Culling Techniques

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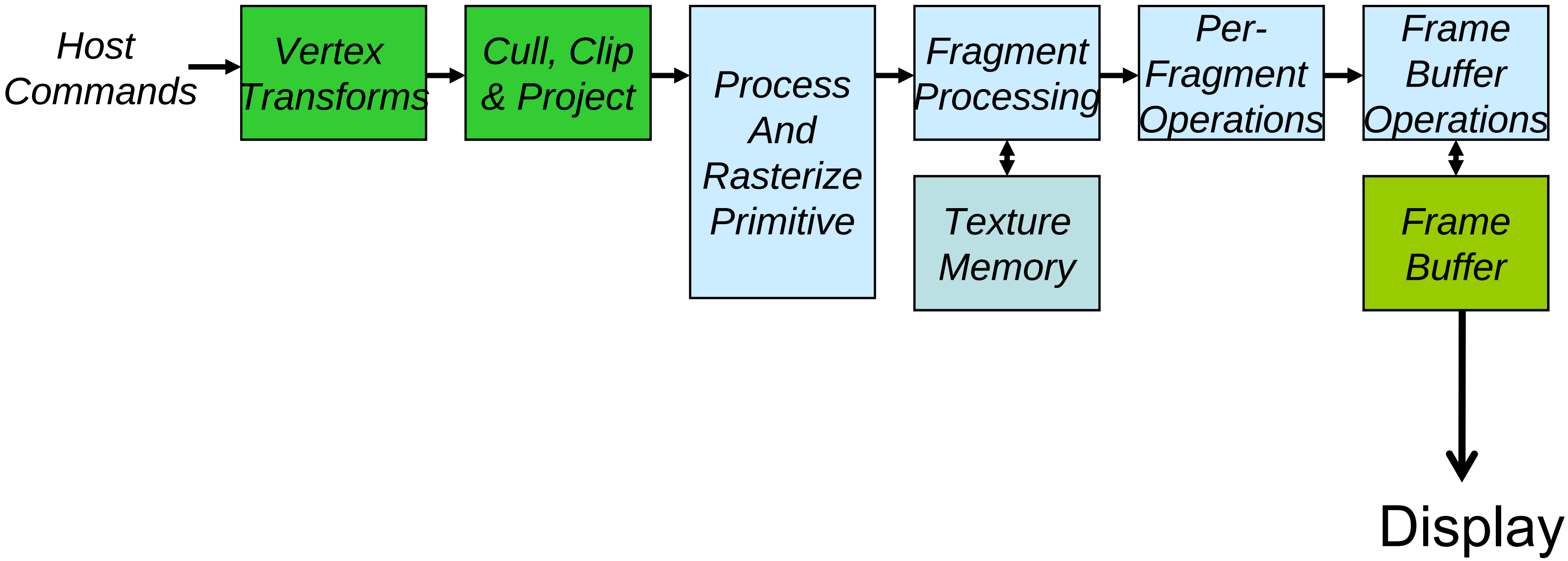
Course URL:
http://jupiter.kaist.ac.kr/~sungeui/SGA/

At the Previous Class

- The overview of the course
  - Two main rendering techniques: rasterization and ray tracing
  - Their issues with different configurations

Rasterization: Rendering Pipeline



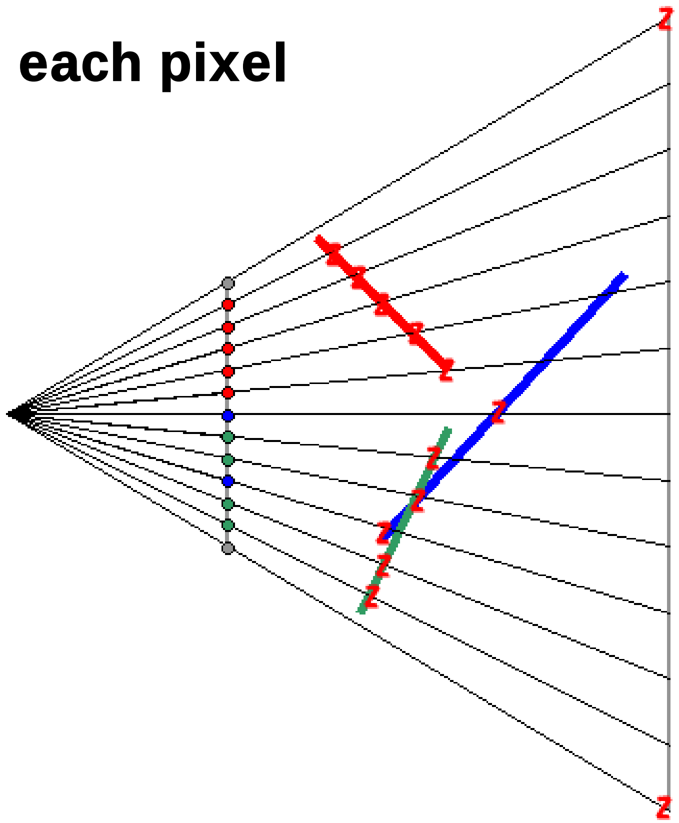
Depth Buffer

Algorithm:

Maintain current closest surface at each pixel

Rendering Loop:

set depth of all pixels to Z_{MAX}
foreach primitive in scene
    foreach pixel in primitive
        compute z_{prim} at pixel
        if ($z_{prim} < depth_{pixel}$) then
            pixel = object color
            $depth_{pixel} = z_{prim}$
        endif
    endfor
endfor



Depth Buffer: Advantage

- Simple
- Can process one primitive at a time in any order
- Can easily composite one image/depth with another image/depth
  - Useful for parallel rendering especially for sort-last based method
- Spatial coherence
  - Incremental evaluation in loops
  - Good memory coherence

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Depth Buffer: Disadvantage

- Transparency is hard to handle
  - Has to be done in strict back-to-front order
- Lots of overdraw
- Read / Modify / Write is hard to make fast
- Requires a lot of storage
- Quantization artifacts

Limitations of Rasterization

- The performance ~ linear to # of triangles
- Massive models with high-depth or low-depth complexity
  - Require output sensitive rendering methods
  - Culling techniques for high-depth complexity
  - Multi-resolution techniques for low-depth complexity

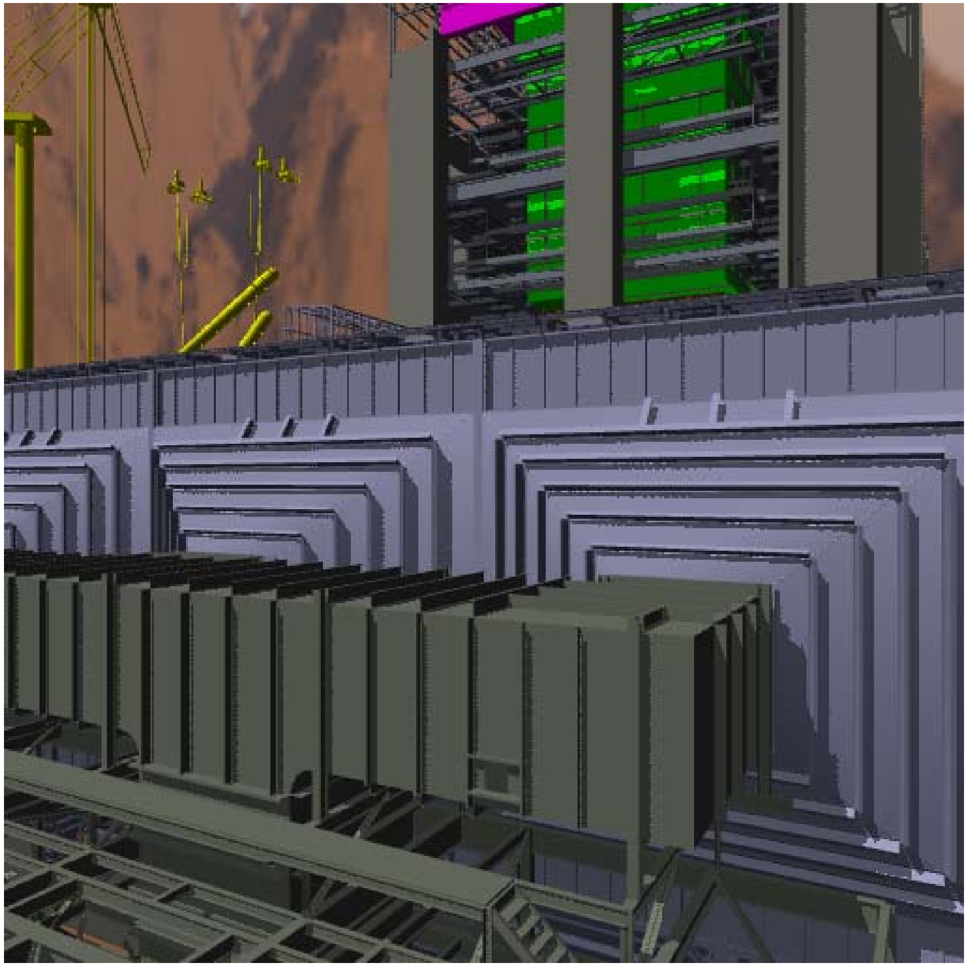
What are Culling and Clipping?

- Culling
  - Throws away entire objects and primitives that cannot possibly be visible
- Clipping
  - “Clips off” the visible portion of a primitive
  - Simplifies rasterization
  - Used to create “cut-away” views of a model

Visibility Culling Methods

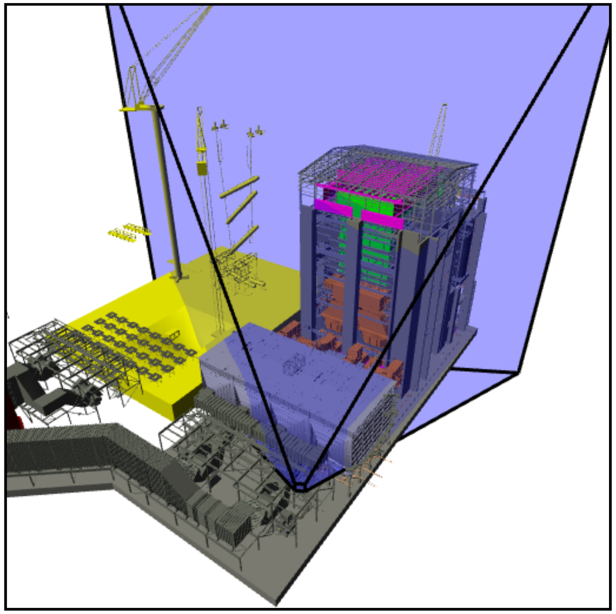
- Back-face culling
- View frustum culling
- Occlusion culling
- Hierarchical culling

Culling Example

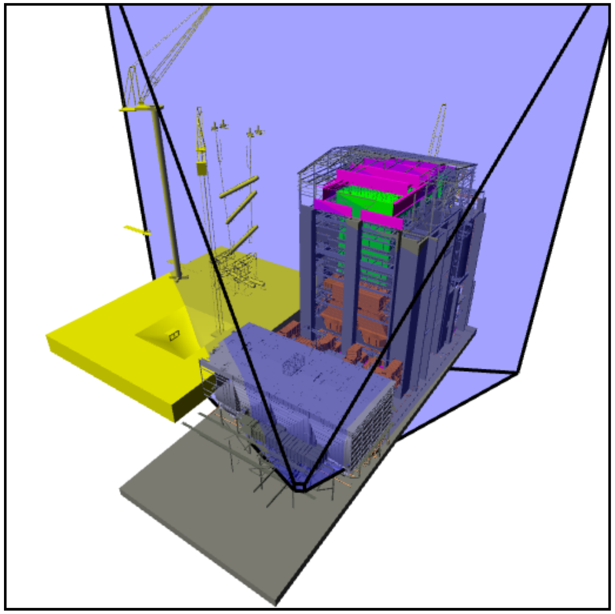


- Power plant model
  - 13 M triangles
  - 1.7 M triangles - gutted version show here with no internal pipes

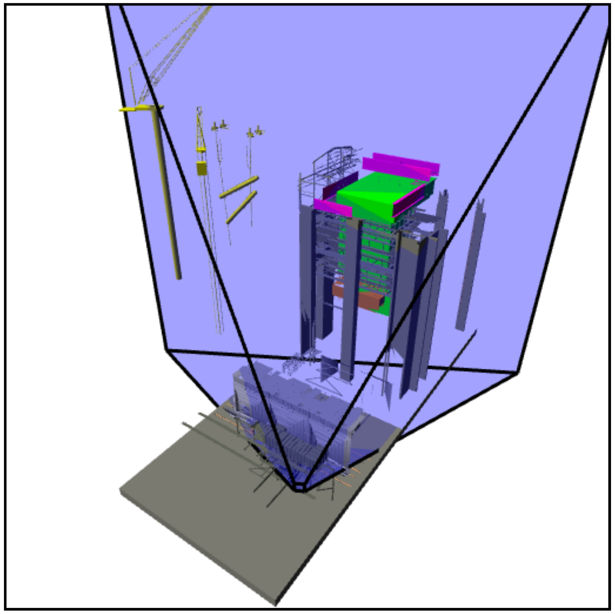
Culling Example



Full model
1.7 Mtris



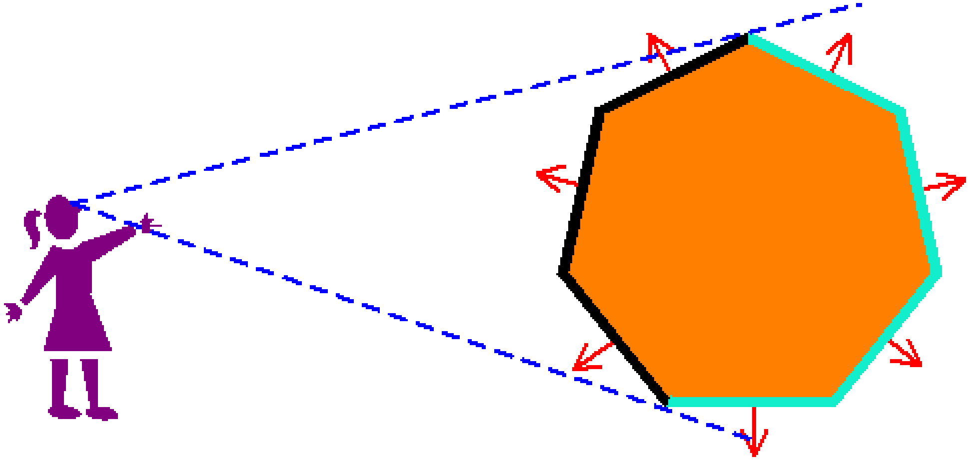
View frustum culling
1.4 Mtris



Occulsion culling
89 Ktris

Back-Face Culling

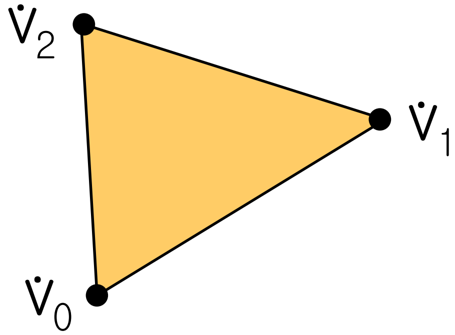
- Special case of occlusion - **convex self-occlusion**
  - for closed objects (has well-defined inside and outside) some parts of the surface must be blocked by other parts of the surface
- Specifically, the backside of the object is not visible



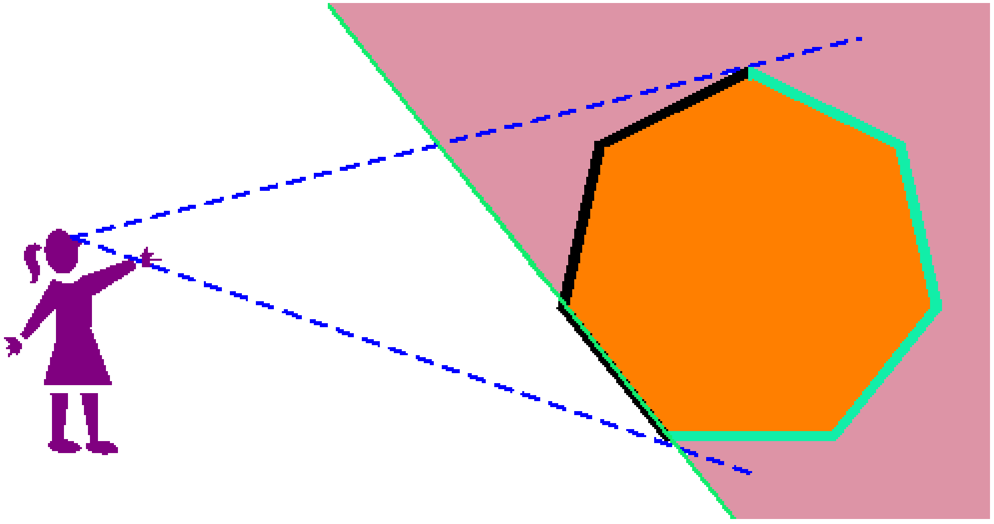
Face Plane Test

- **Compute the plane for the face:**

$$\vec{n} = (\dot{v}_1 - \dot{v}_0) \times (\dot{v}_2 - \dot{v}_0)$$
$$d = \vec{n} \cdot \dot{v}_0$$



- **Cull if eye point in the negative half-space**

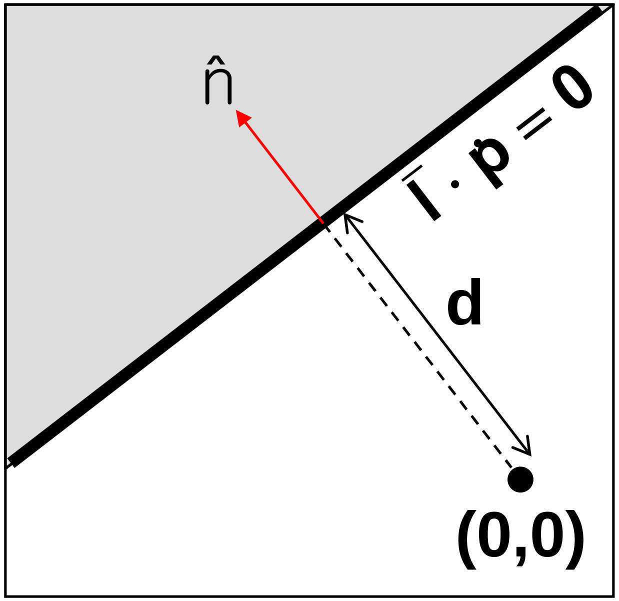


Lines and Planes

- **Implicit equation for line (plane):**

$$n_x x + n_y y - d = 0$$

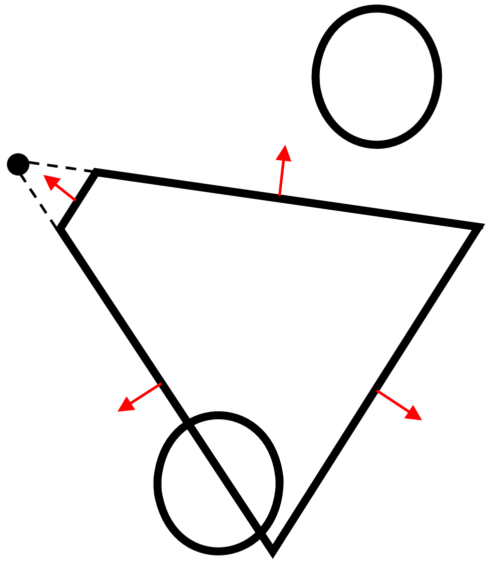
$$\begin{bmatrix} n_x & n_y & -d \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = 0 \Rightarrow \mathrm{T} \cdot p = 0$$



- **If** n **is normalized then d gives the distance of the line (plane) from the origin along** n

View Frustum Culling

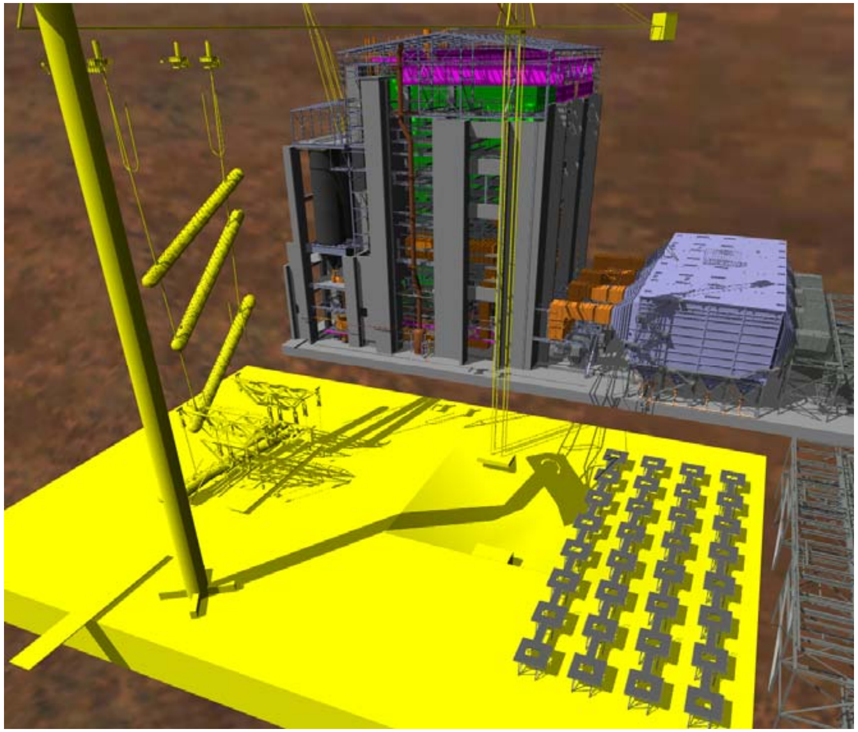
- Test objects against planes defining view frustum



- Uses BVs of objects to improve the performance of view-frustum culling

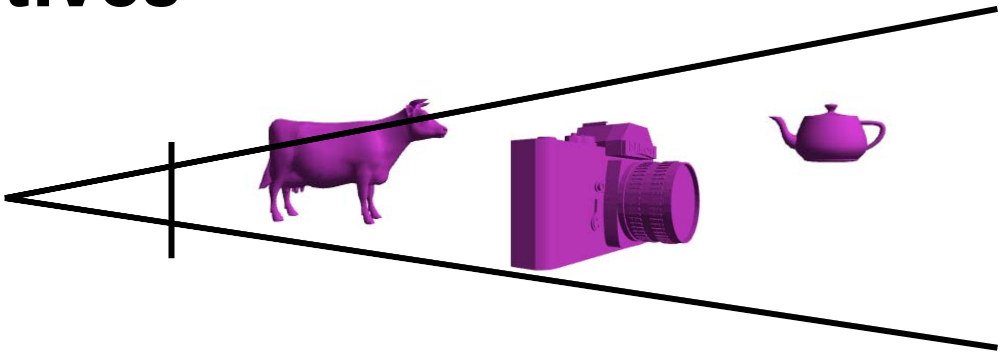
Depth Complexity

- **Number of triangles per each pixel**
  - **Likely to grow as the model complexity increases**



Occlusion Culling

- Detects visibility of primitives
- If invisible, do not need to process such primitives



- What are ingredients for the success of the method?
  - Fast visibility checking
  - Conservative primitive enclosing with BVs, etc.

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Occlusion Query

- An occlusion query asynchronously returns the number of fragments that pass z-test
- Typical use: In multi-pass rendering, skip subsequent passes if the first one rendered too few pixels
- Usage:
  - Create the query
  - Issue a begin event to start counting
  - Draw something
  - Issue an end event to stop counting
  - Get the result

Excerpted from NVIDIA slides

Occlusion Query: OpenGL

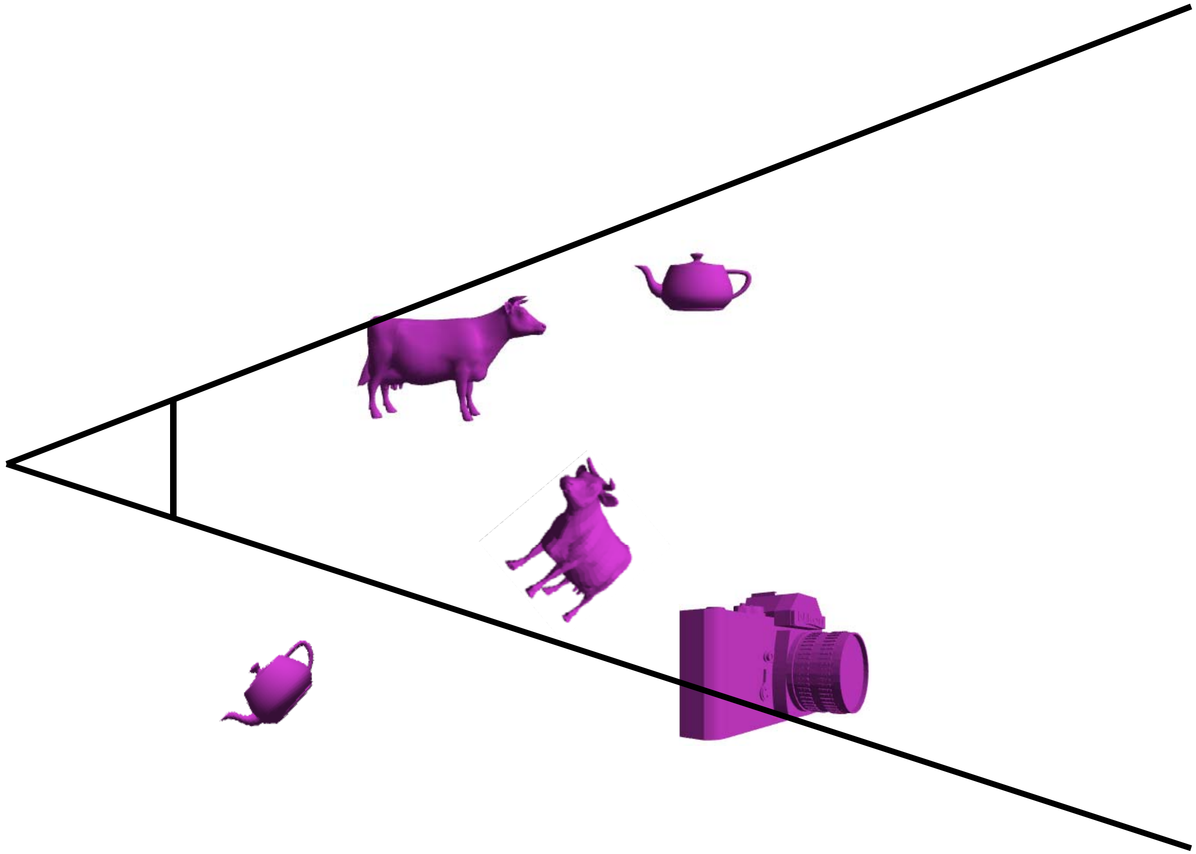
- **Extension: GL_ARB_occlusion_query**

```
// Generate ID
GLuint queryID;
glGenQueriesARB(1, &queryID);
...

// Count
glBeginQueryARB(GL_SAMPLES_PASSED_ARB, queryID);
Draw(...);
glEndQueryARB(GL_SAMPLES_PASSED_ARB);
...

// Get result
int fragmentsDrawn;
glGetQueryObjectuivARB(queryID, GL_QUERY_RESULT_ARB, &fragmentsDrawn);
```


Excerpted from NVIDIA slides

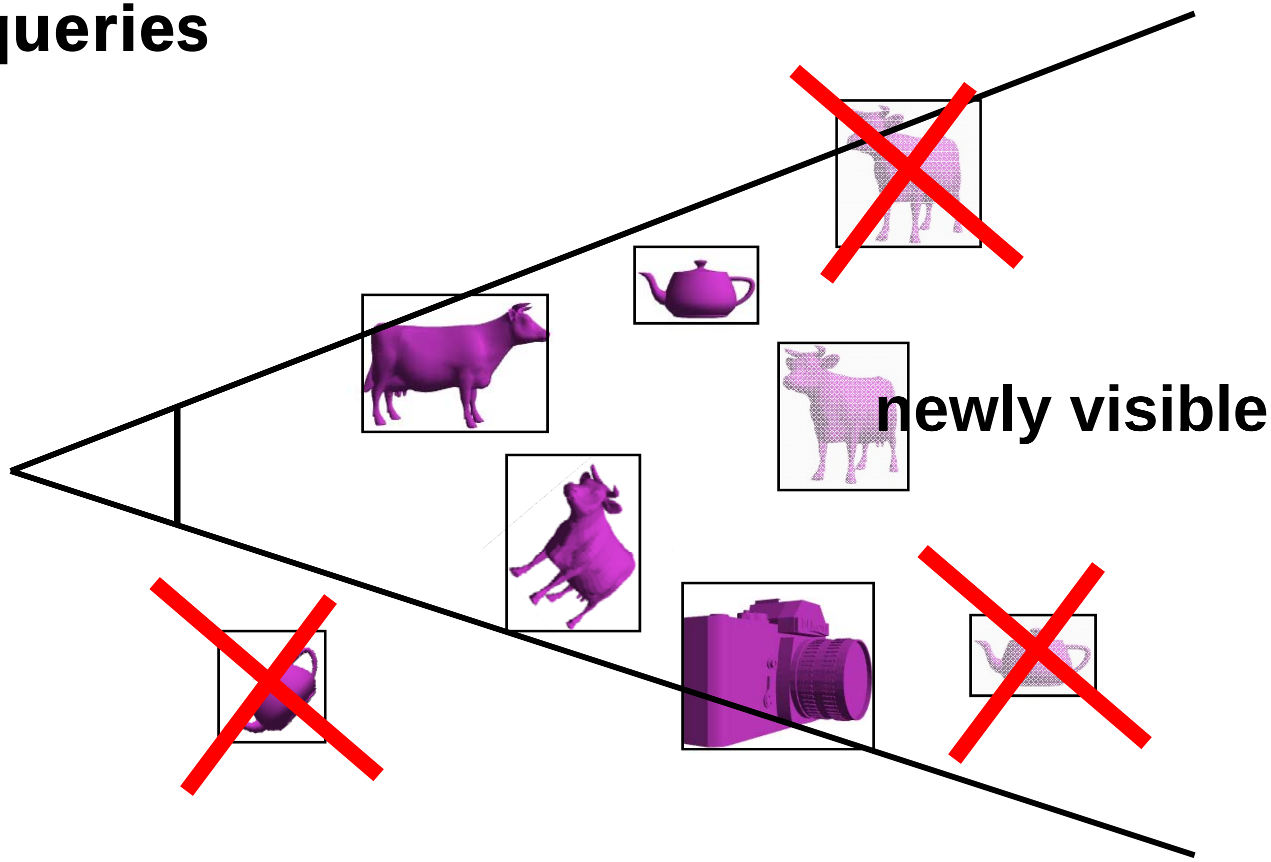
Occlusion Culling with Occlusion Queries

- Render objects visible in previous frame (occlusion representation)



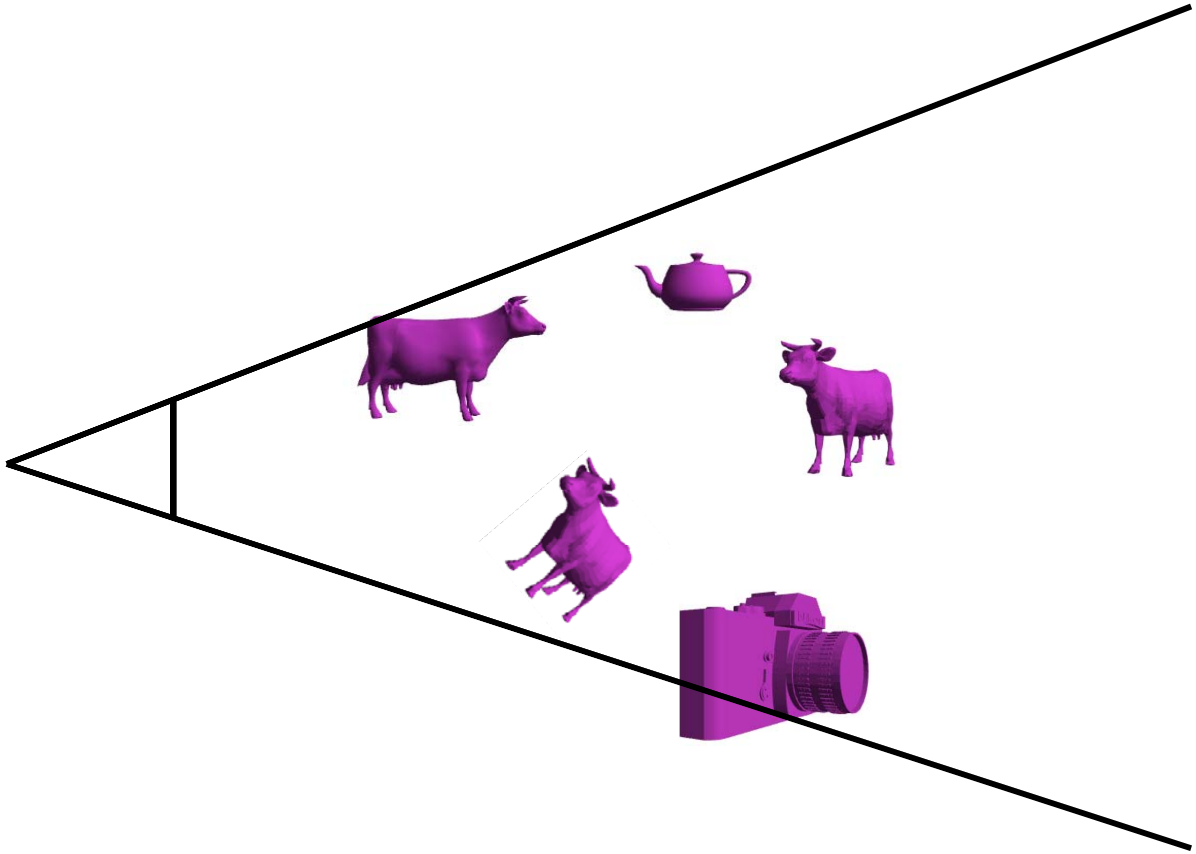
Occlusion Culling with Occlusion Queries

- Turn off color and depth writes
- Render object bounding boxes with occlusion queries



Occlusion Culling with Occlusion Queries

- Re-enable color writes
- Render newly visible objects



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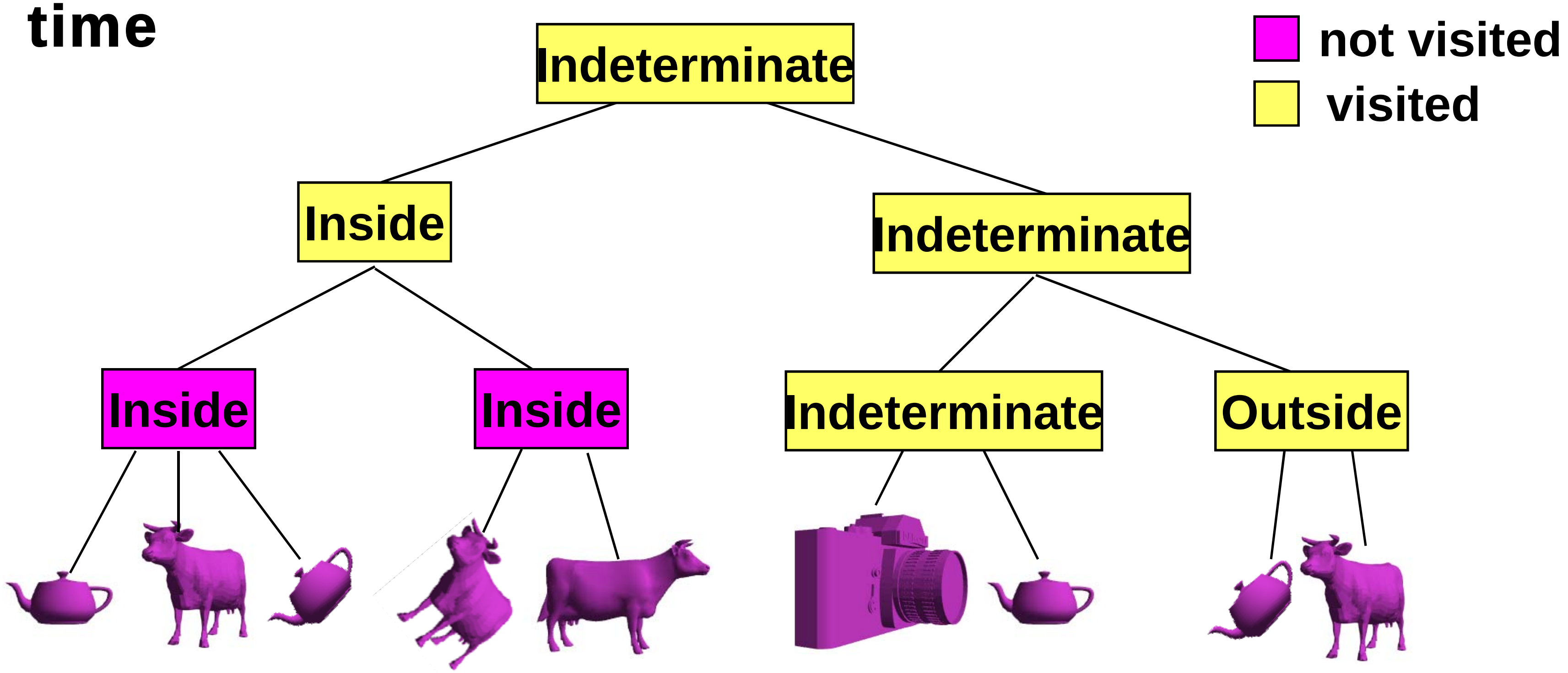
Assumptions & Limitations

- Assume temporal coherence
  - How about the initial frame?

- Can we take advantage of spatial coherence between objects?

Hierarchical Culling

- Culling needs to be cheap!
- Bounding volume hierarchies accelerate culling by trivially rejecting/accepting entire sub-trees at a time



Example of hierarchical view-frustum culling

Visibility Computations

- Fundamental question:
  - Between which parts of a scene does there exist an unobstructed path?
- Types of visibility computations
  - Hidden surface removal
  - Visibility culling
- Some other related applications
  - Line-of-sight
  - Sound propagation
  - Path planning and robotics

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Classes of Visibility Algorithms

- **Point vs. Region visibility**
  - **Compute parts of the scene visible at a point or any point in a region**

- **Object vs. Image precision**
  - **Compute parts of an object (or which pixel) that are visible**
  - **Operates directly on or discretized representation of the geometry**

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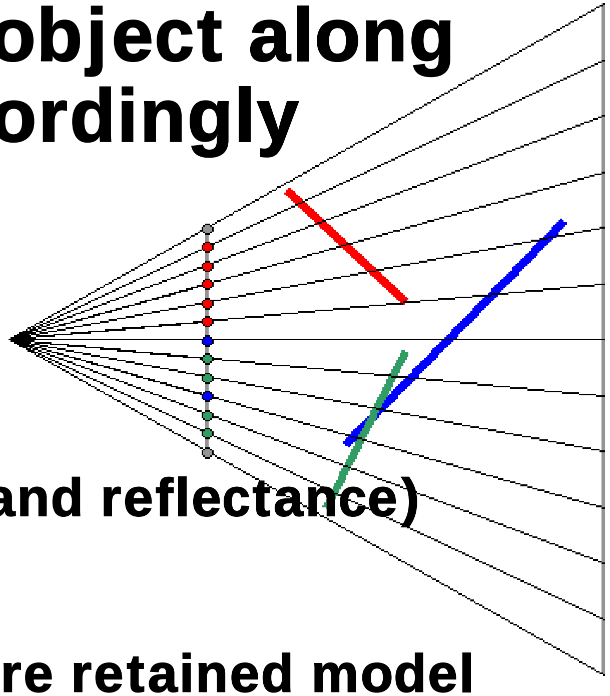
Ray Tracing: Visibility Issue



- For each pixel, find closest object along the ray and shade pixel accordingly
- Advantages
  - Conceptually simple
  - Can support CSG
  - Can be extended to handle global illumination effects (ex: shadows and reflectance)
- Disadvantages
  - Renderer must have access to entire retained model
  - Hard to map to special-purpose hardware

Next Time..

- Study culling techniques
  - E.g., Multi-resolution methods