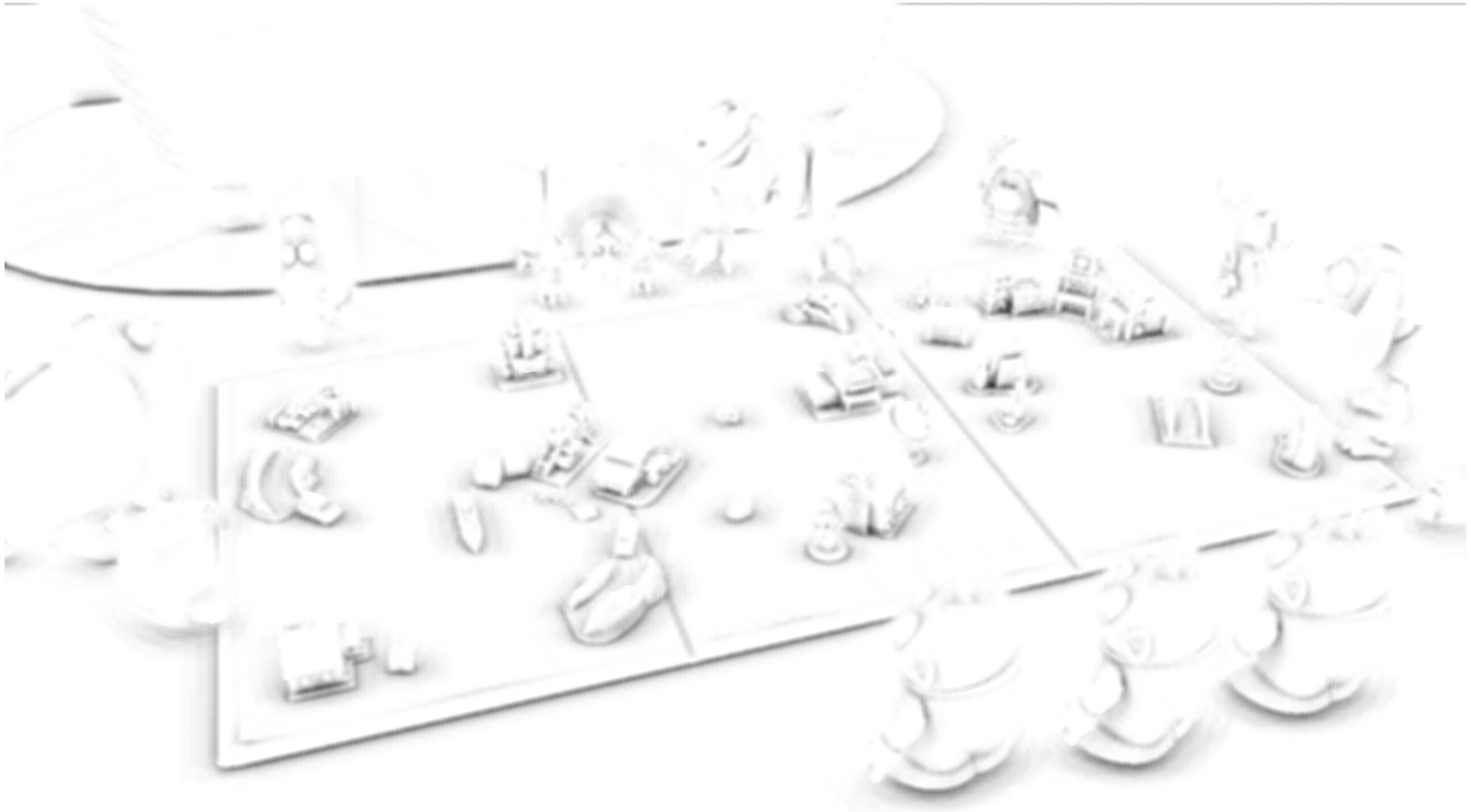
Trend 5: Screen-Space GI Techniques



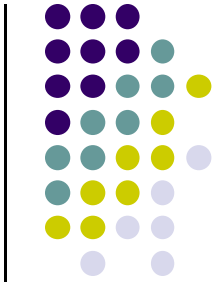
- Toy Story 3: Screen space Ambient Occlusion

SSAO in Toy story 3

- Viewing just the ambient term of shading

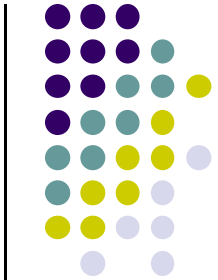


Trend 6: Physics Engines on GPU



- Nvidia Physx engine
- SDK: developer.nvidia.com/object/physx_features.html
  - Complex rigid body object physics system
  - Advanced character control
  - Ray-cast and articulated vehicle dynamics
  - Multi-threaded/Multi-platform/PPU Enabled
  - Volumetric fluid creation and simulation
  - Cloth and clothing authoring and playback
  - Soft Bodies
  - Volumetric Force Field Simulation
  - Vegetation

References



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