CS580:
Ray Tracing

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(윤성의)

Course URL:
http://sgvr.kaist.ac.kr/~sungeui/GCG/

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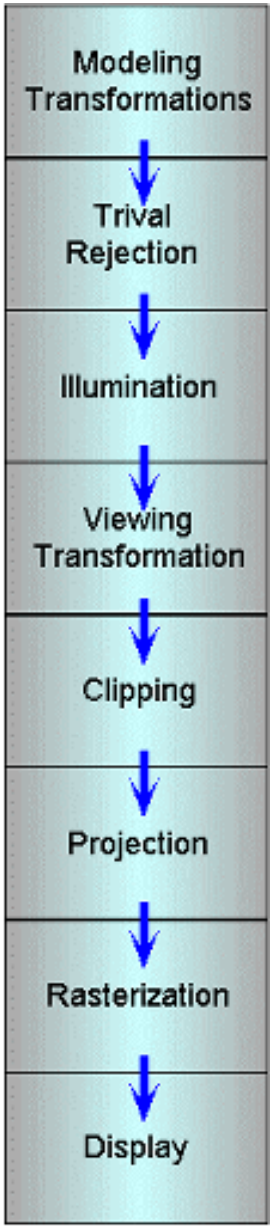
Class Objectives (Ch. 10)

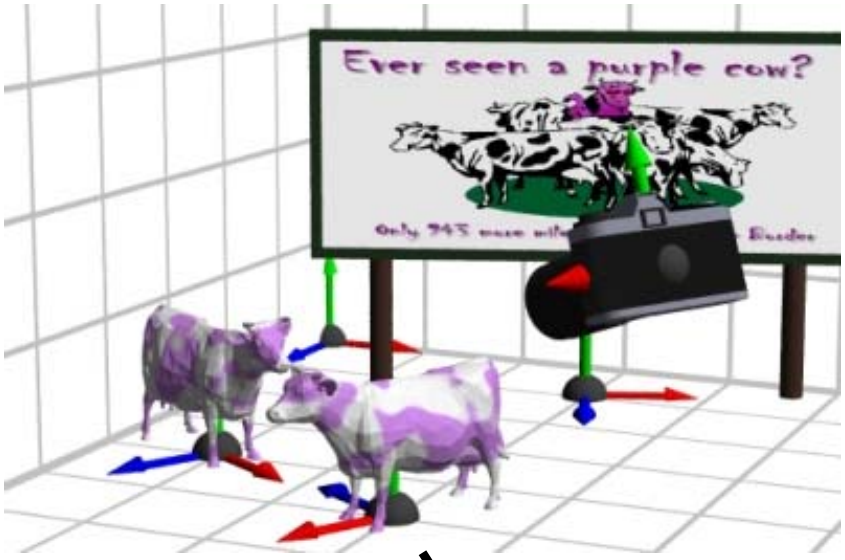
- **Understand a basic ray tracing**
- **Know its acceleration data structure and how to use it**

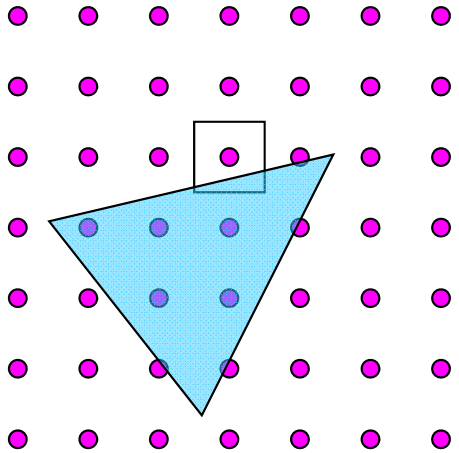
Honor Code and Etiquette

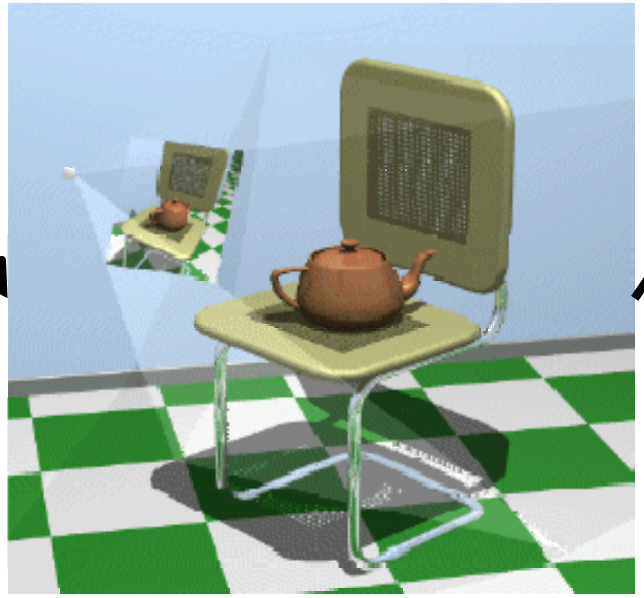
- **Collaboration encouraged, but *assignments must be your own work***
- **Cite any other's work if you use their codes**
  - **If you copy someone else's codes, you will get F**
  - **If your ones are copied, you will also get F**
- **Classroom etiquette**
  - **Help you and your peer to focus on the class**
  - **Turn off cell phones**
  - **Arrive to the class on time**
  - **Avoid private conversations**
  - **Be attentive in class**
- **Let's introduce each other**

The Classic Rendering Pipeline







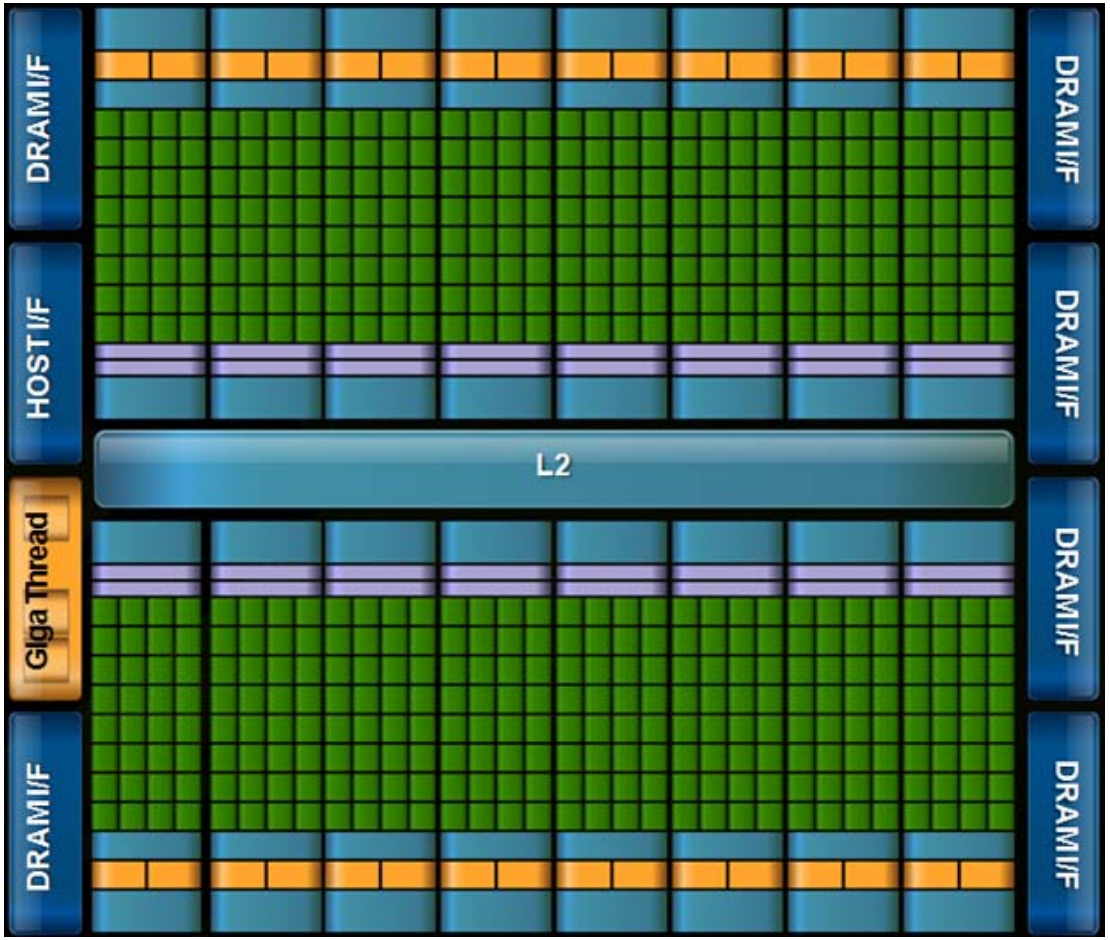


Why we are using rasterization?

- **Efficiency**
- **Reasonably quality**

Fermi GPU Architecture

16 SM (streaming processors)



512 CUDA cores

Memory interfaces

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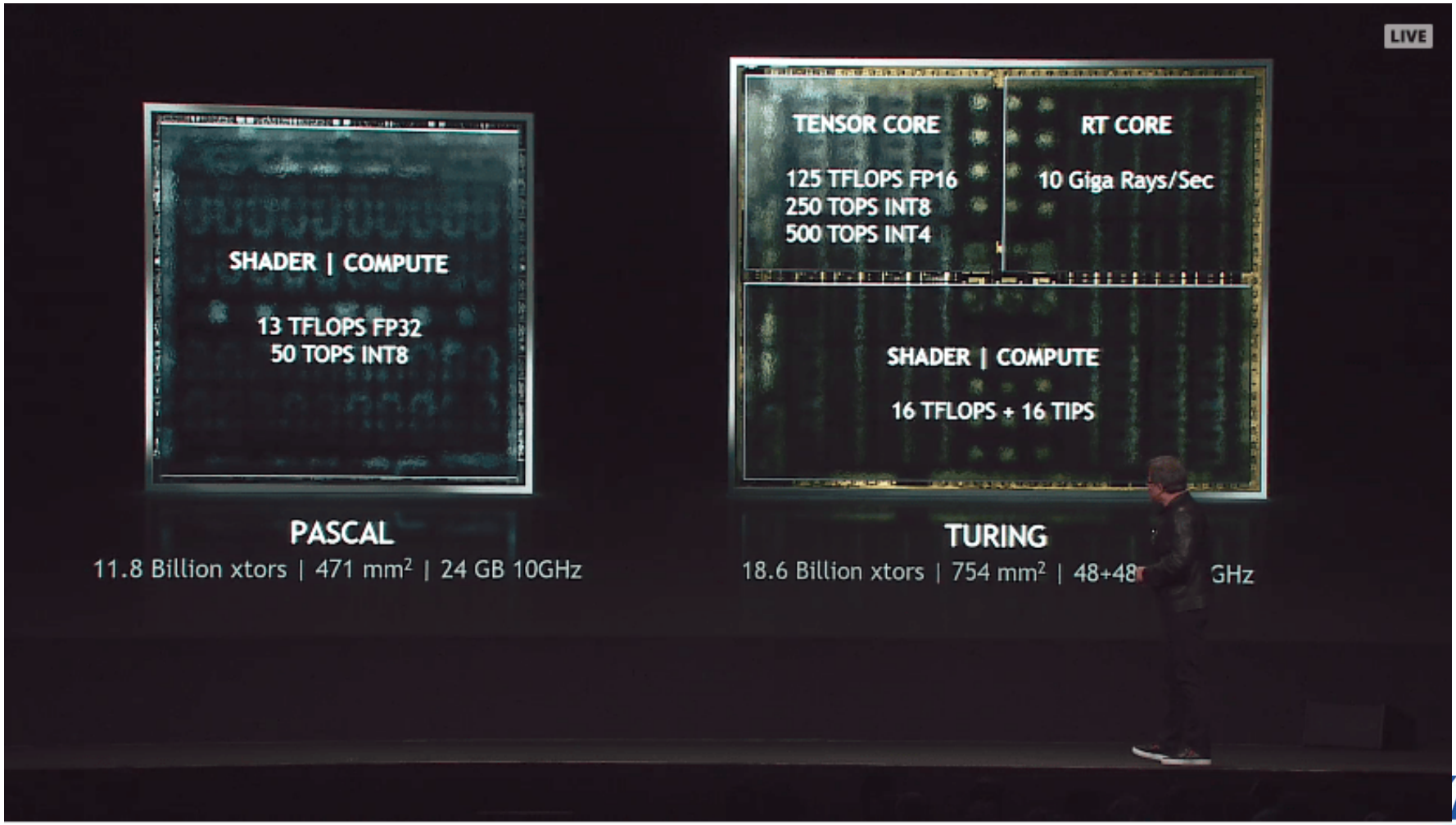
Turing Architecture, 2018

- **Aims to combine shade, compute, ray tracing, and AI**



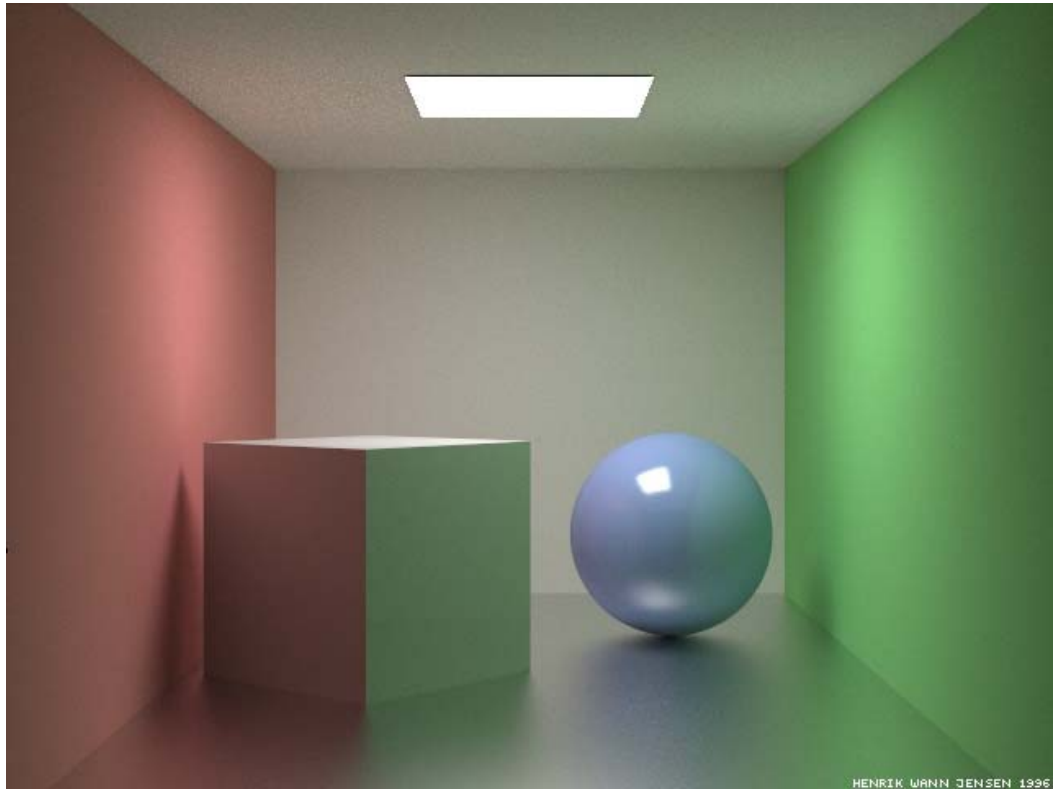
Where Rasterization Is

From Battlefield: Bad Company, EA Digital Illusions CE AB

From Eric Haines

But what about other visual cues?

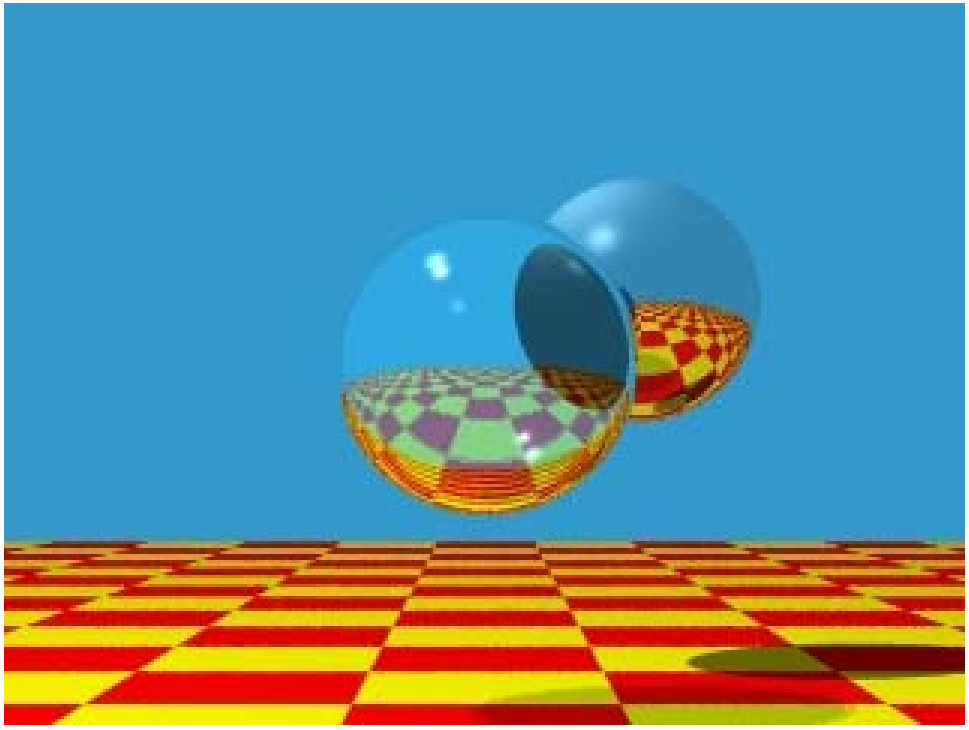
- Lighting
  - Shadows
  - Shading: glossy, transparency
- Color bleeding, etc



from Henrik's homepage

Recursive Ray Casting

- **Gained popularity in when Turner Whitted (1980) recognized that *recursive* ray casting could be used for global illumination effects**

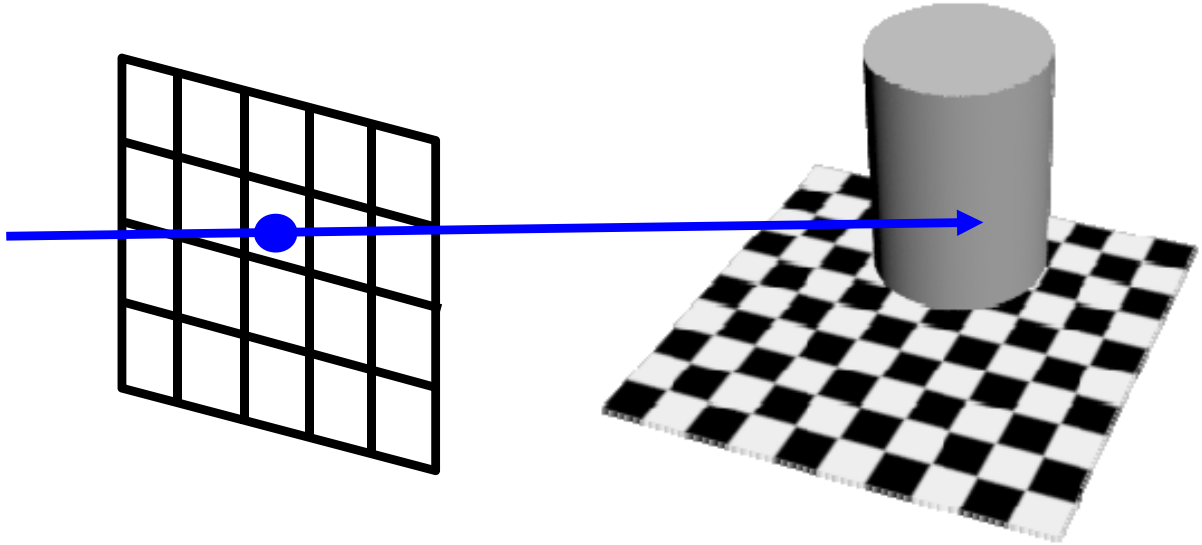


Ray Casting and Ray Tracing

- Trace rays from eye into scene
  - Backward ray tracing
- Ray casting used to compute visibility at the eye
- Perform ray tracing for arbitrary rays needed for shading
  - Reflections
  - Refraction and transparency
  - Shadows

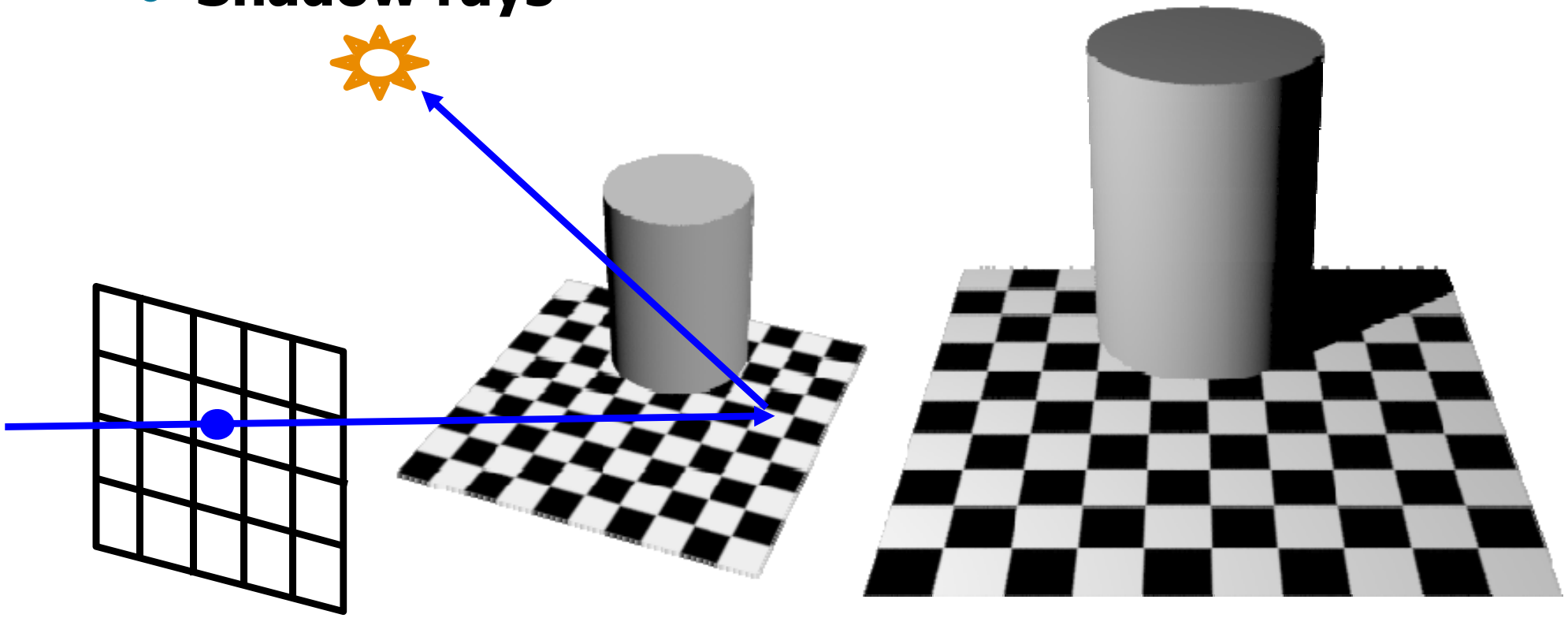
Basic Algorithms

- **Rays are cast from the eye point through each pixel in the image**



Shadows

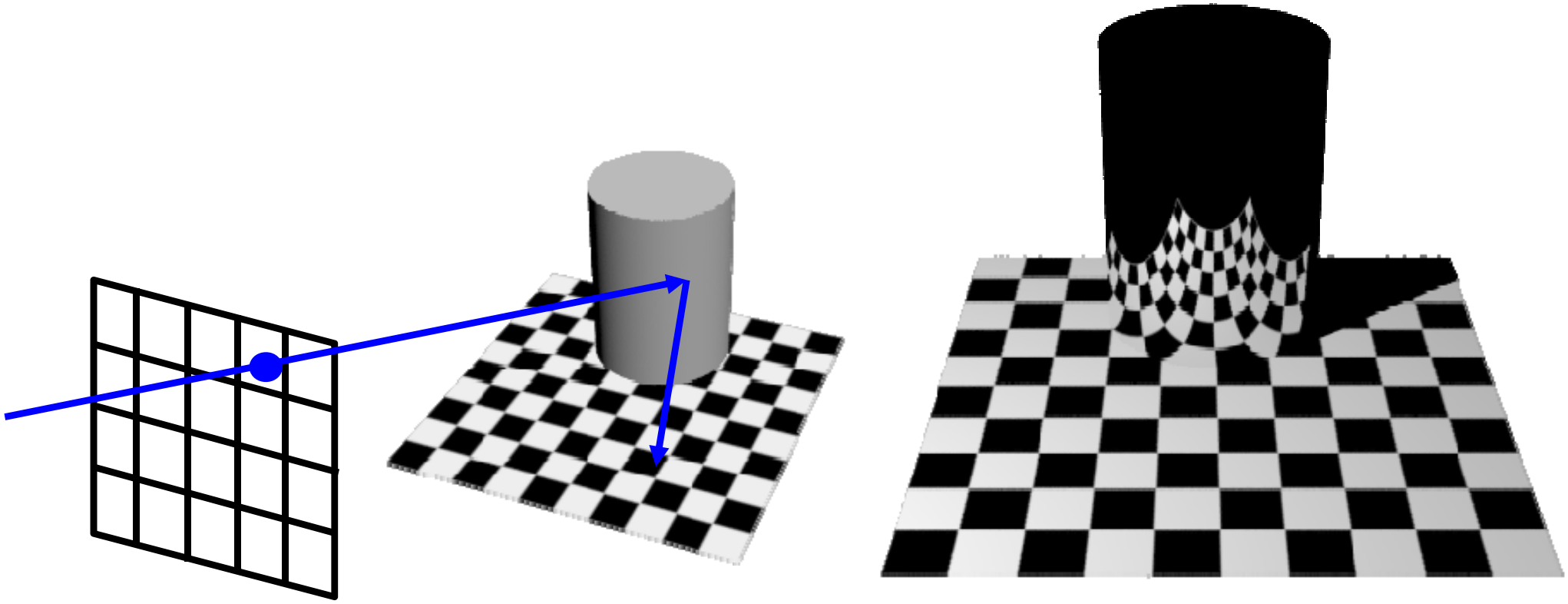
- Cast ray from the intersection point to each light source
  - Shadow rays



Used 3ds Max

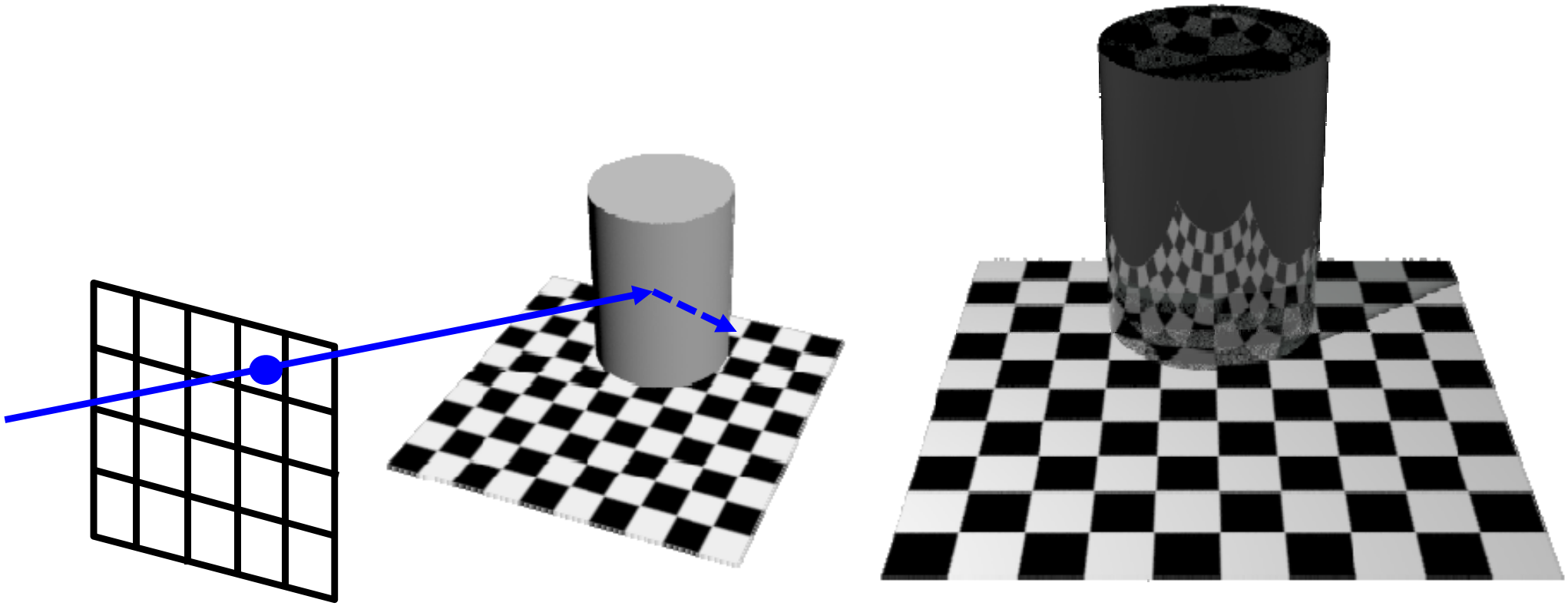
Reflections

- **If object specular, cast secondary reflected rays**



Refractions

- **If object tranparent, cast secondary refracted rays**



An Improved Illumination Model [Whitted 80]

- **Phong illumination model**

$$I_r = \sum_{j=1}^{numLights} \left(k_a^j I_a^j + k_d^j I_d^j (\hat{N} \bullet \hat{L}_j) + k_s^j I_s^j (\hat{V} \bullet \hat{R})^{n_s} \right)$$

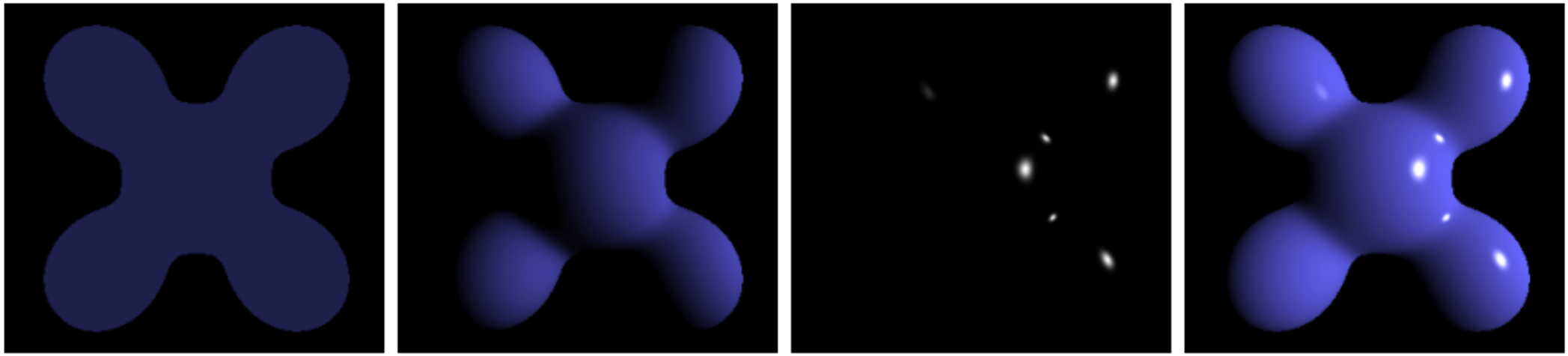
- **Whitted model**

$$I_r = \sum_{j=1}^{numLights} \left(k_a^j I_a^j + k_d^j I_d^j (\hat{N} \bullet \hat{L}_j) \right) + k_s S + k_t T$$

  - **S and T are intensity of light from reflection and transmission rays**
  - **Ks and Kt are specular and transmission coefficient**

OpenGL's Illumination Model

$$I_r = \sum_{j=1}^{numLights} \left(k_a^j I_a^j + k_d^j I_d^j \max((\hat{N} \bullet \hat{L}_j), 0) + k_s^j I_s^j \max((\hat{V} \bullet \hat{R})^{n_s}, 0) \right)$$



From Wikipedia

Details are available at Ch. 8 Illumination and Shading

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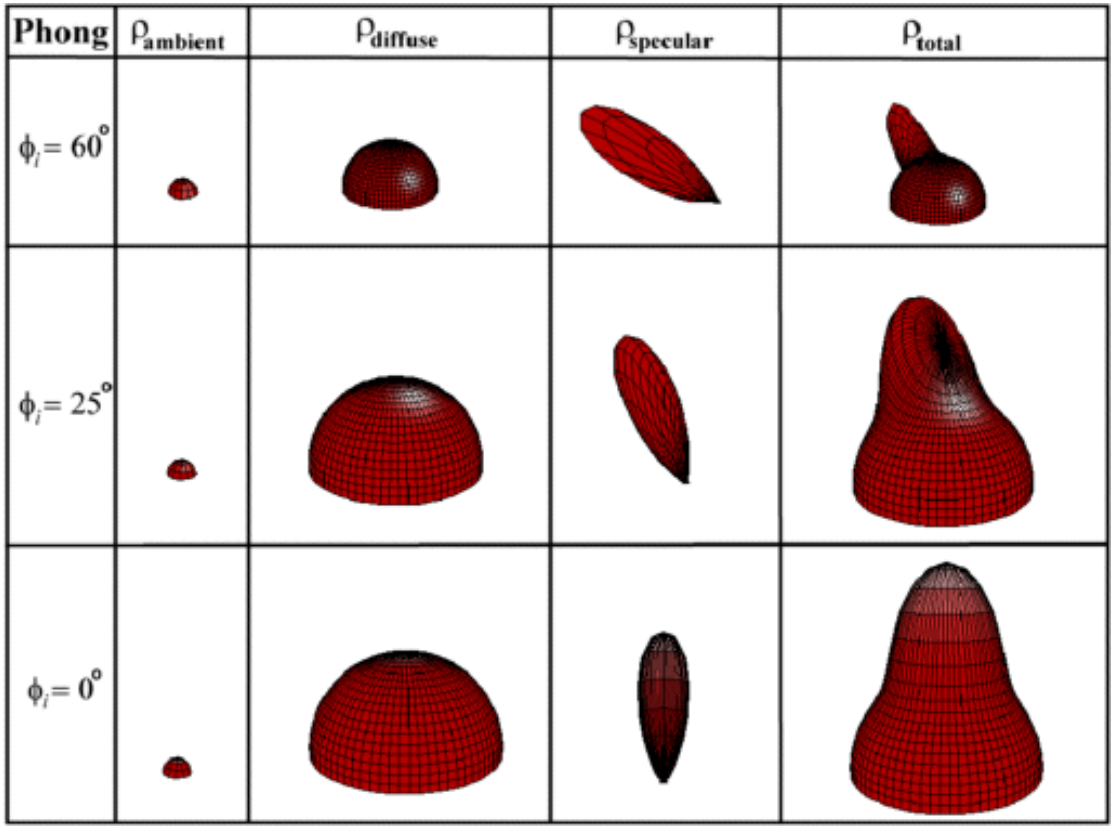
Some Examples

$$I_r = \sum_{j=1}^{numLights} \left(k_a^j I_a^j + k_d^j I_d^j \max((\hat{N} \bullet \hat{L}_j), 0) + k_s^j I_s^j \max((\hat{V} \bullet \hat{R}), 0)^{n_s}\right)$$



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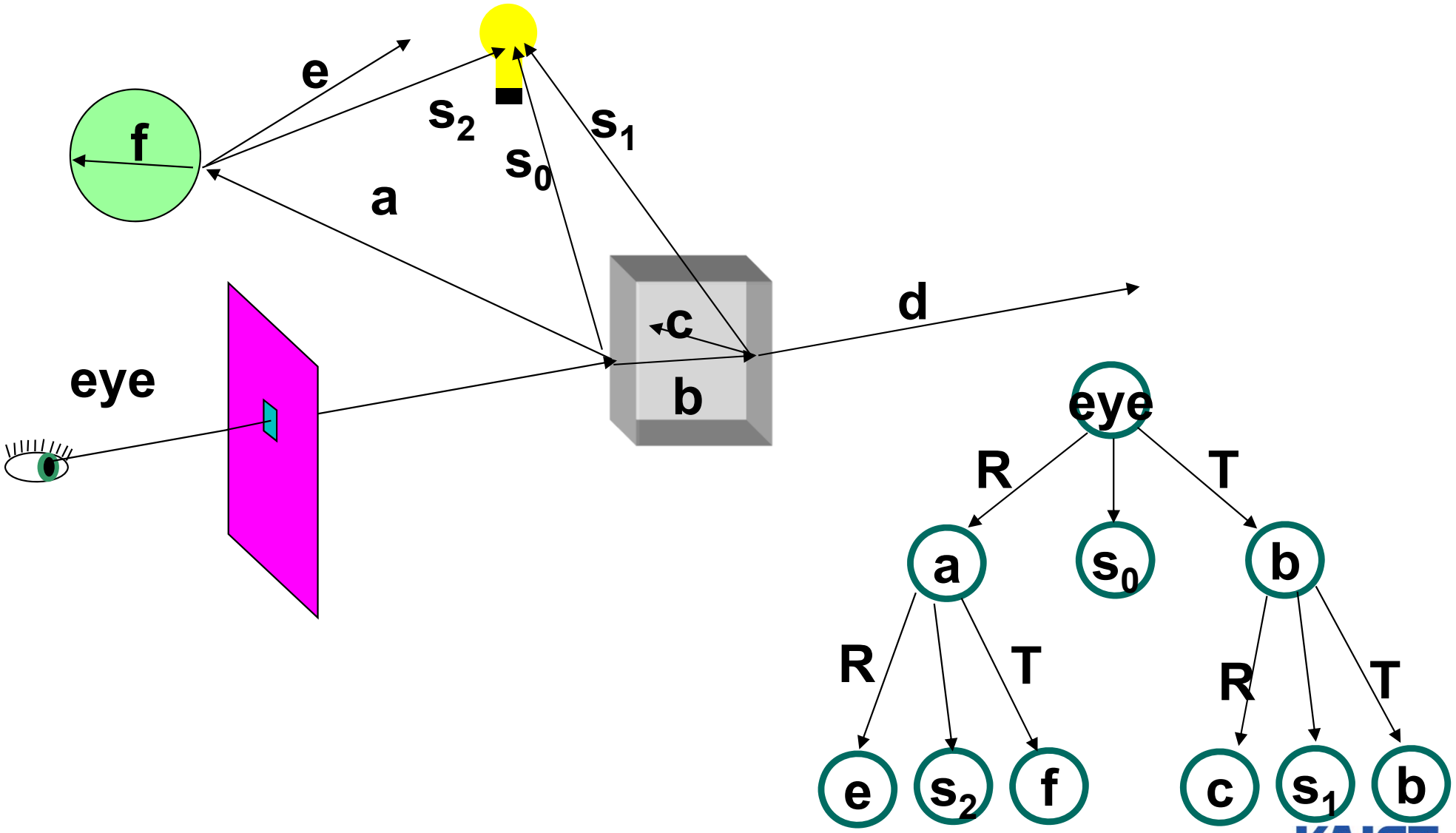
Ray Tree



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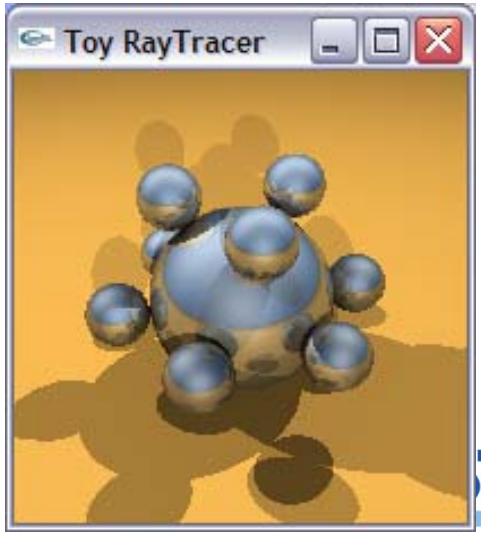
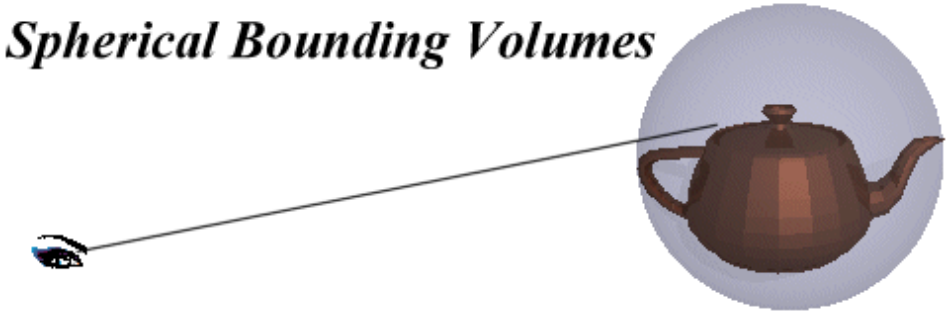
Acceleration Methods for Ray Tracing

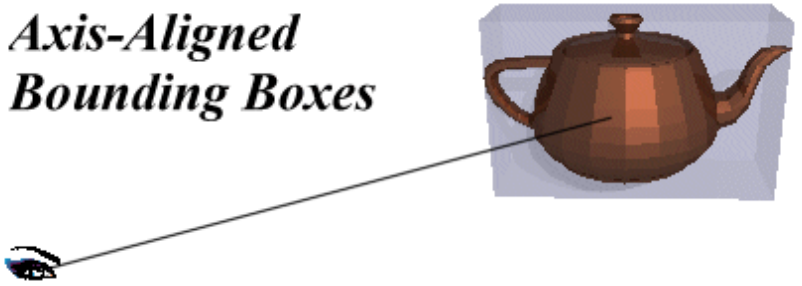
- Rendering time for a ray tracer depends on the number of ray intersection tests per pixel
  - The number of pixels X the number of primitives in the scene
- Early efforts focused on accelerating the ray-object intersection tests
  - Ray-triangle intersection tests
- More advanced methods required to make ray tracing practical
  - Bounding volume hierarchies
  - Spatial subdivision (e.g., kd-trees)



Bounding Volumes

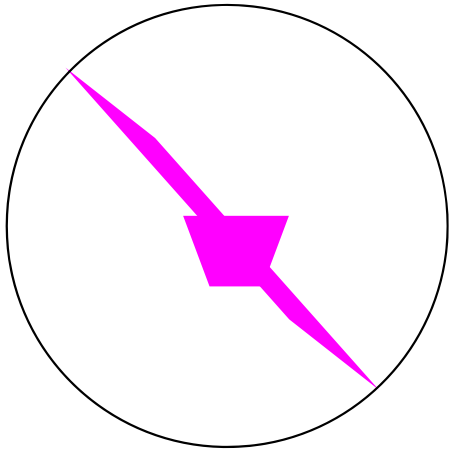
- **Enclose complex objects within a simple-to-intersect objects**
  - **If the ray does not intersect the simple object then its contents can be ignored**
  - **The likelihood that it will strike the object depends on how tightly the volume surrounds the object.**
- **Spheres are simple, but not tight**
- **Axis-aligned bounding boxes often better**
  - **Can use nested or hierarchical bounding volumes**



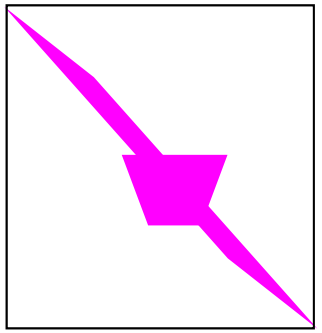


Bounding Volumes

- **Sphere [Whitted80]**
  - **Cheap to compute**
  - **Cheap test**
  - **Potentially very bad fit**

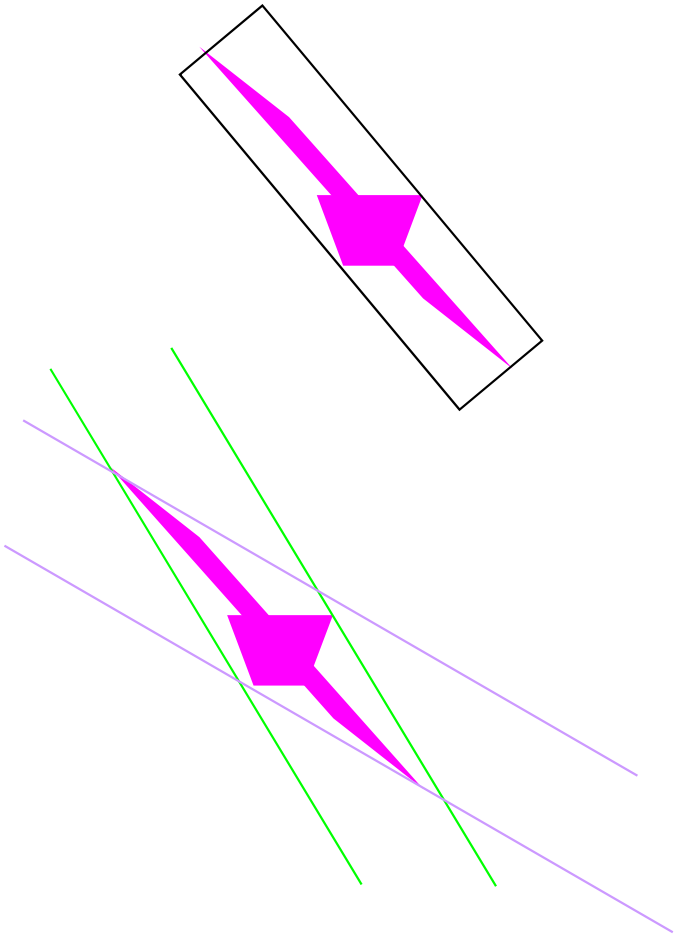


- **Axis-Aligned Bounding Box**
  - **Very cheap to compute**
  - **Cheap test**
  - **Tighter than sphere**



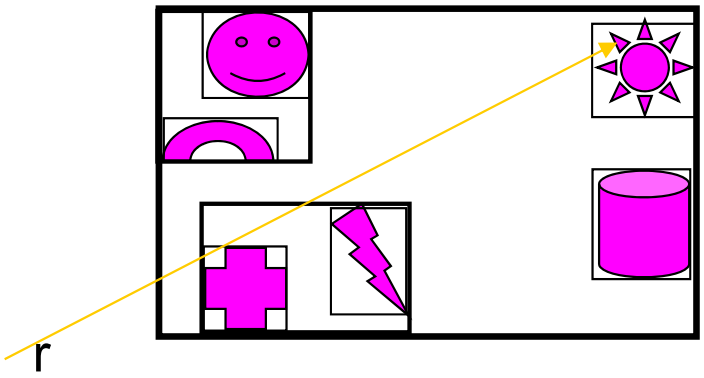
Bounding Volumes

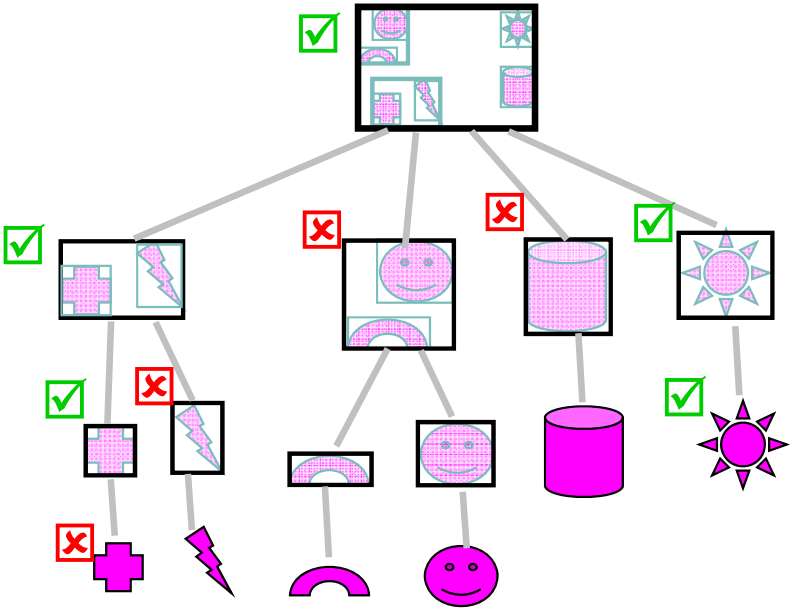
- **Oriented Bounding Box**
  - **Fairly cheap to compute**
  - **Fairly Cheap test**
  - **Generally fairly tight**
- **Slabs / K-dops**
  - **More expensive to compute**
  - **Fairly cheap test**
  - **Can be tighter than OBB**



Bounding Volume Hierarchy (BVH)

- Organize bounding volumes as a tree
  - Choose a partitioning plane and distribute triangles into left and right nodes
- Each ray starts with the scene BV and traverses down through the hierarchy





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Test-Of-Time 2006 Award

RT-DEFORM: Interactive Ray Tracing of Dynamic Scenes using BVHs

Christian Lauterbach, Sung-eui Yoon, David Tuft, Dinesh Manocha

IEEE Interactive Ray Tracing, 2006


RT-DEFORM: Interactive Ray Tracing of Dynamic Scenes using BVHs

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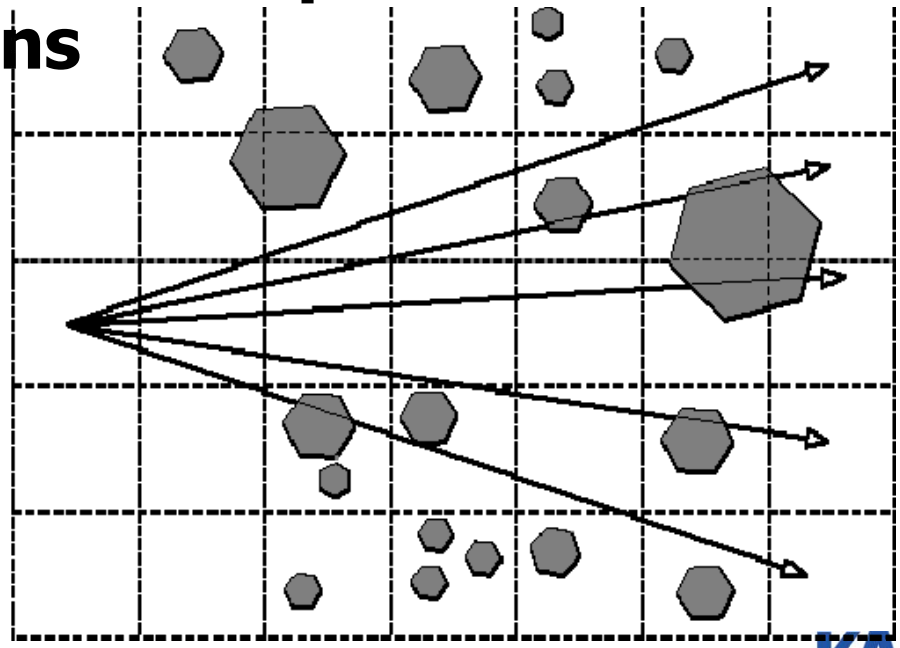
Spatial Subdivision

Idea: Divide space in to subregions

- **Place objects within a subregion into a list**
- **Only traverse the lists of subregions that the ray passes through**
- **"Mailboxing" used to avoid multiple test with objects in multiple regions**
- **Many types**
  - **Regular grid**
  - **Octree**
  - **BSP tree**
  - **kd-tree**

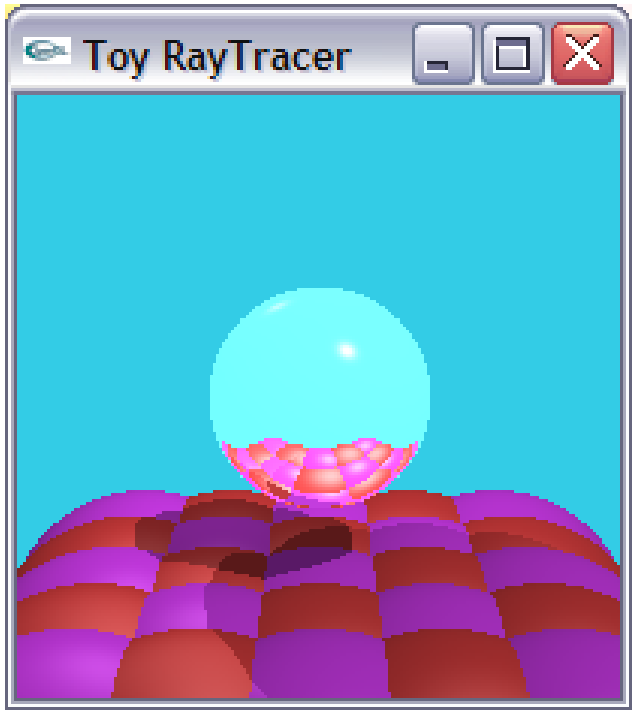


Ray Tracing with kd-tree or BVHs

- Goal: find closest hit with scene
- Traverse tree front to back (starting from root)
- At each node:
  - If leaf: intersect with triangles
  - If inner: traverse deeper

Classic Ray Tracing

- **Gathering approach**
  - **From lights, reflected, and refracted directions**
- **Pros of ray tracing**
  - **Simple and improved realism over the rendering pipeline**



- **Cons:**
  - **Simple light model, material, and light propagation**
  - **Not a complete solution**
  - **Hard to accelerate with special-purpose H/W**

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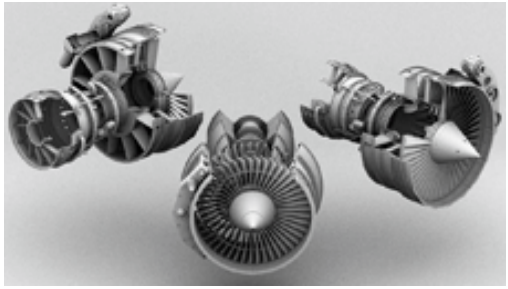
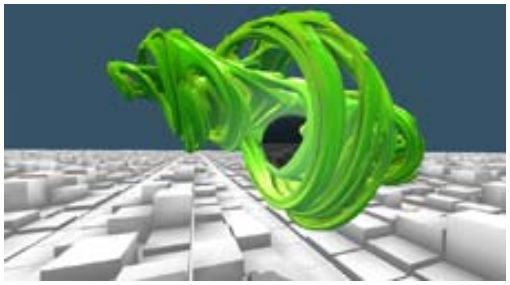
History

- **Problems with classic ray tracing**
  - **Not realistic**
  - **View-dependent**
- **Radiosity (1984)**
  - **Global illumination in diffuse scenes**
- **Monte Carlo ray tracing (1986)**
  - **Global illumination for any environment**

Interactive Ray Tracing Kernels

- **OptiX, Nvidia**
  - **Utilize GPU computing architectures and CUDA**

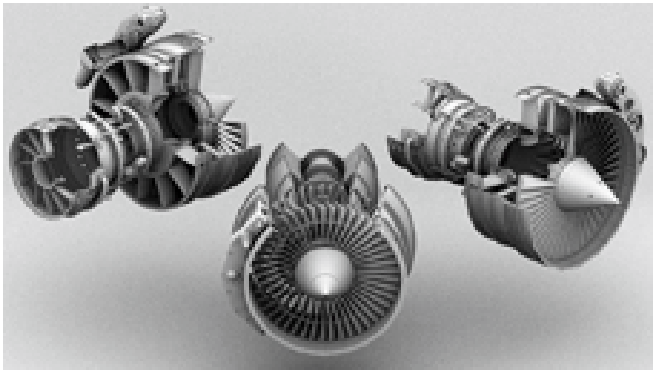




- **Embree, Intel**
  - **Utilize CPUs (multi-threaded and SIMD)**



PA1

- Get to know OptiX or Embree
  - Download, and compile either one of those two methods
  - Or just use precompiled ones
  - Try out a few scenes
  - Upload images of those scenes in KLMS
- Deadline
  - 11:59pm on 3/12
- Note
  - Easy one, but start early



Homework

- **Go over the next lecture slides before the class**
- **Watch 2 paper (or videos) and submit your summaries every Tue. class**
  - **Just one paragraph for each summary**

Example:

Title: XXX XXXX XXXX, Conf: XXX, Year: XXX
Abstract: this video is about accelerating the performance of ray tracing. To achieve its goal, they design a new technique for reordering rays, since by doing so, they can improve the ray coherence and thus improve the overall performance.

Any Questions?

- **Come up with one question on what we have discussed in the class and submit at the end of the class**
  - **1 for already answered questions**
  - **2 for questions that have some thoughts or surprise me**

- **Write a question more than 3 times before the mid-term exam**
  - **Online submission is available at the course webpage**

Class Objectives were:

- Understand a basic ray tracing
- Know its acceleration data structure and how to use it

Next Time

- **Radiosity**