CS482:
Ray Tracing

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(윤성의)

Course URL:
http://sglab.kaist.ac.kr/~sungeui/ICG/

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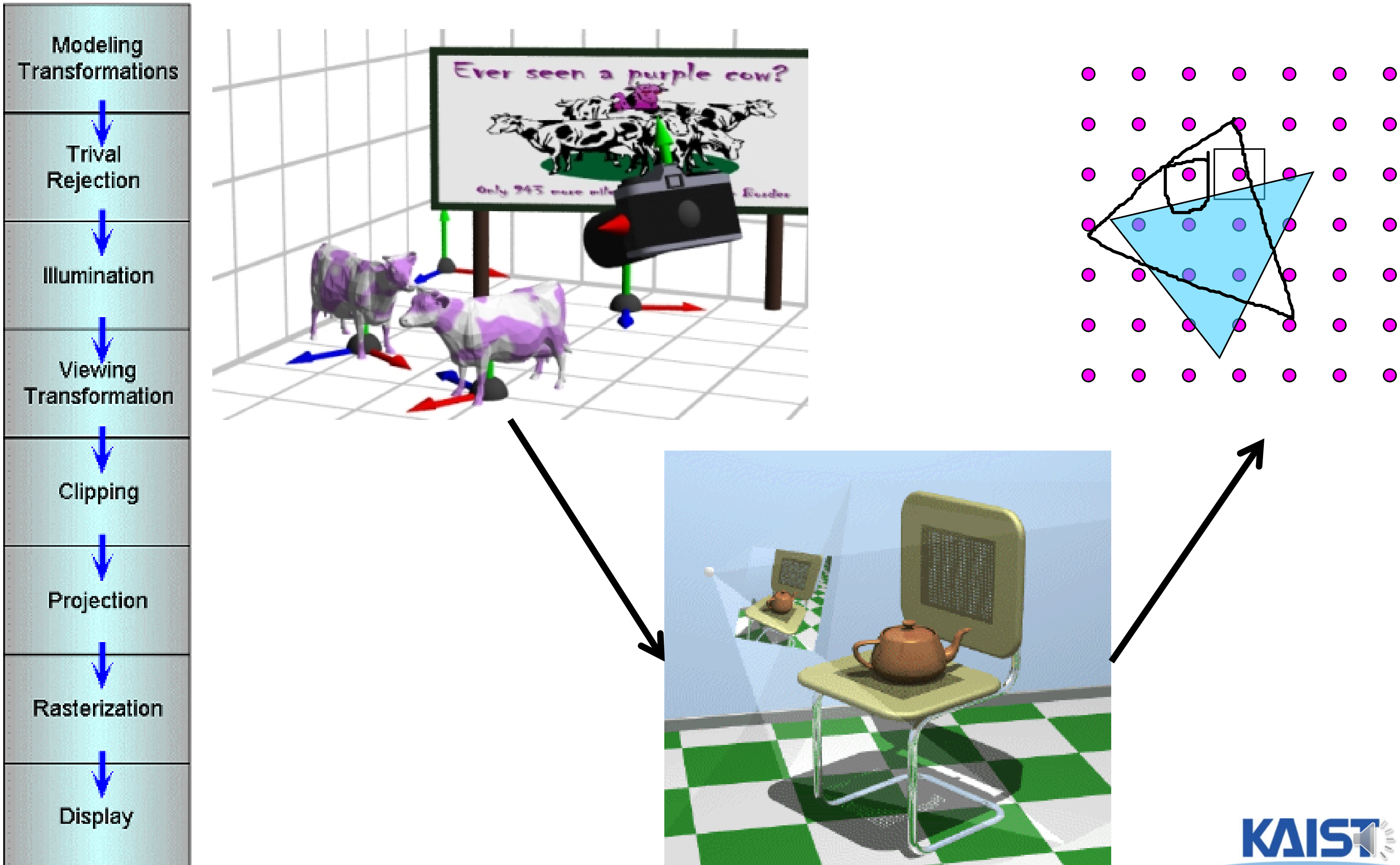
Class Objectives (Ch. 10)

- **Understand a basic ray tracing**
- **Know its acceleration data structure and how to use it**
- **Rendering book https://sgvr.kaist.ac.kr/~sungeui/render/**

The Classic Rendering Pipeline

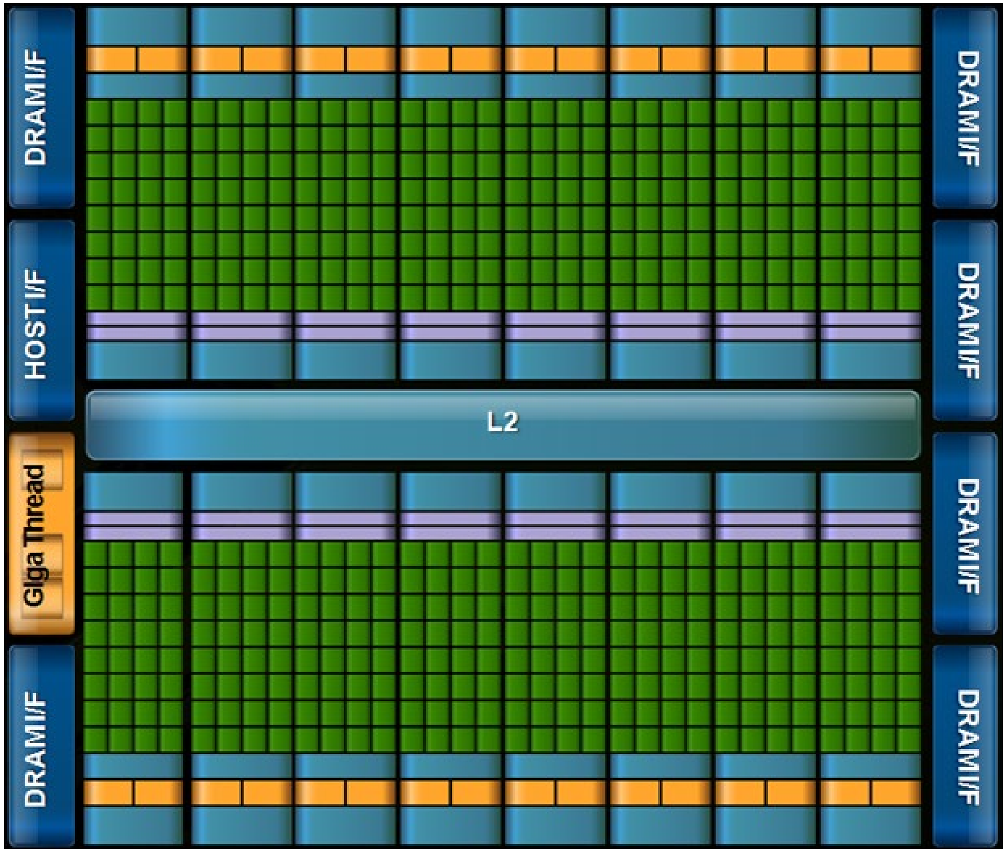


Why we are using rasterization?

- Efficiency
- Reasonably quality

Fermi GPU Architecture

16 SM (streaming processors)

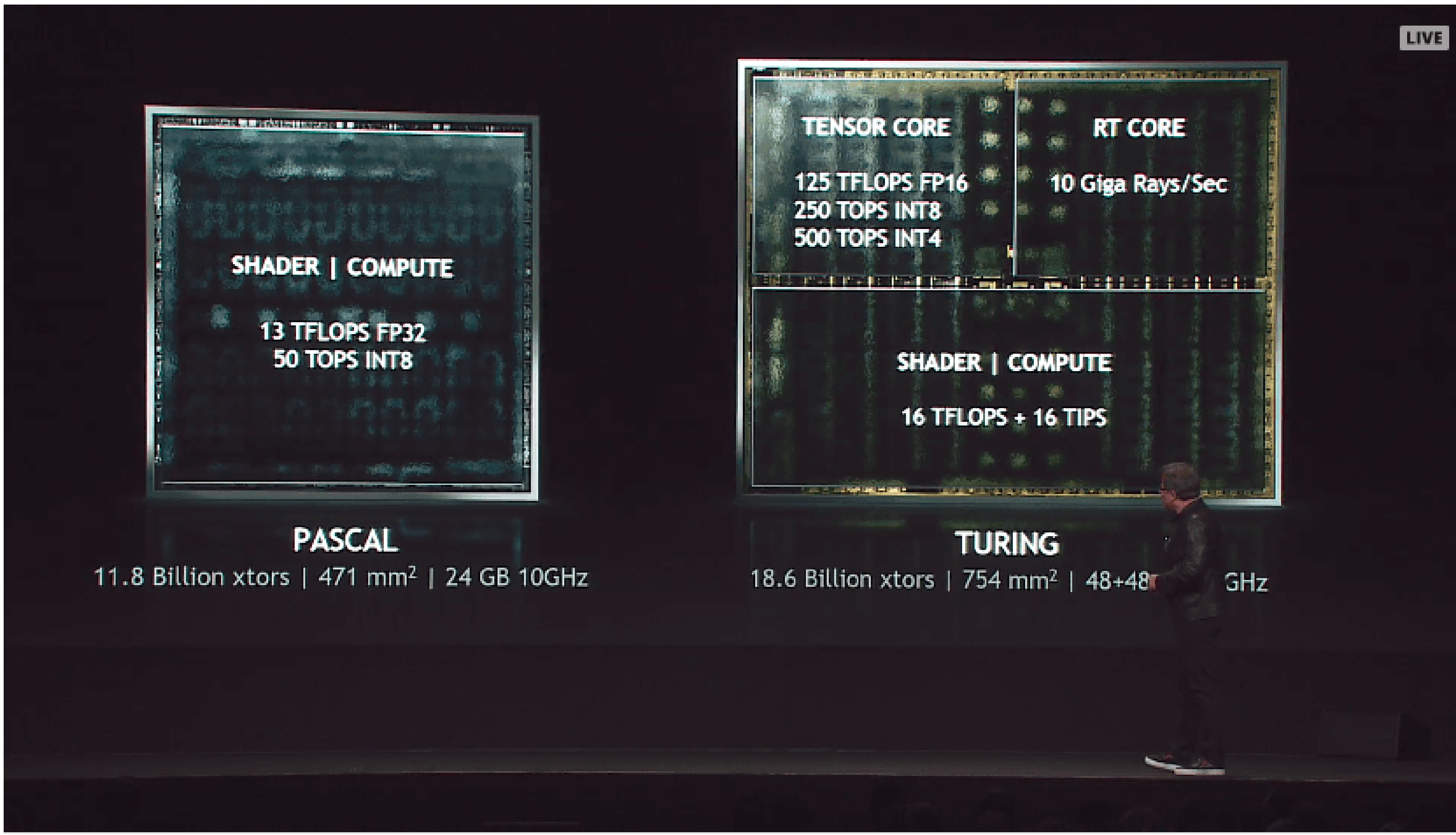


512 CUDA cores

Memory interfaces

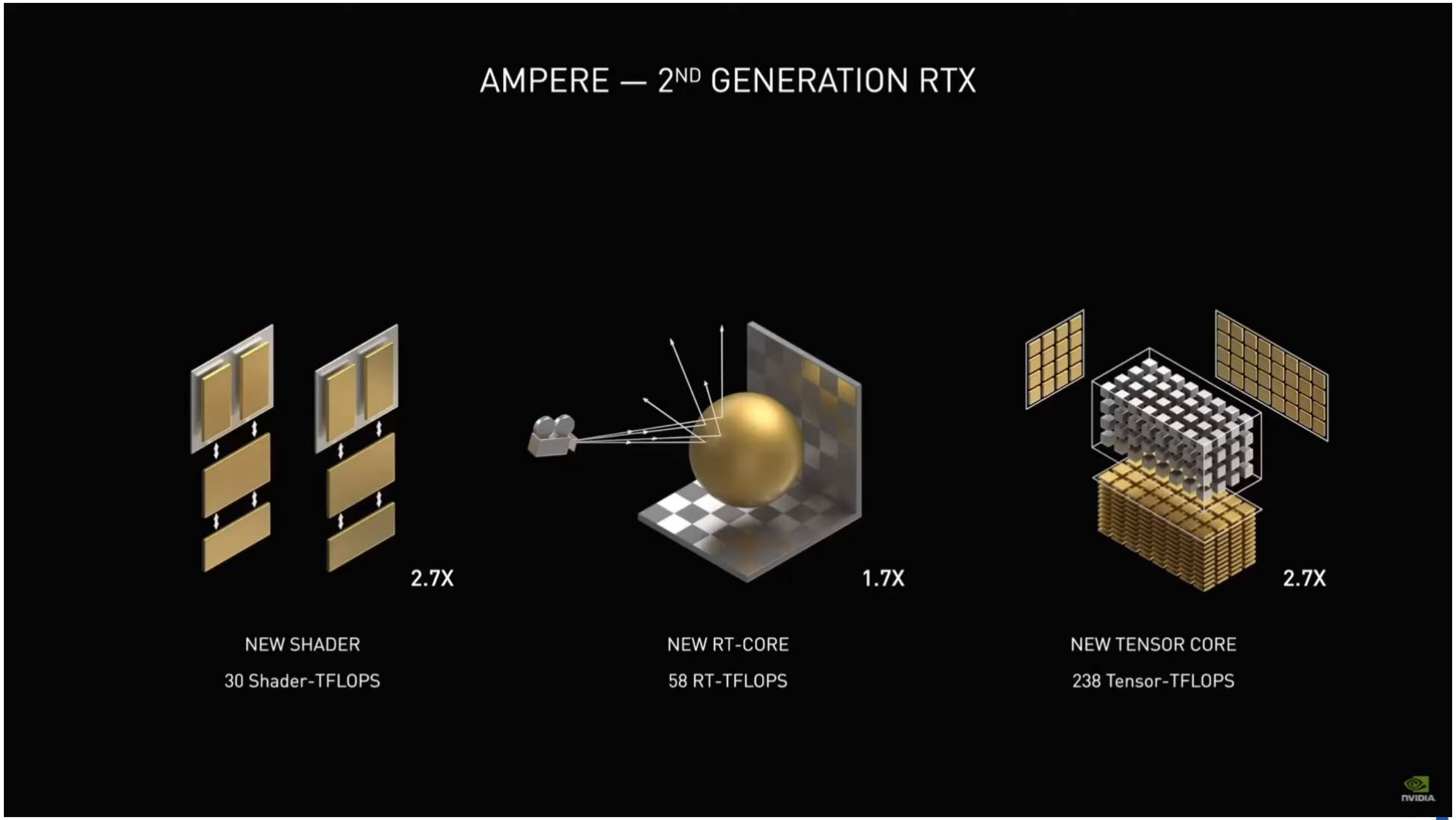
Turing Architecture, 2018

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



A100
Ampere Architecture, 2020

- **More cores, faster computation than Turing Architecture**



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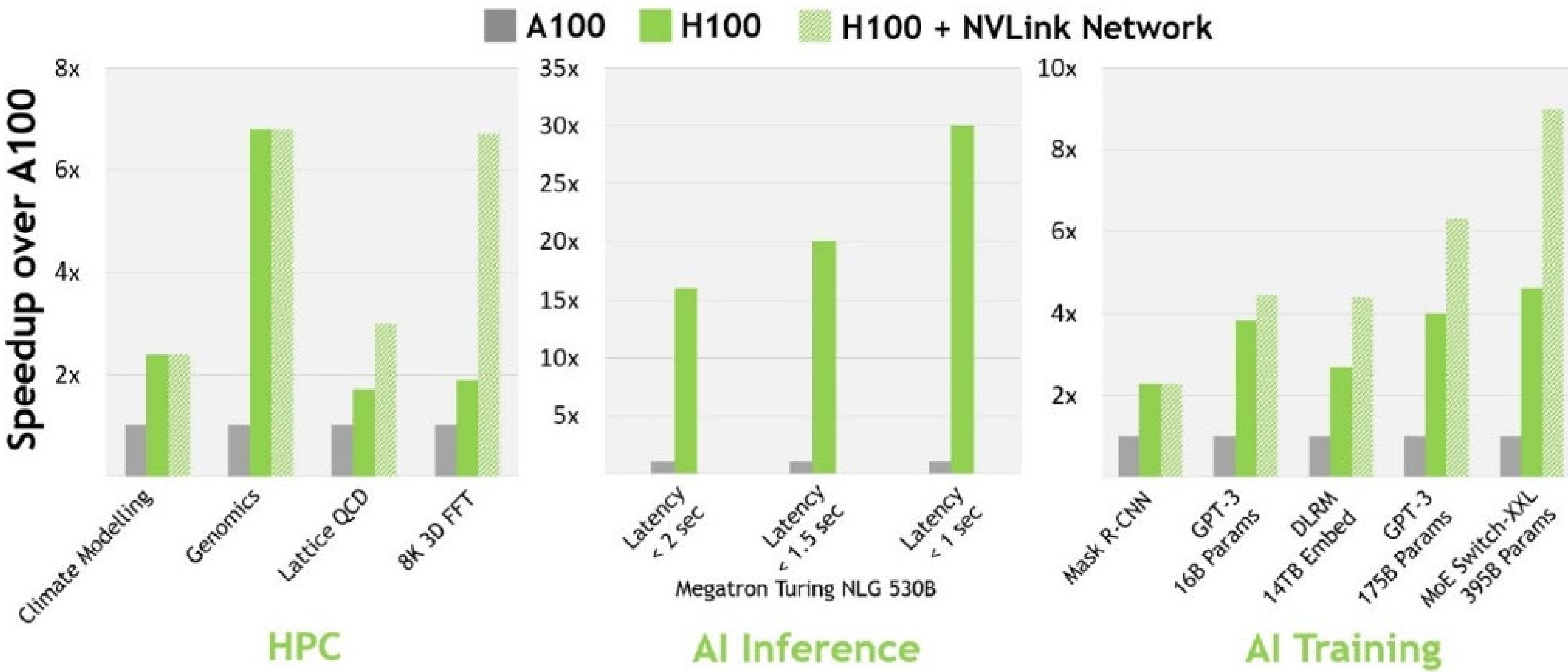
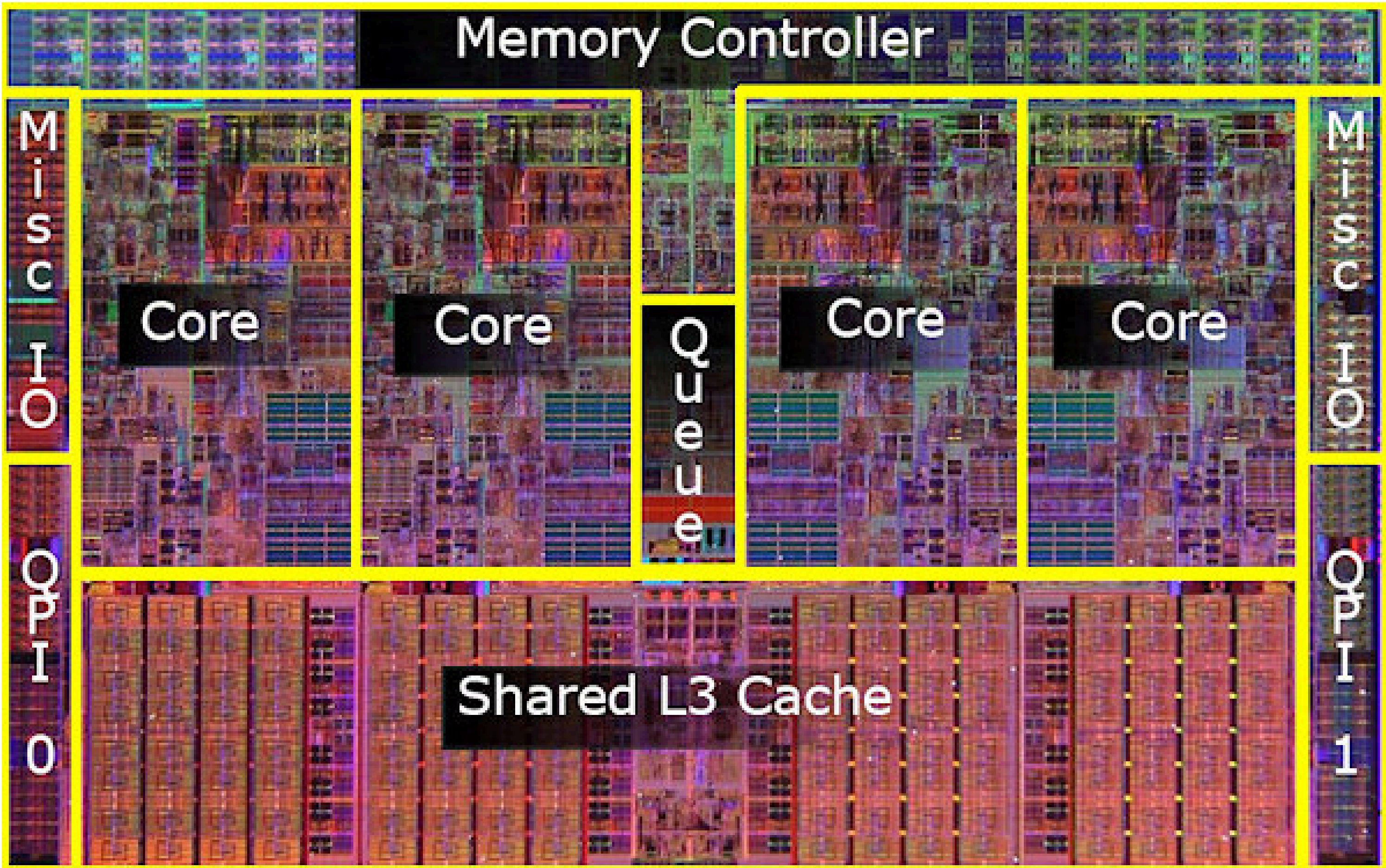
Nvidia Hopper Architecture (18K FP32 cores)

H100
Hopper (or Ada Lovelace), 2022



Recent CPU Chips (Intel's Core i7 processors) around 2020



Intel Core i9-13900K (USD 650 == 800 Korean won)

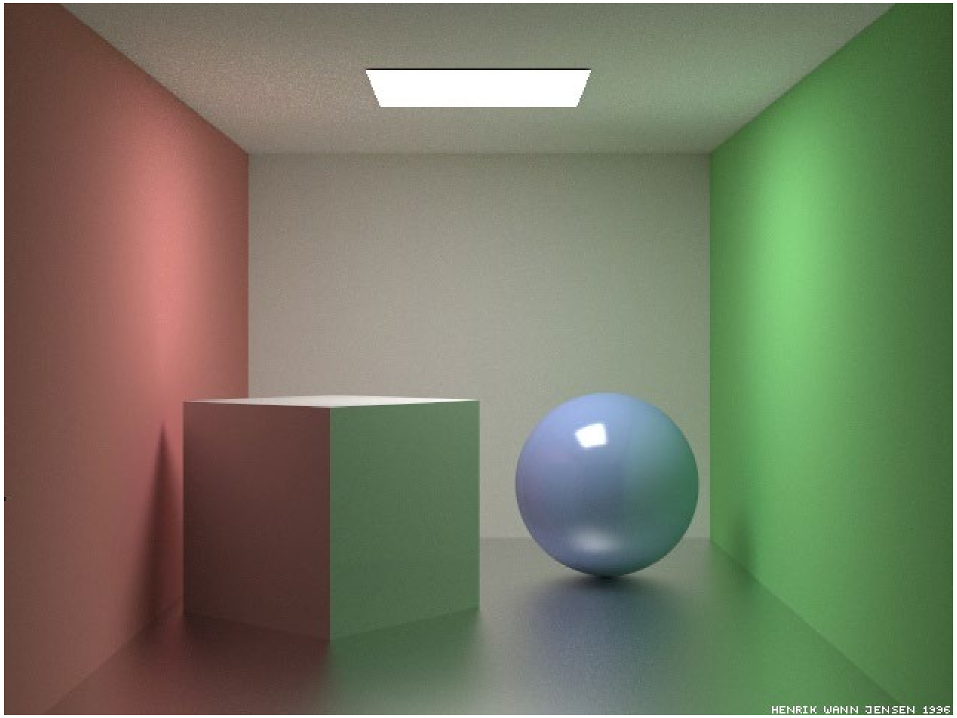
Where Rasterization Is

From Battlefield: Bad Company, EA Digital Illusions CE AB

From Eric Haines

But what about other visual cues?

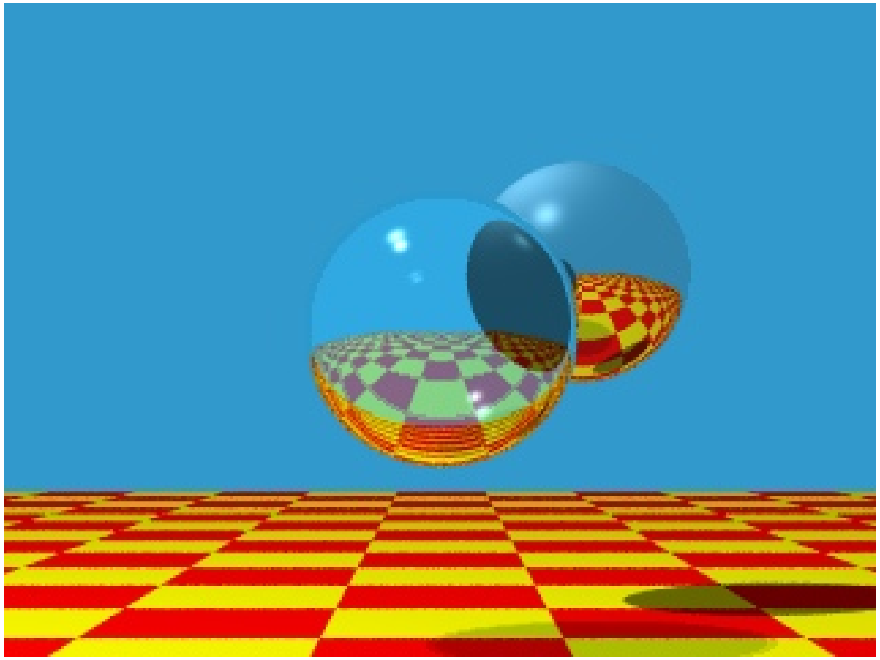
- Lighting
  - Shadows
  - Shading: glossy, transparency
- Color bleeding, etc



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**

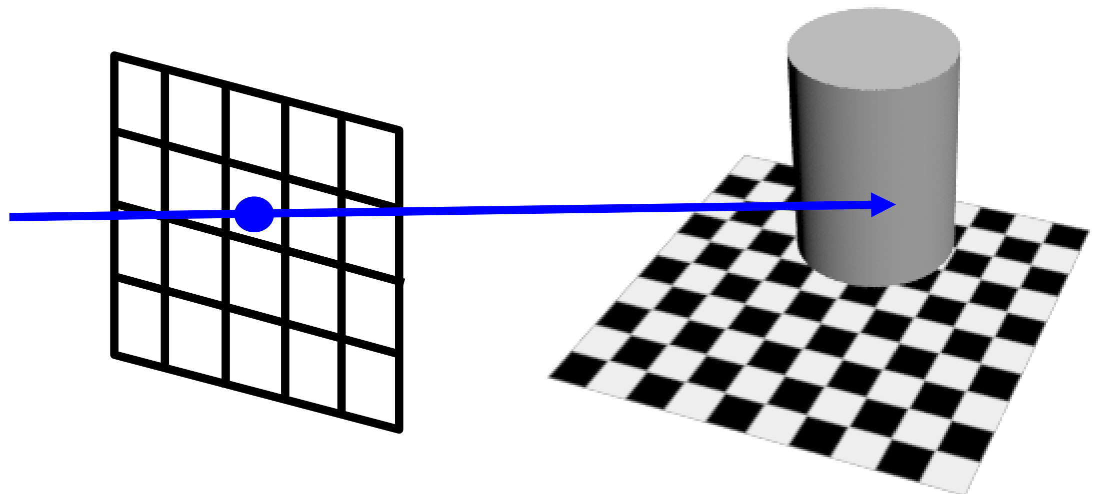


Ray Casting and Ray Tracing

- **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**

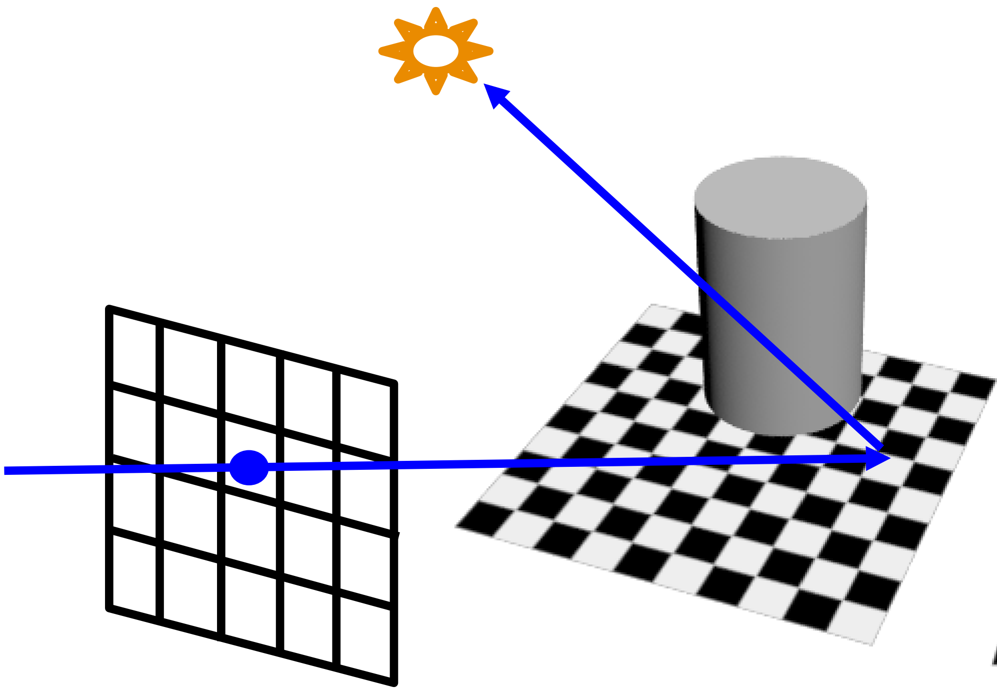
Basic Algorithms

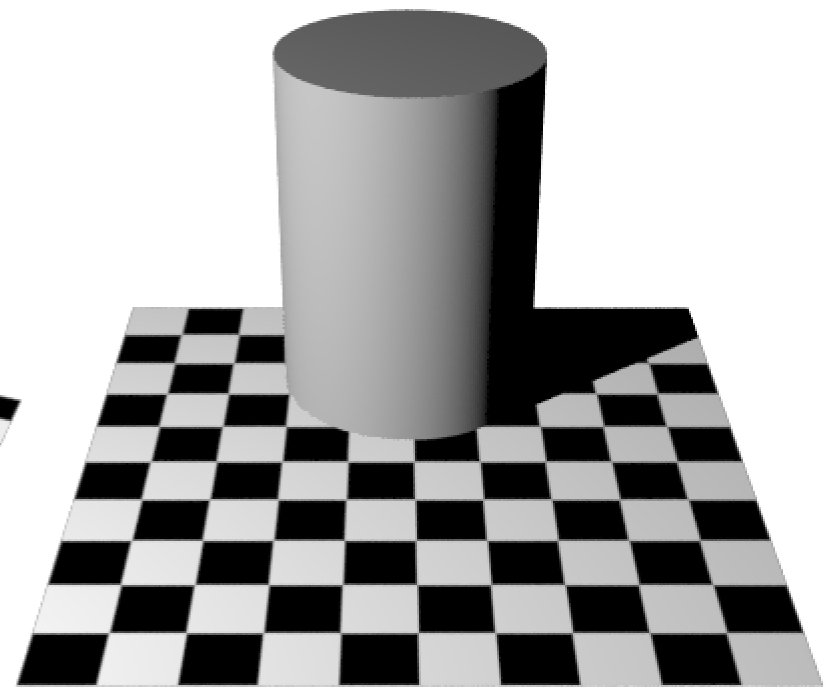
- **Rays are cast from the eye point through each pixel in the image**



Shadows

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

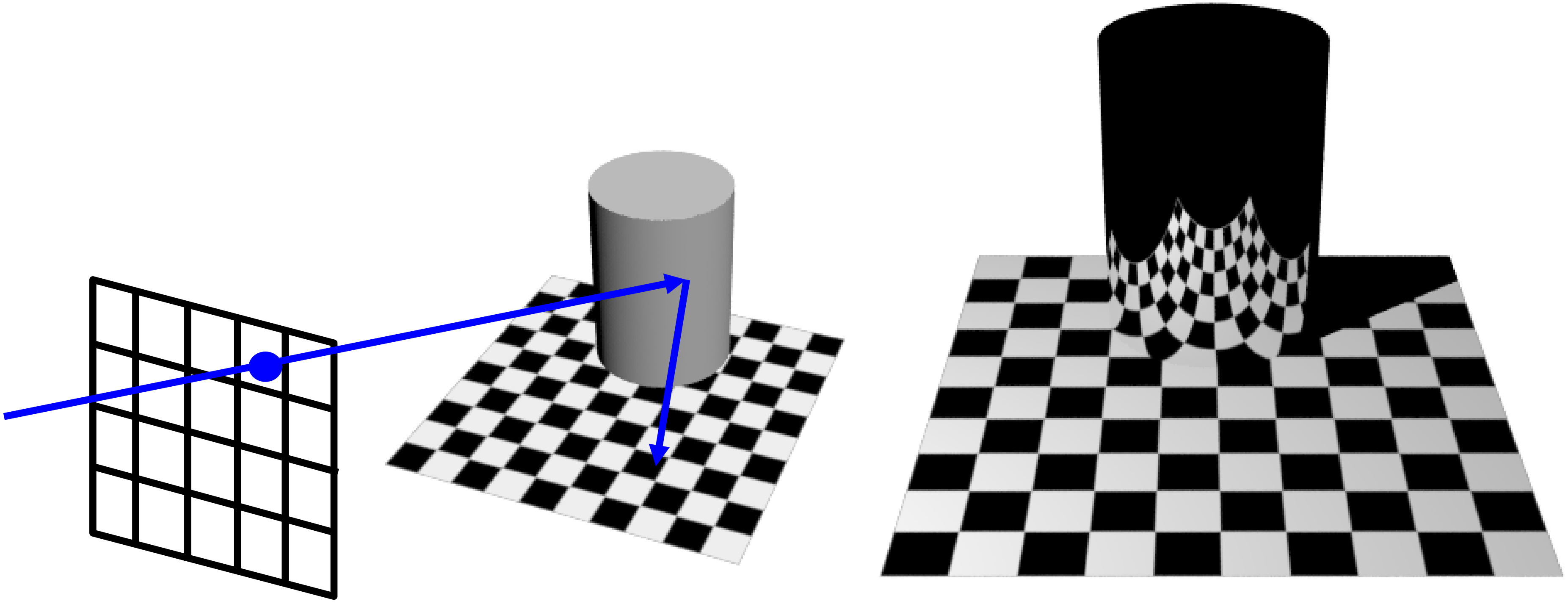




Used 3ds Max

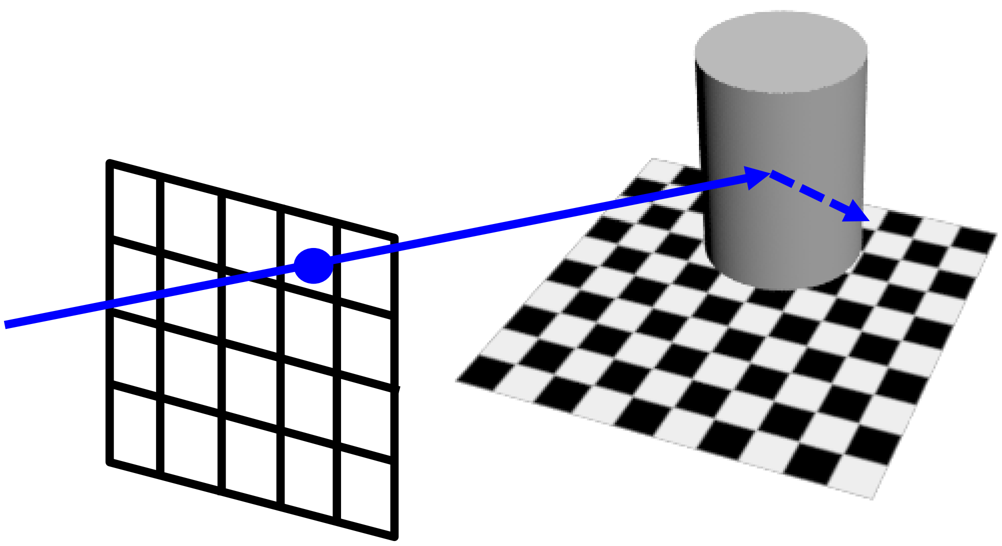
Reflections

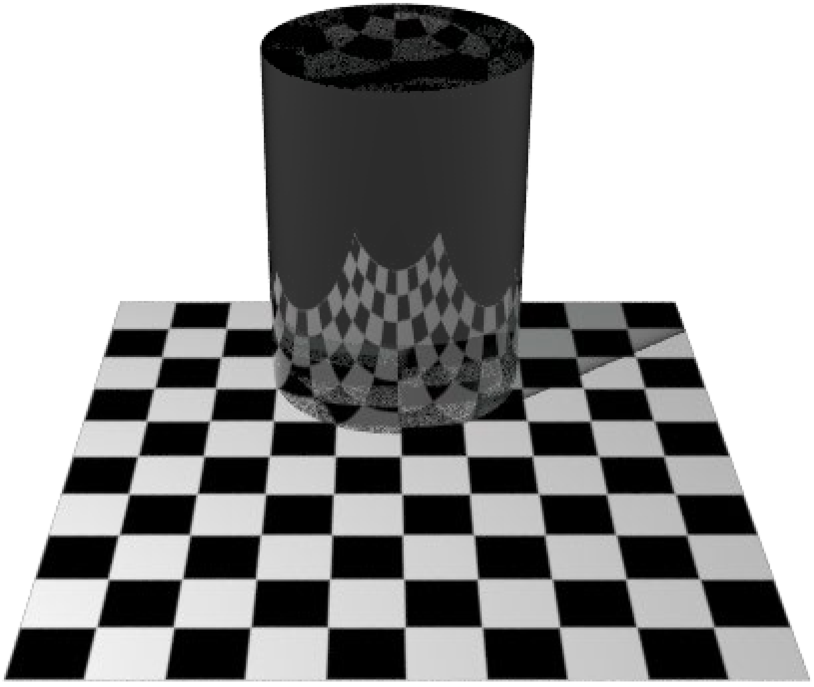
- **If object specular, cast secondary reflected rays**



Refractions

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





An Improved Illumination Model [Whitted 80]

- **Phong illumination model**

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

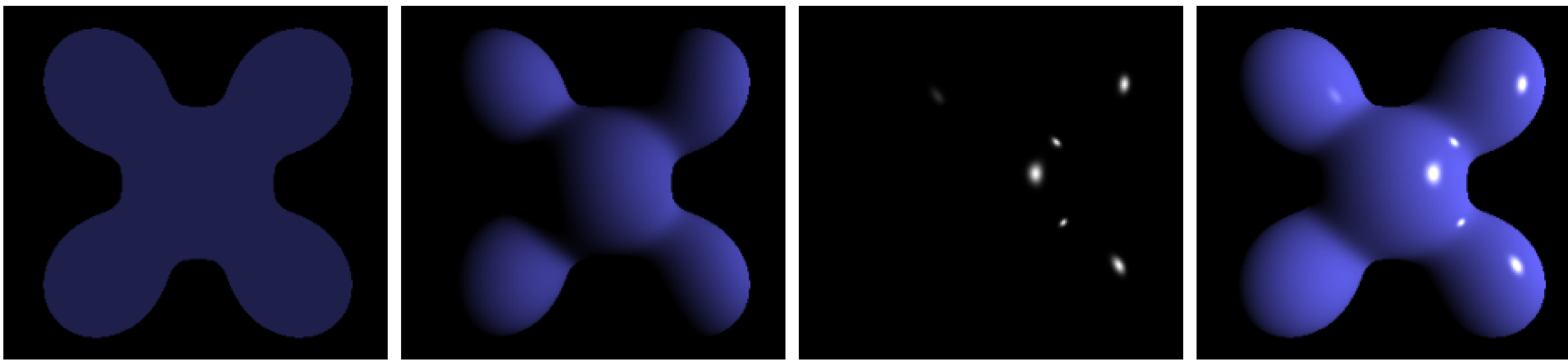
- **Whitted model**

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

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

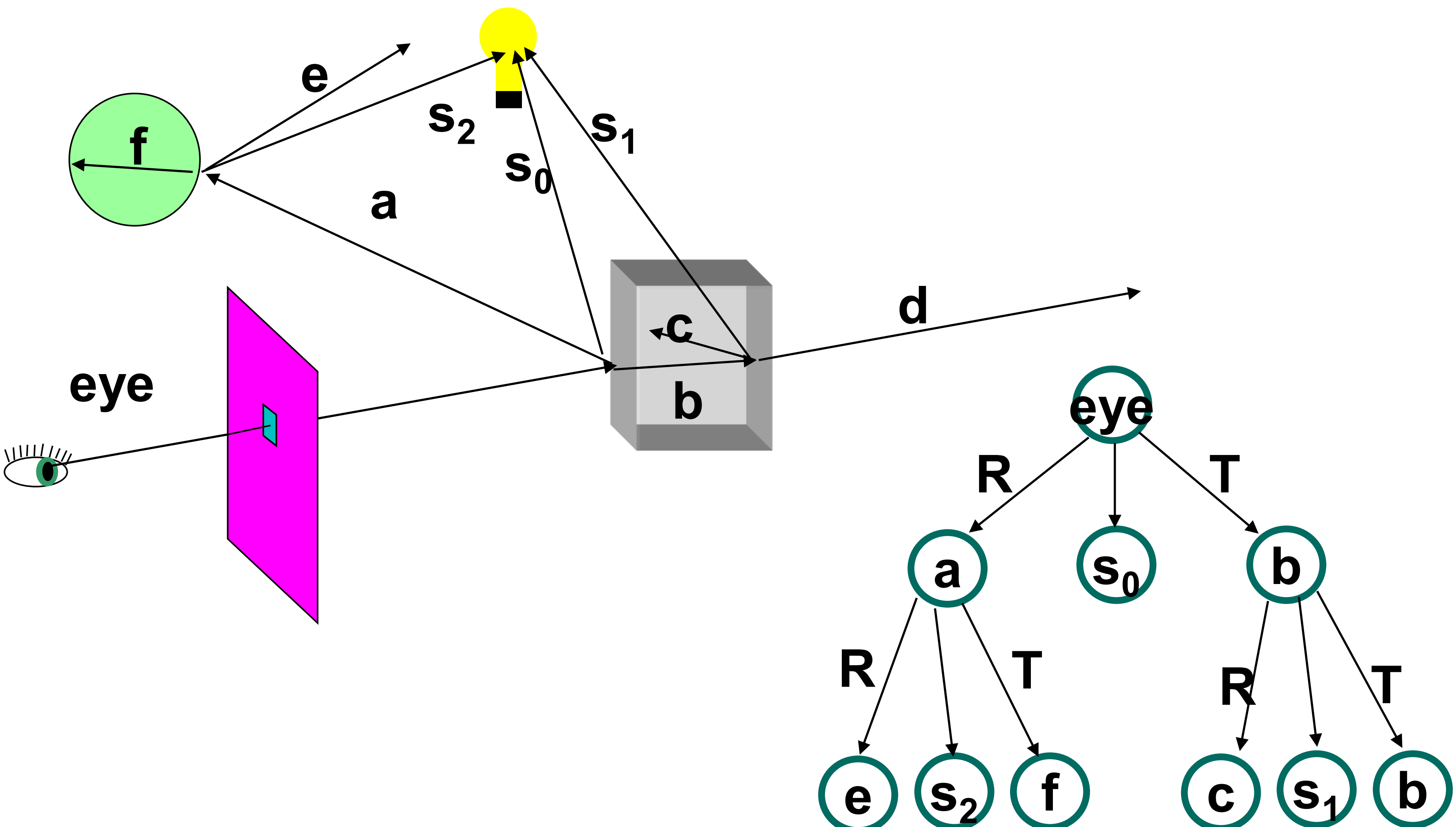
OpenGL's Illumination Model

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



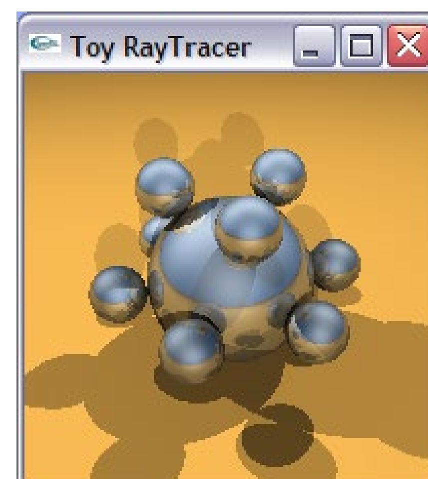
From Wikipedia

Ray Tree



Acceleration Methods for Ray Tracing

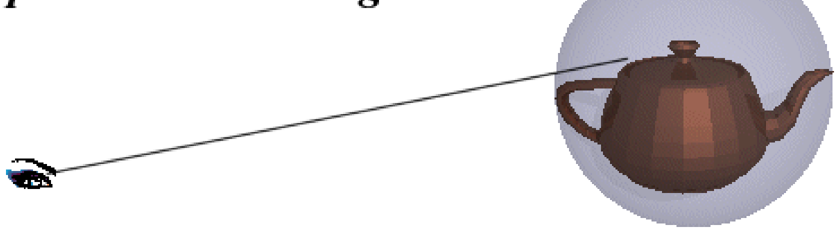
- Rendering time for a ray tracer depends on the number of ray intersection tests per pixel
  - The number of pixels X the number of primitives in the scene
- Early efforts focused on accelerating the ray-object intersection tests
  - Ray-triangle intersection tests
- More advanced methods required to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



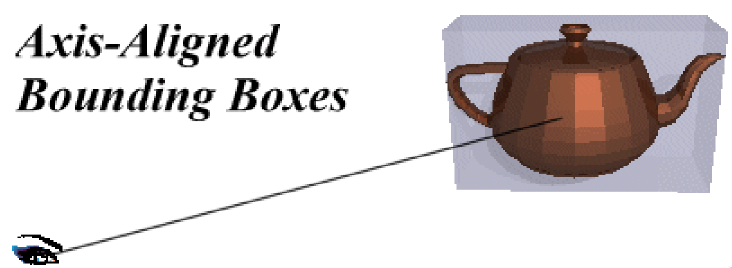
Bounding Volumes

- **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**

Spherical Bounding Volumes

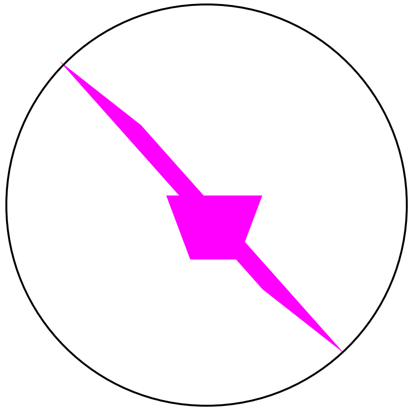


Axis-Aligned Bounding Boxes

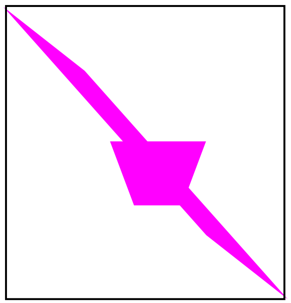


Bounding Volumes

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

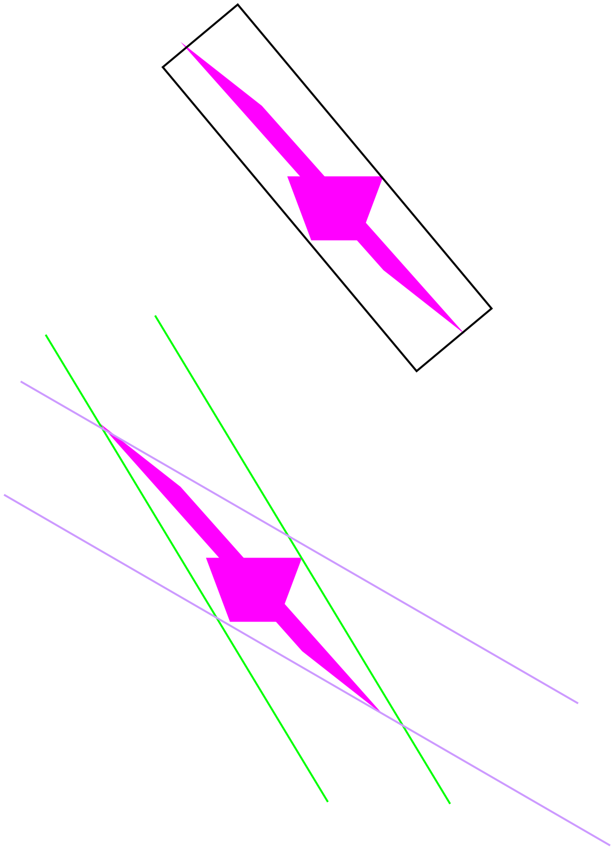


- Axis-Aligned Bounding Box
  - Very cheap to compute
  - Cheap test
  - Tighter than sphere



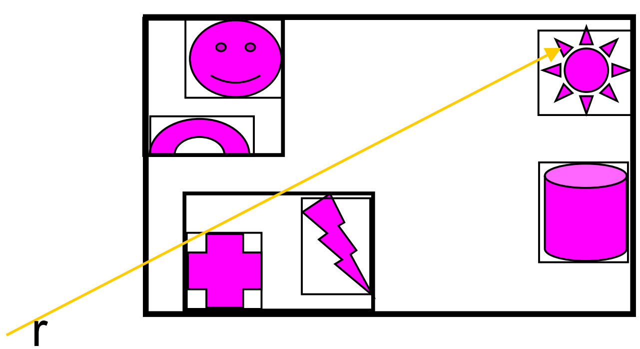
Bounding Volumes

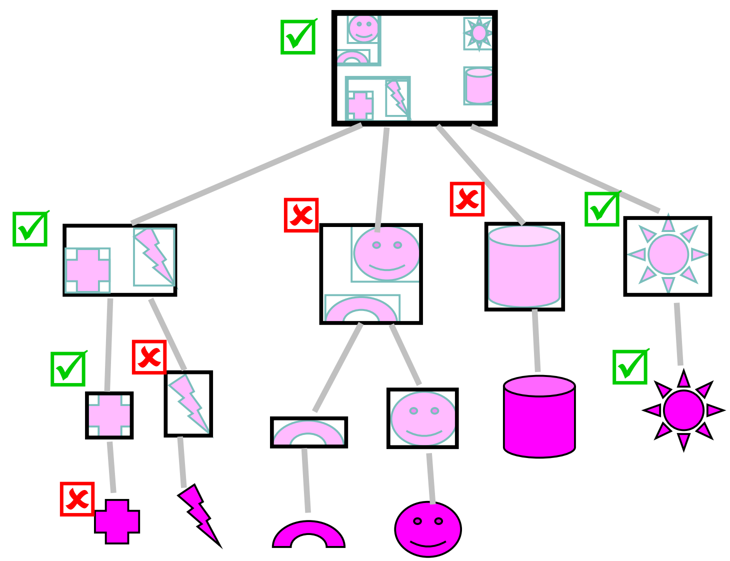
- **Oriented Bounding Box**
  - **Fairly cheap to compute**
  - **Fairly Cheap test**
  - **Generally fairly tight**
- **Slabs / K-dops**
  - **More expensive to compute**
  - **Fairly cheap test**
  - **Can be tighter than OBB**



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**





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

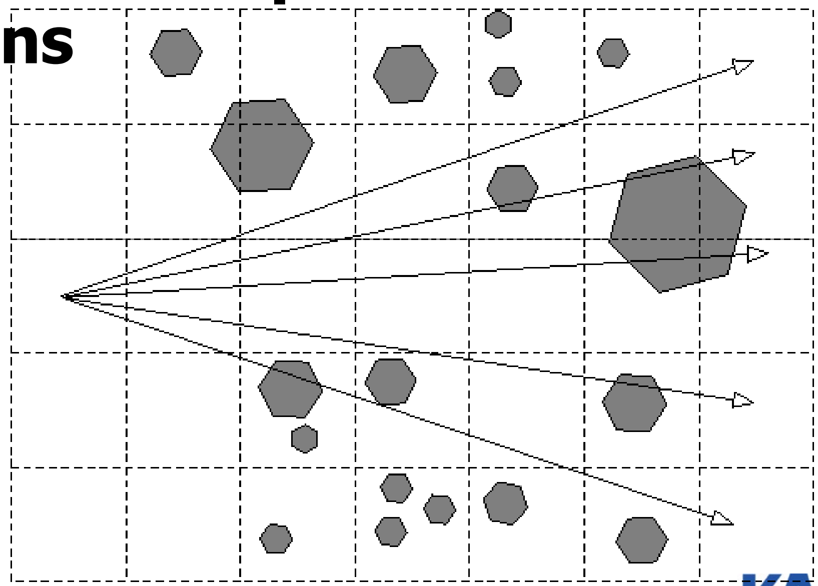

RT-DEFORM: Interactive Ray Tracing of Dynamic Scenes using BVHs

Christian Lauterbach[*] University of North Carolina at Chapel Hill
Sung-Eui Yoon[†] Lawrence Livermore National Laboratory
David Tuft[‡] University of North Carolina at Chapel Hill
Dinesh Manocha[§] University of North Carolina at Chapel Hill

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



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

History

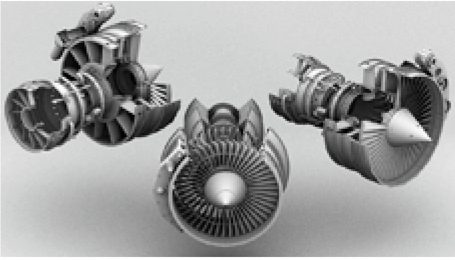
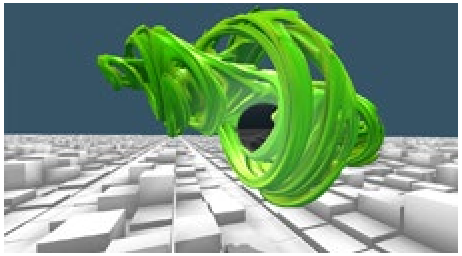
- **Problems with classic ray tracing**
  - **Not realistic**
  - **View-dependent**

- **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

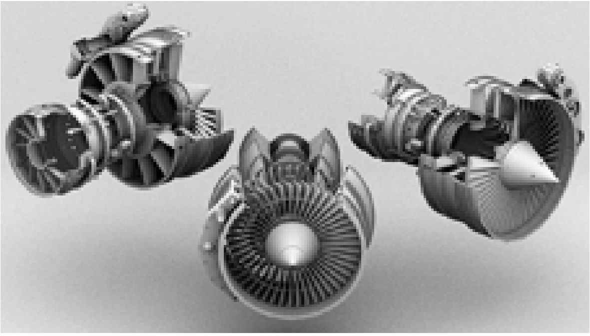




- Embree, Intel
  - Utilize CPUs (multi-threaded and SIMD)



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
  - Check the KLMS
- 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 before every Mon. class**
    - **Just one paragraph for each summary**

Example:

Title: XXX XXXX XXXX

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 typical questions**
  - **2 for questions that have some thoughts or surprise me**

- **Write a question more than 4 times on Sep./Oct.**
  - **Online submission is available at the course webpage**

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Class Objectives were:

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

Next Time

- **Radiosity**