Fundamentals of Computer Graphics and Image Processing
Shadows (07)

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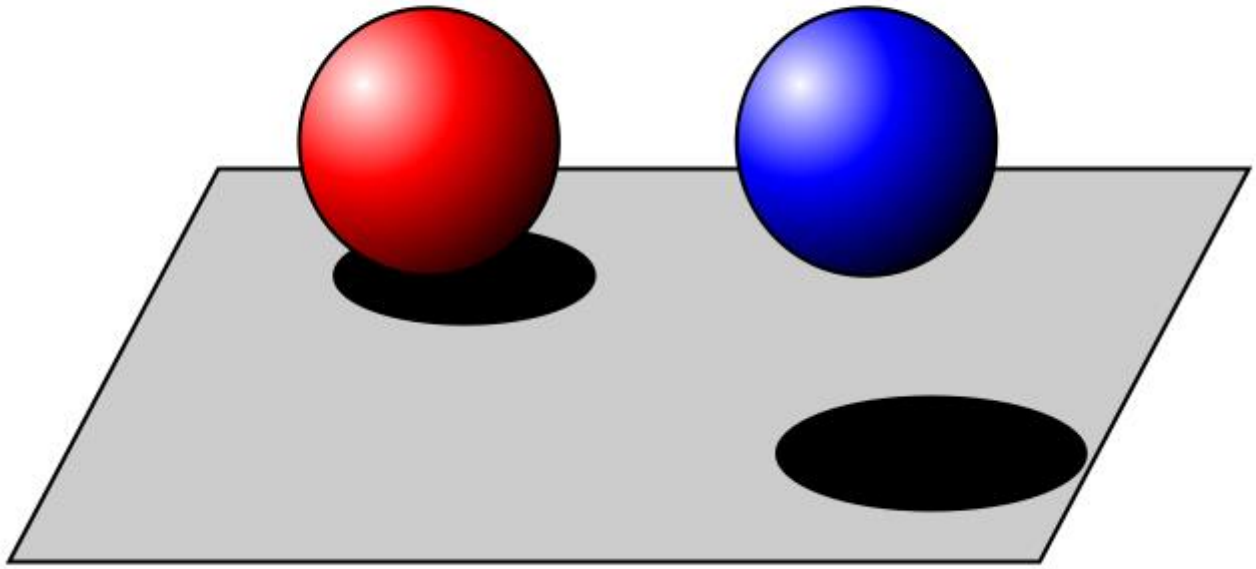
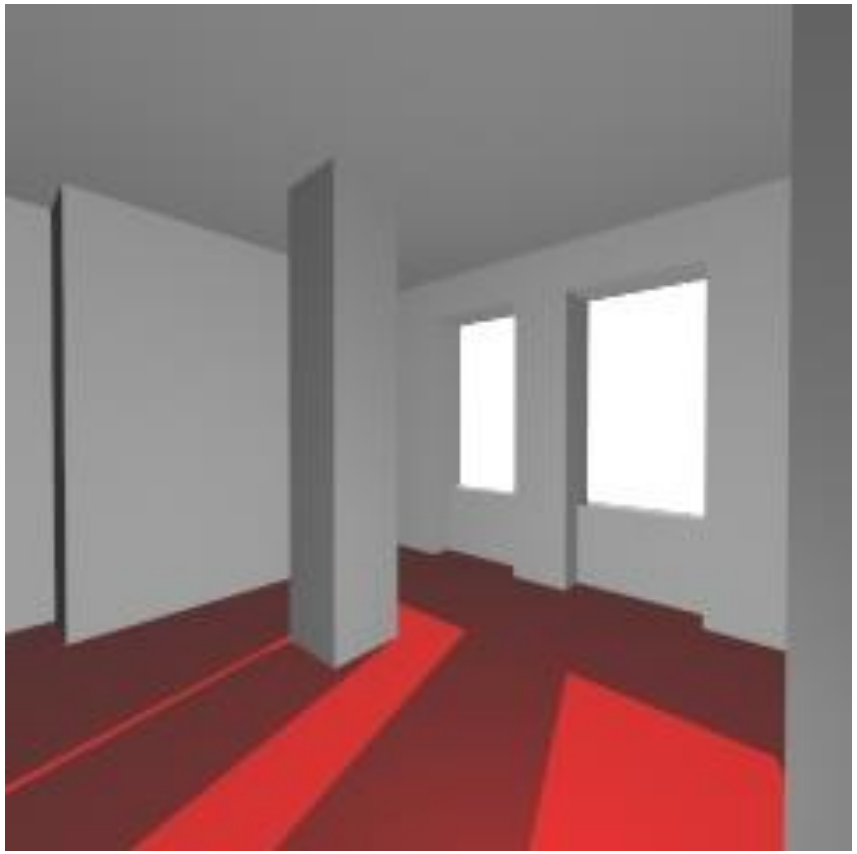
Why shadows?



Shadows in global methods

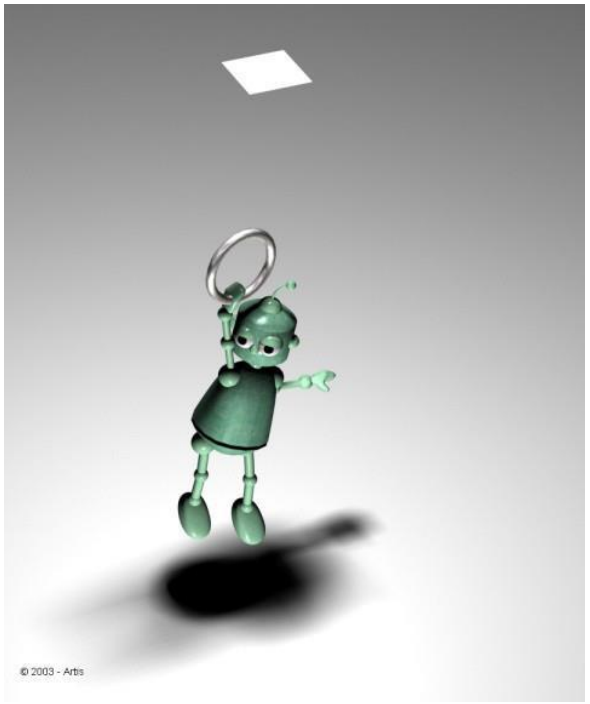
ray-tracing



radiosity

Lights and shadows

- Two basic approaches
  - Hard shadows – only point light sources
  - Soft shadows – area light sources

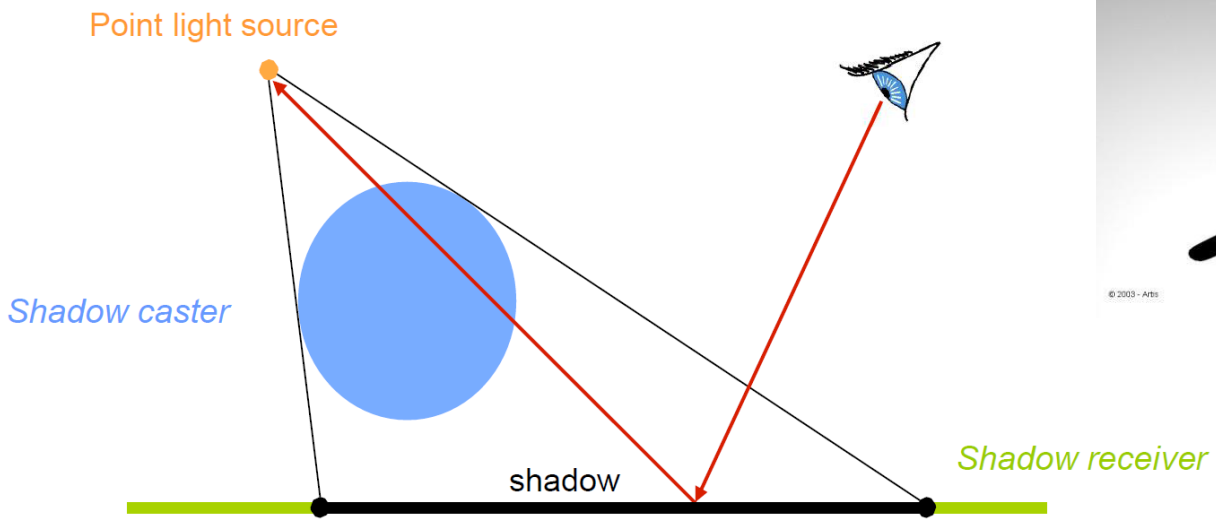


How the lectures should look like #1

- Ask questions, please!!!
- Be communicative
- More active you are, the better for you!

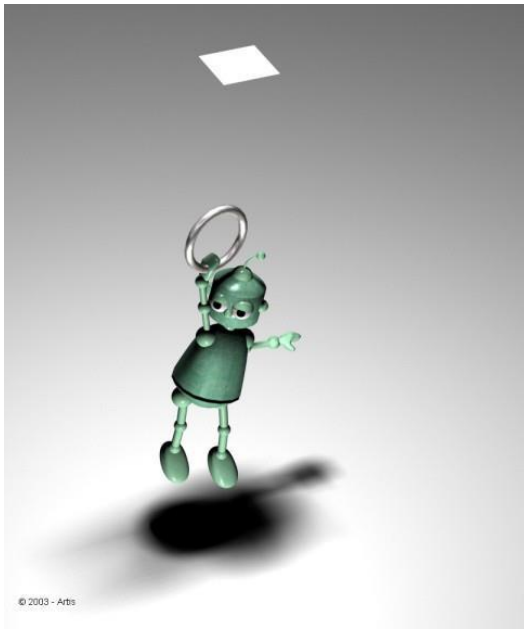
Hard shadow

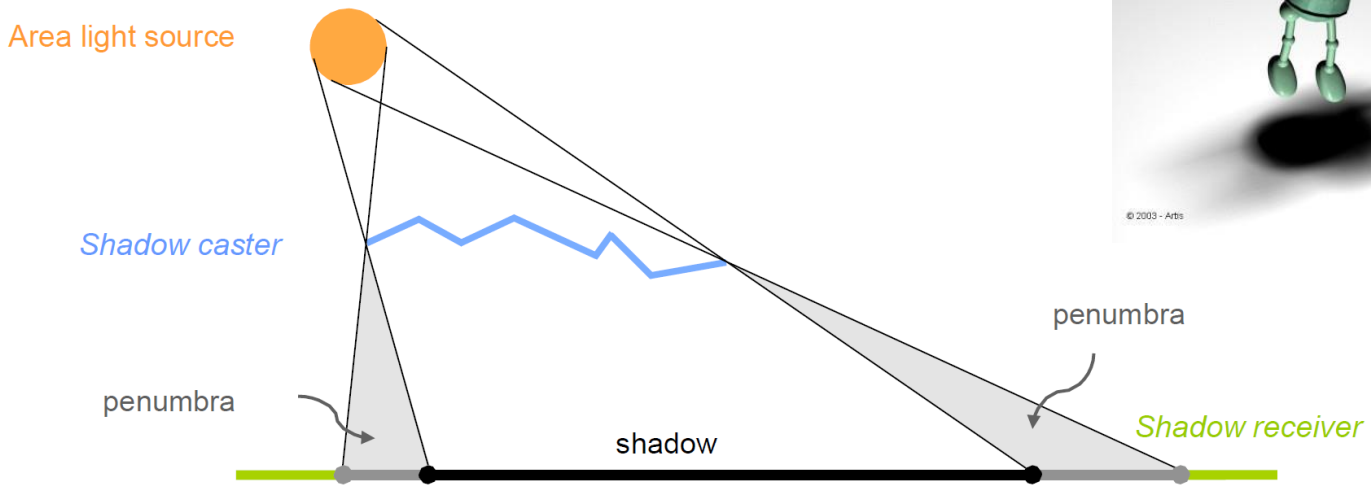
- Point light source
  - A point is in a shadow if it is not visible from the light source



Soft shadow

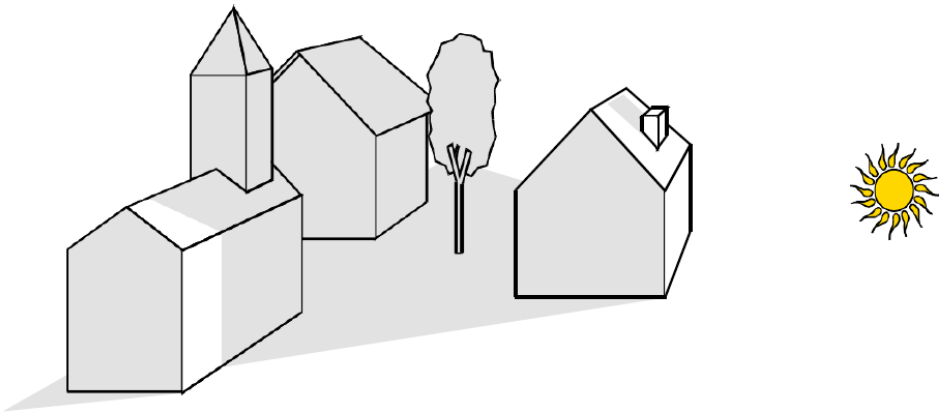
- Three types of surface:
  - **Shadow**: light source completely hidden
  - **Penumbra**: light source partially hidden
  - **Lit**: light source completely visible



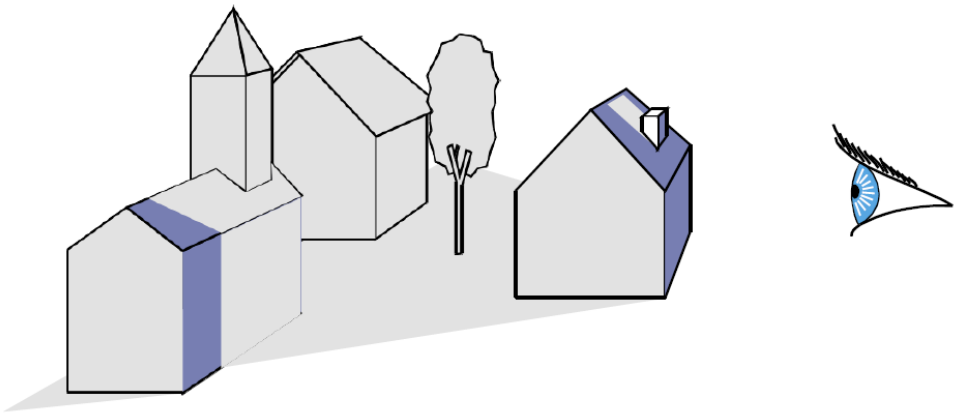


Shadows / visibility

A point is lit if it is visible from the light source



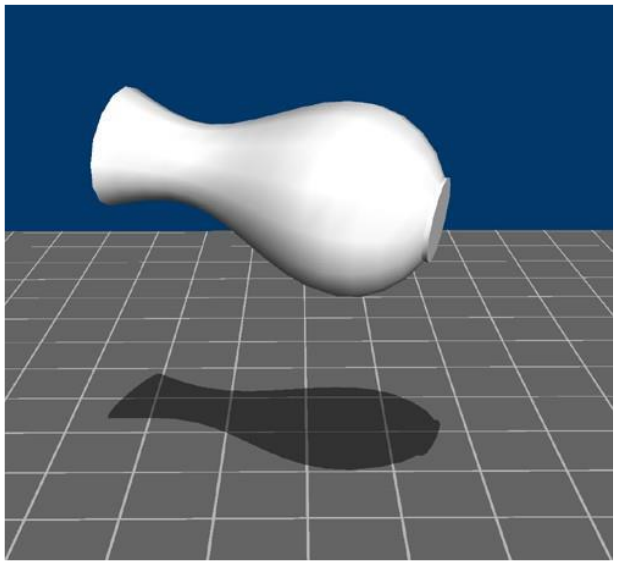
Computing shadows = visible surface determination

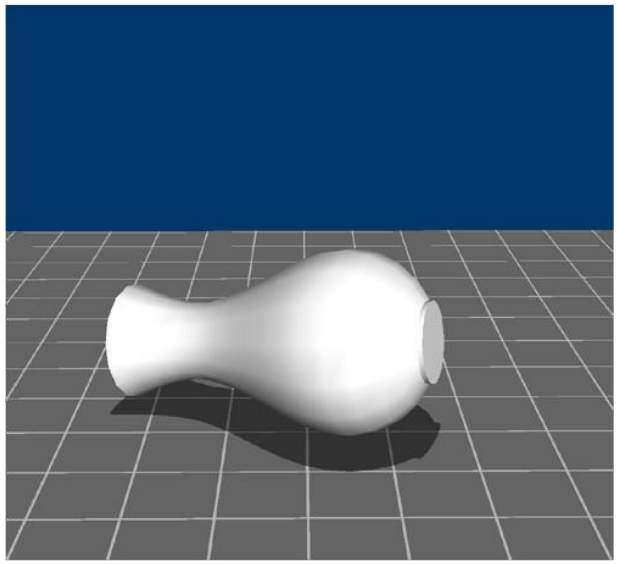


MIT EECS 6.837, Durand and Cutler

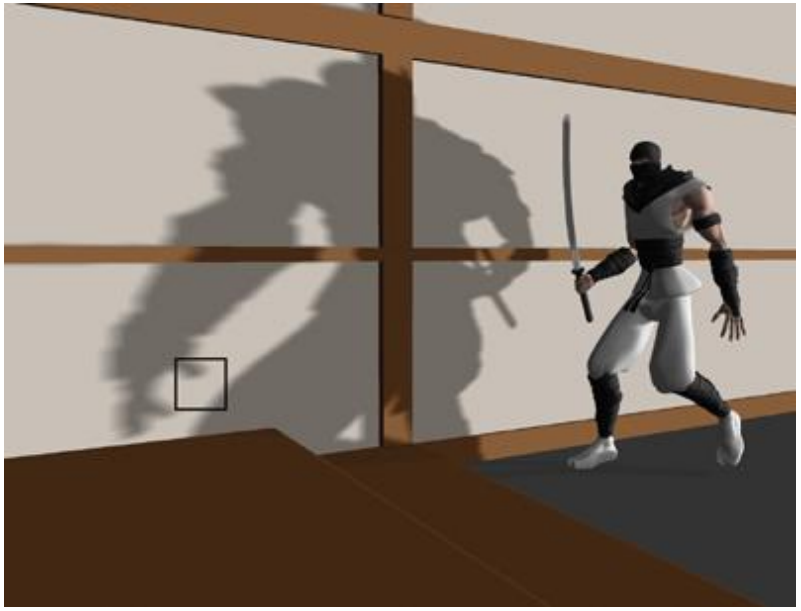
Flat shadows

- Draw the graphics primitives again, projected on the ground
  - Fast, easy to code
  - No self shadows, no shadows on curved surfaces and no shadows on other objects





Shadows in rasterization



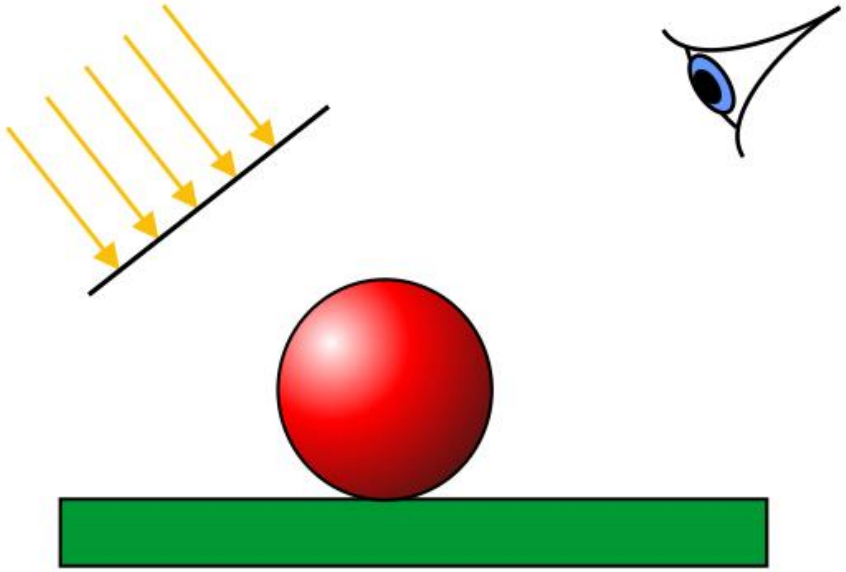
Shadow maps
screen space

Shadow volumes
geometry space

Shadow mapping

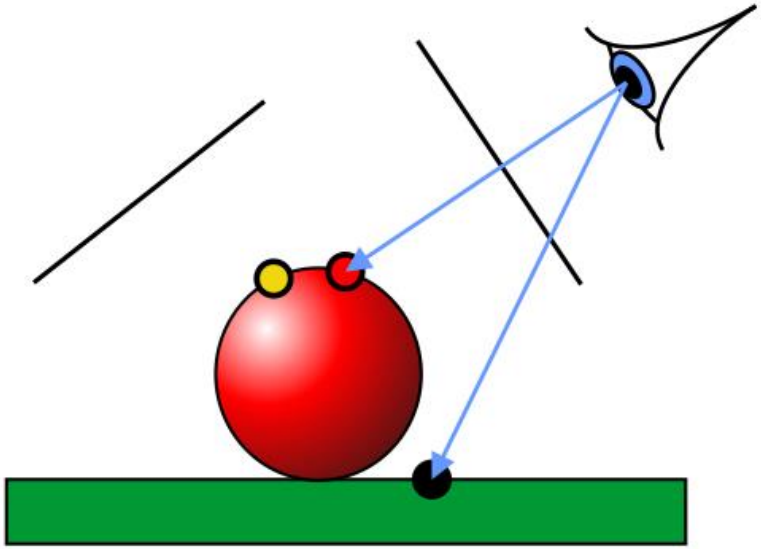
Shadow maps

- z-buffer analogy
- look from the light
- "render" the scene and store depth information in a shadow map
  - 2D raster data
  - smallest distance between light and objects



Shadow maps

- For a polygon pixel to be rendered

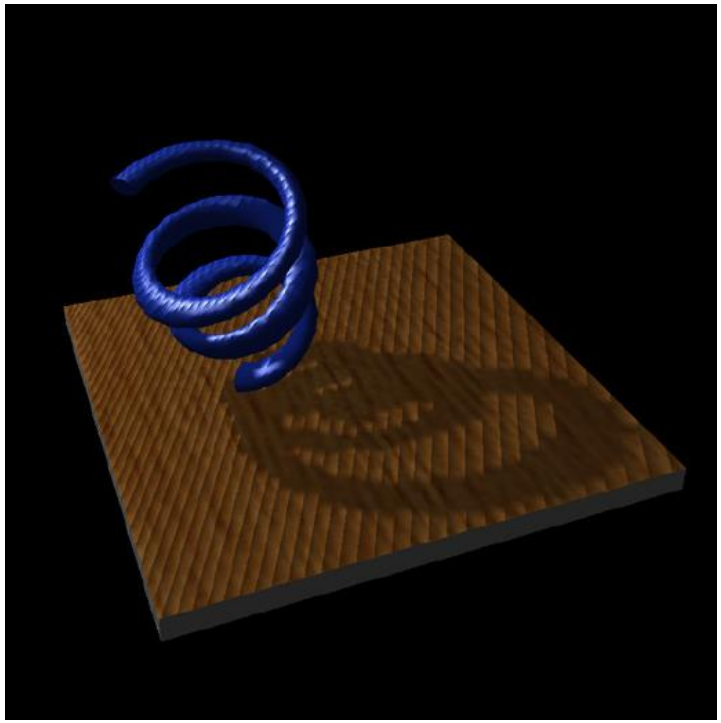


- Find its position in the light's projection plane → transform camera-space position (x,y,z)

- If z > shadow map [x,y]
  then in shadow

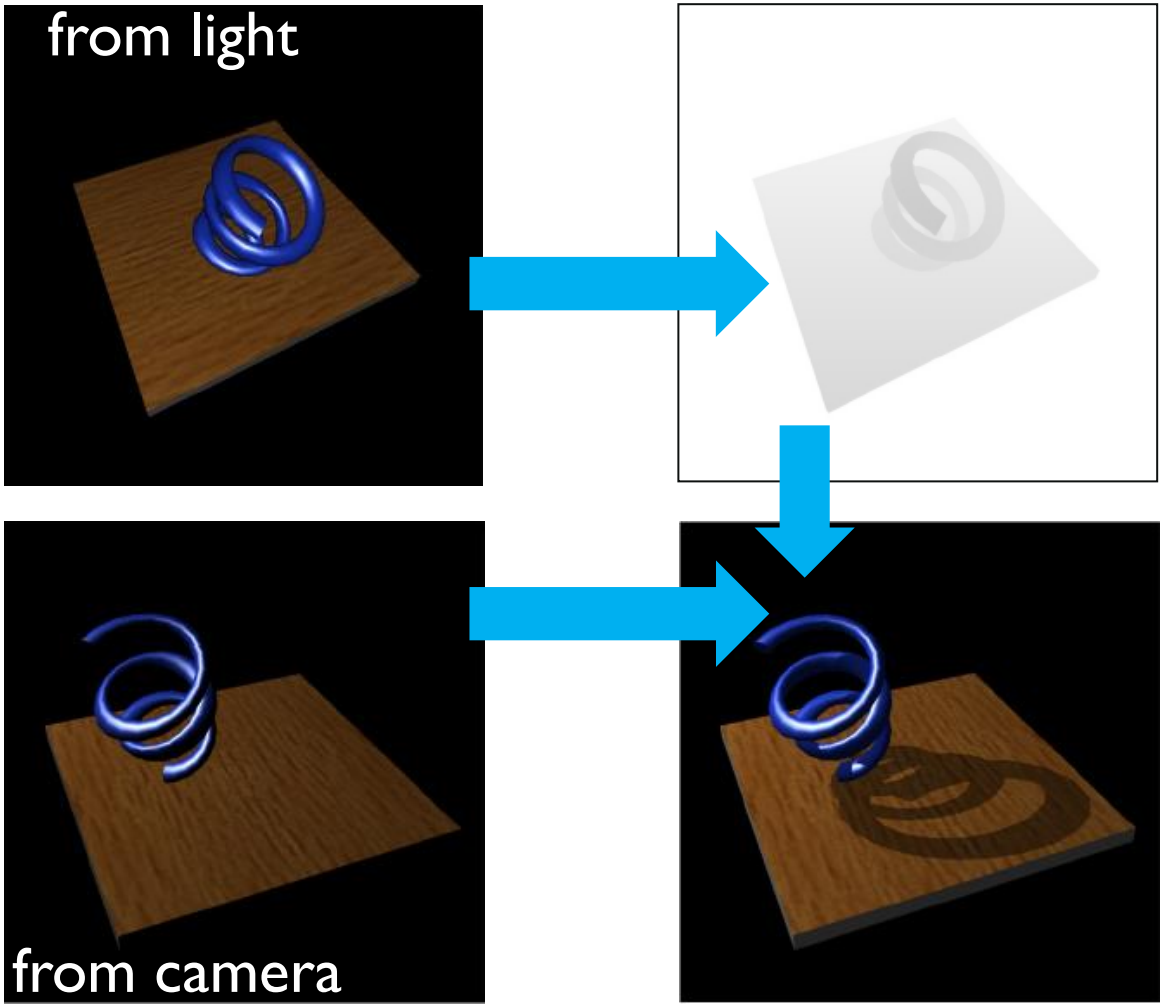
Shadow maps pros & cons

- memory consumption
  - 1 light = 1 shadow map
  - high resolution necessary
- aliasing
  - use high resolution
  - filtering necessary
- smooth (soft) shadows
  - when filtered



- imprecise due to z-buffer quantization (non-linear)
- light-specific transformation

Shadow mapping example



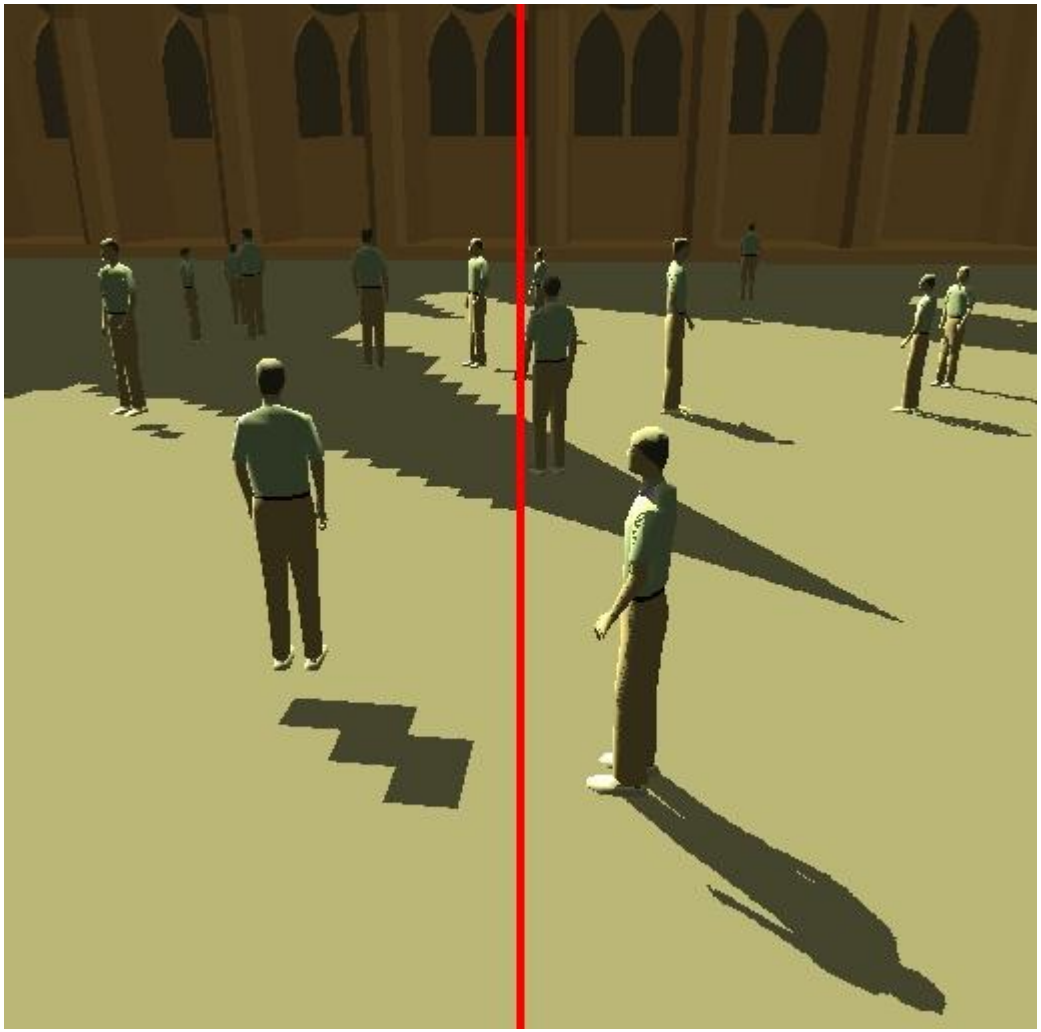
depth buffer from light's point of view

final image

http://www.nealen.net/projects/ibr/shadows.pdf

Shadow map resolution

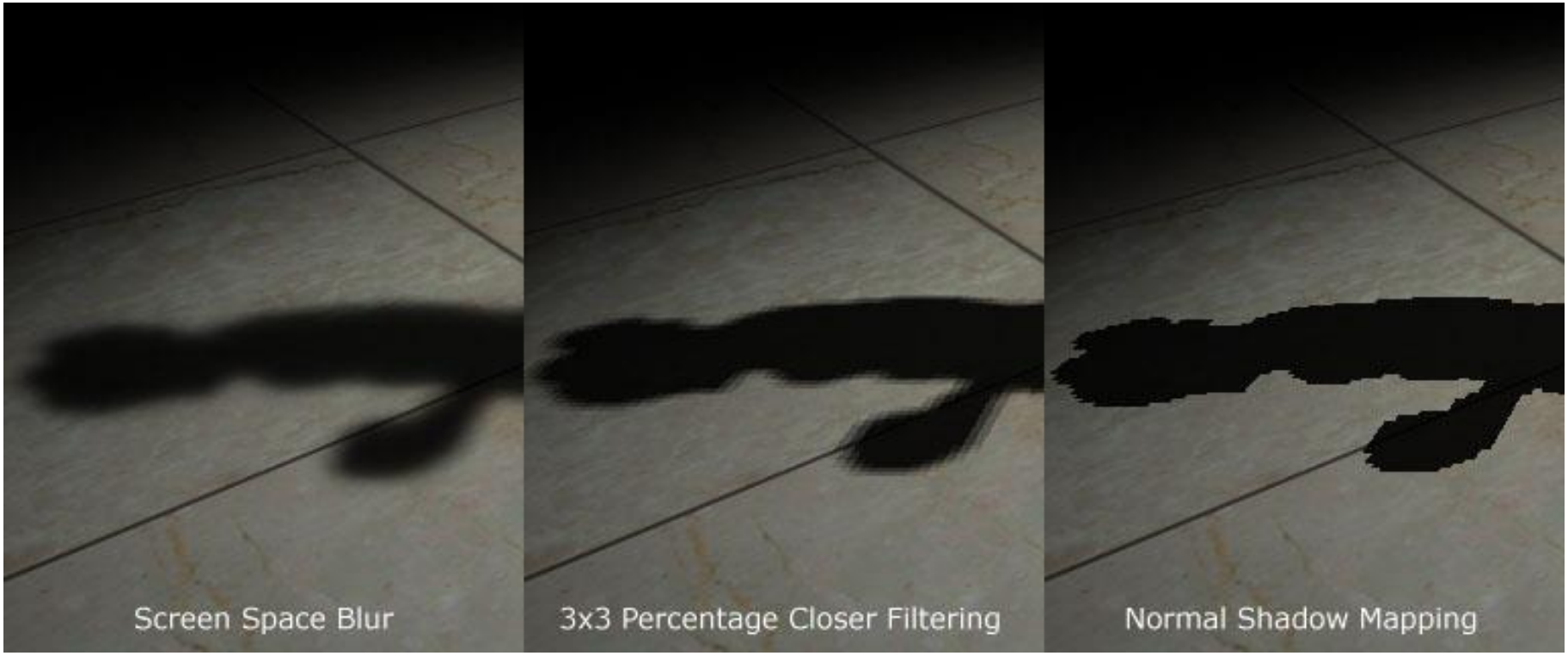
- How many points are stored in the 2D shadow map
- Low counts = shadow artifacts



Stamminger, Drettakis: Perspective Shadow Maps

Filtering and soft shadows

- Removes artifacts (jagged edges)
- Simulates soft shadows



Soft-Edged Shadows, http://www.gamedev.net

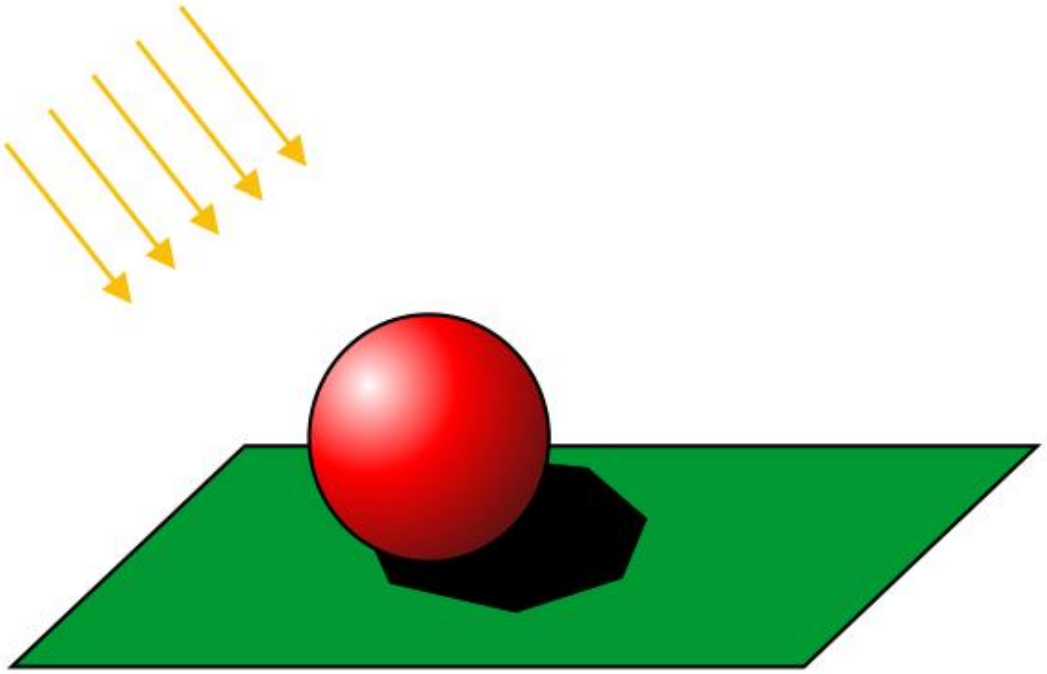
Shadow volumes

Shadow volumes

- create dummy geometry object extending each object in the direction of the light
  - shadow volume

- when displaying an object to a pixel (x,y,z), test if (x,y,z) is inside/outside the shadow volume

Shadow volumes

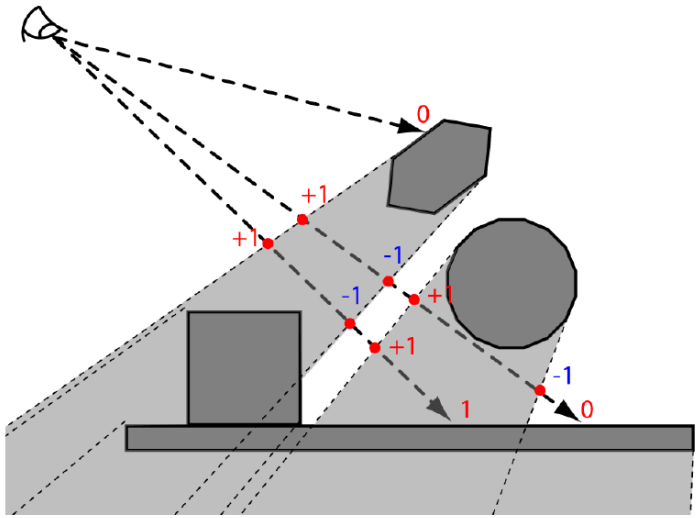


Pseudo-code

1. Compute ambient light for whole scene and update z-buffer along with that
2. **Which screen areas are in shadow?**
3. For all areas outside the shadow:
    4. Compute diffuse and specular light components
5. Iterate for all lights

Shadow volumes implementation

1. For each *shadow casters,* build a **shadow volume**
2. For each fragment, **count** how many times we enter (+1) and leave (-1) a shadow volume
   > 0 : in shadow
   = 0 : lit



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Shadow volumes implementation

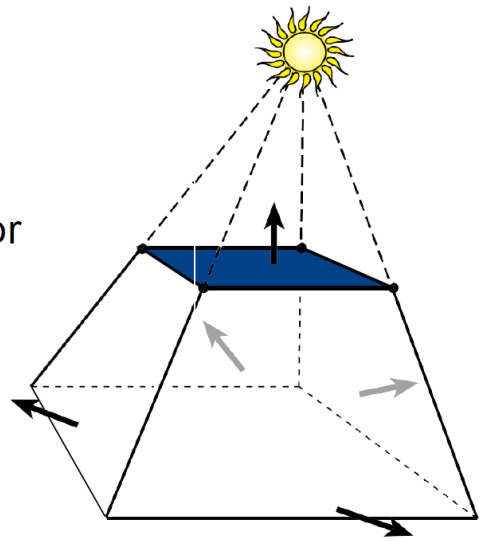
Shadow Volumes algorithm

Building a shadow volume

- Silhouette of each object from the light source
- Infinite quads touching
  - the light source
  - Each silhouette edge

Counting entering/leaving

- Use the *stencil buffer*
- Use the orientation of each shadow quad for the sign



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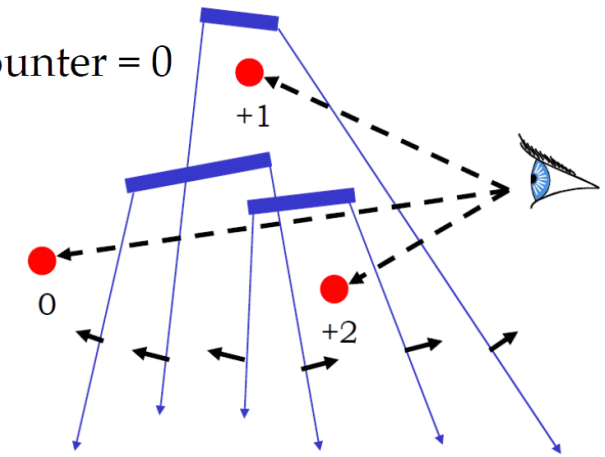
Shadow volumes implementation

Stencil Buffer Algorithm

1. Initialize stencil buffer to 0
2. Draw scene with ambient light only
3. Turn off frame buffer & z-buffer updates
4. First passs: draw FRONT-facing shadow volume polygons, + 1 to stencil buffer if z-pass
5. Second pass: draw BACK facing shadow volume polygons, − 1 to stencil buffer if z-pass
6. Turn on frame buffer updates
7. Turn on lighting and redraw pixels with counter = 0



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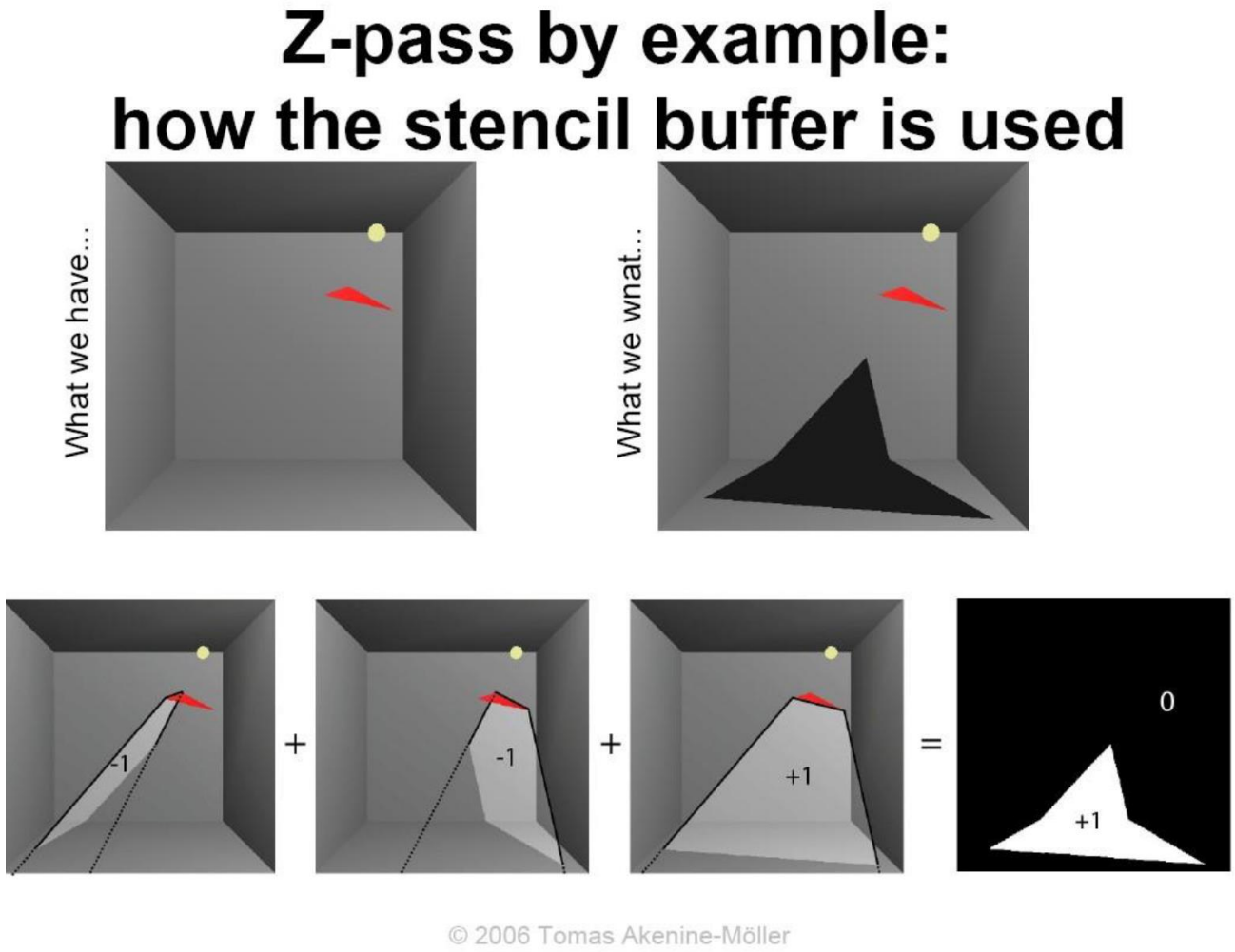
Shadow volumes implementation



Shadow volume pros & cons

- hard shadows
  - modifications for soft shadows necessary
- GPU implementation using stencil buffer
- high complexity for high-polygon models
- what if camera is inside the shadow volume?
- shadow volumes expensive on CPU
  - now vertex shaders

Shadows vs. light types

- Directional (parallel) light
  - easy shadow maps and shadow volumes
- Spot light
  - shadow map by perspective transformation
  - easy shadow volume
- Omni-directional light
  - shadow map hard
  - easy shadow volume (same as spotlight)
- Area light
  - approximate by multiple lights

How the lectures should look like #2

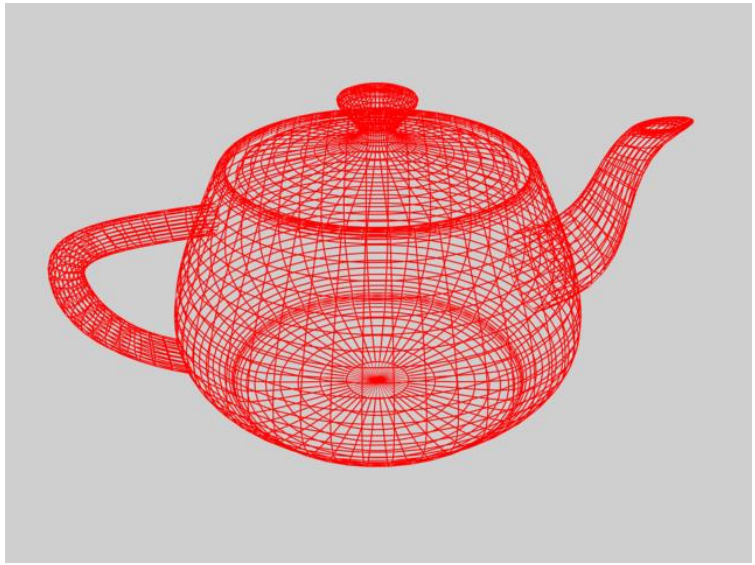
- Ask questions, please!!!
- Be communicative
- More active you are, the better for you!

Rendering pipeline summary

Summary

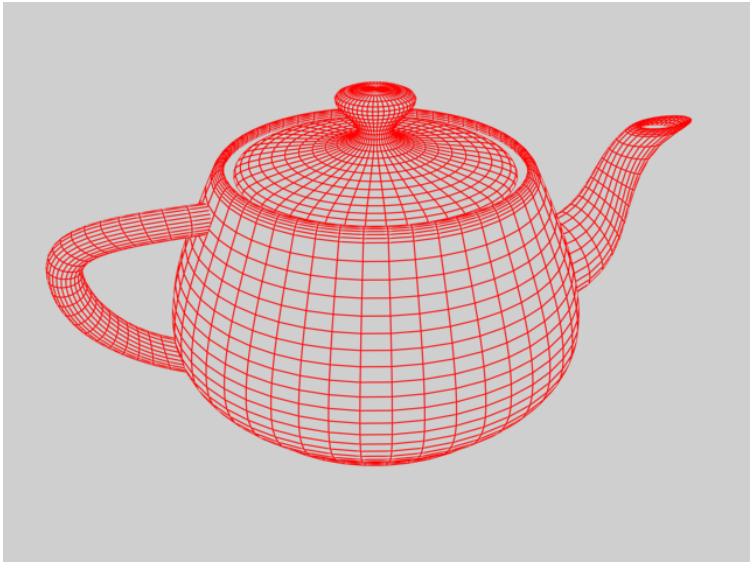
Rendering pipeline summary

- Local, world (global), camera coordinates
- Transformations (in 2D & 3D)
- Matrix operations
  - translate, rotate, scale
  - projections (orthogonal, perspective)
- Object representation
  - boundary, volume, polygonal parametric, implicit, F-rep



Rendering pipeline summary

- Line and polygon rasterization
- Linear interpolation
- Antialiasing



- Frustrum - visible volume
- Back-face culling
- Painter's algorithm
- Z-Buffer

Rendering pipeline summary

- Texture coordinates, texture mapping
- Texture filtering
  - Bilinear interpolation
  - Nearest neighbor

Rendering pipeline summary

- Light types
- Lighting models and illumination techniques
  - local, global
  - empiric, physical
- Shading models
  - flat, Gouraud, Phong
- Raytracing, radiosity

Rendering pipeline summary

- Shadow generation in global illumination
- Shadow generation in local models
- Stencil shadows (shadow volume)
- Shadow maps
- Soft shadows

Next Lecture

Animations

Acknowledgements

- Thanks to all the people, whose work is shown here and whose slides were used as a material for creation of these slides:

Matej Novotný, GSVM lectures at FMFI UK

Peter Drahoš, PPGSO lectures at FIIT STU

Output of all the publications and great team work

Very best data from 3D cameras

Questions ?!

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