CSE 167:
Introduction to Computer Graphics
Lecture #16: Shadows

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Fall Quarter 2011

Announcements

- Important dates:
  - Final project outline due November 23rd
    - Email to me at `jschulze@ucsd.edu`
  - Final project presentations: Friday December 2nd, 1-3pm
  - Final Exam: December 9th, 3-6pm

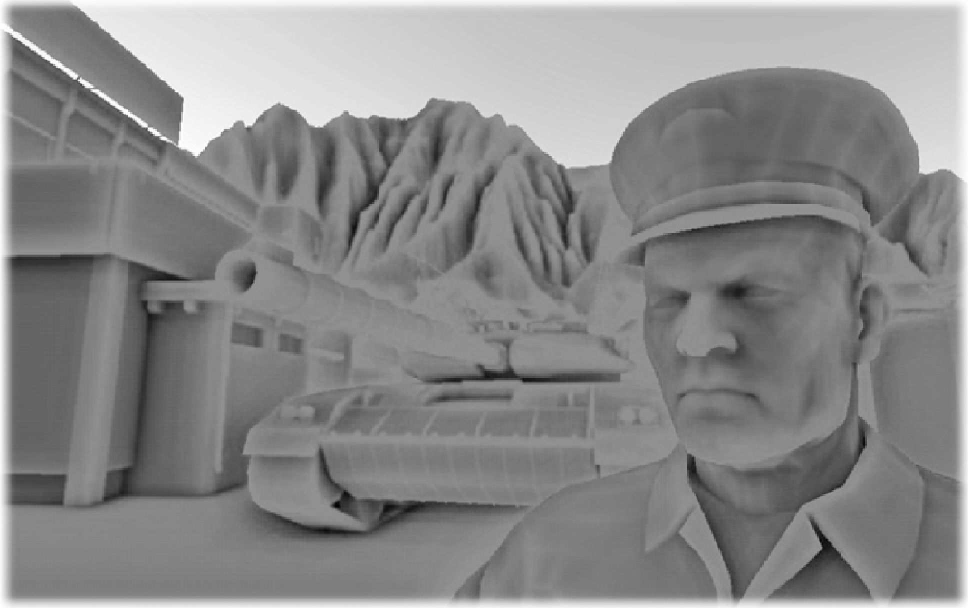
- TA Evaluation for Gregory Long OR Jorge Schwarzhaupt
  - Pick the TA you interacted more with

Lecture Overview

- Ambient Occlusion
- Shadow Mapping

Screen Space Ambient Occlusion

- Screen Space Ambient Occlusion = SSAO
- Rendering technique for approximating ambient occlusion in real time
- Developed by Vladimir Kajalin while working at Crytek
- First use in 2007 PC game Crysis



SSAO component

SSAO Demo

- Video

SSAO Algorithm

- Copy frame buffer to texture
- Pixel shader samples depth values around current pixel and tries to compute amount of occlusion
- Occlusion depends on depth difference between sampled point and current point
- SSAO shader code from Crysis available on-line

SSAO Discussion

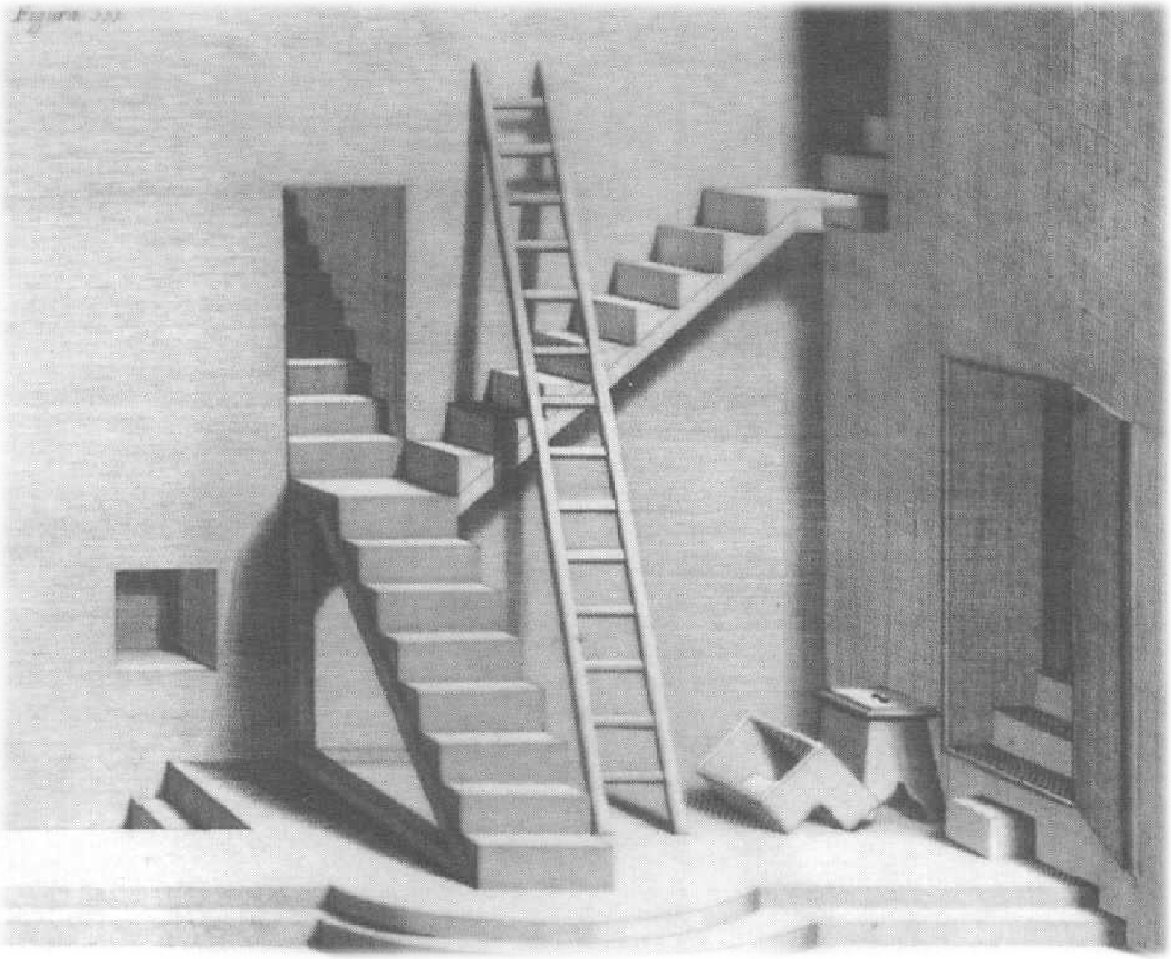
- Advantages:
  - Independent from scene complexity.
  - No pre-processing, no memory allocation in RAM
  - Works with dynamic scenes
  - Works in the same way for every pixel
  - No CPU usage: executed completely on GPU
- Disadvantages:
  - Local and view-dependent (dependent on adjacent texel depths)
  - Hard to correctly smooth/blur out noise without interfering with depth discontinuities, such as object edges

Lecture Overview

- Ambient Occlusion
- Shadow Mapping

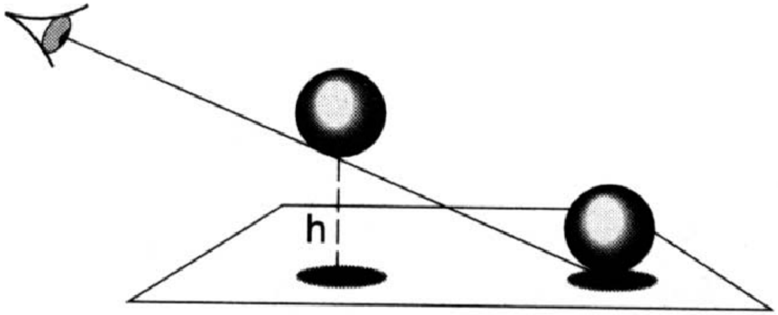
Why Are Shadows Important?

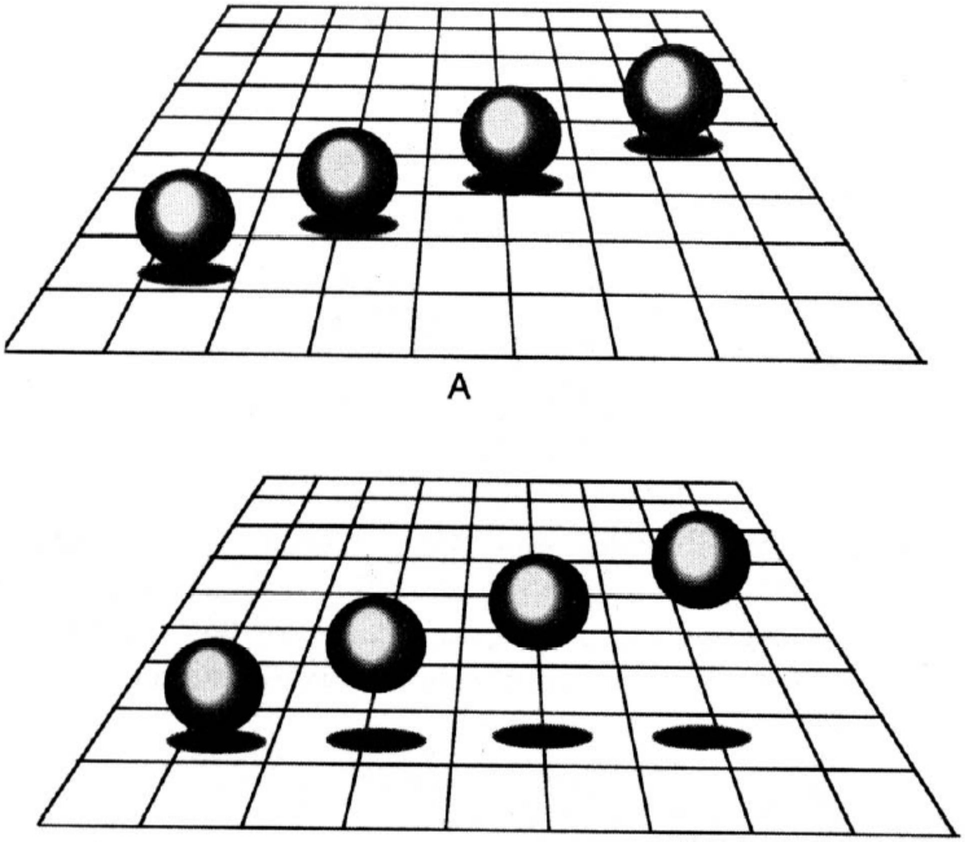
- Give additional cues on scene lighting



Why Are Shadows Important?

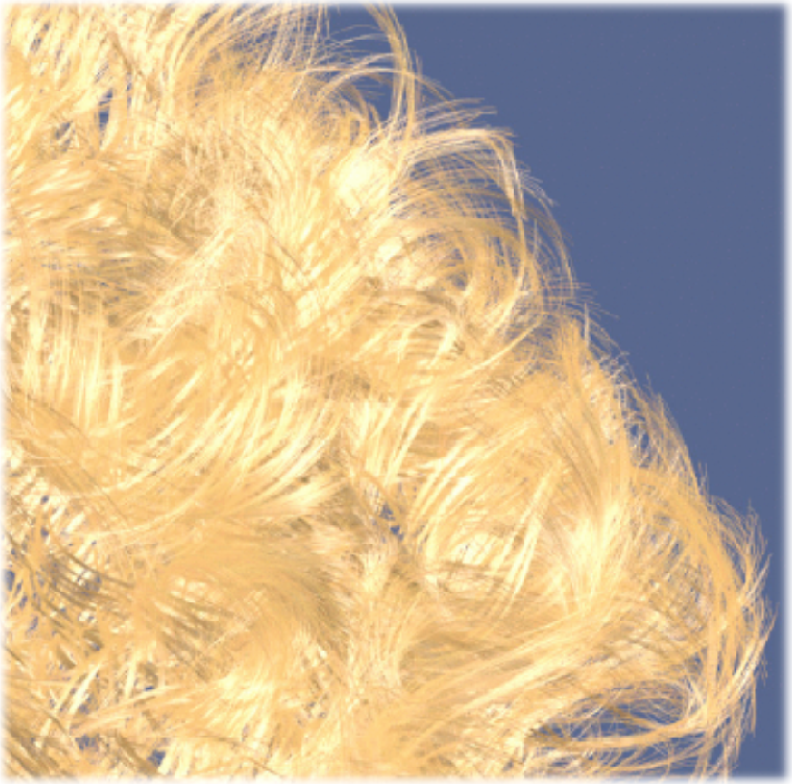
- Contact points
- Depth cues



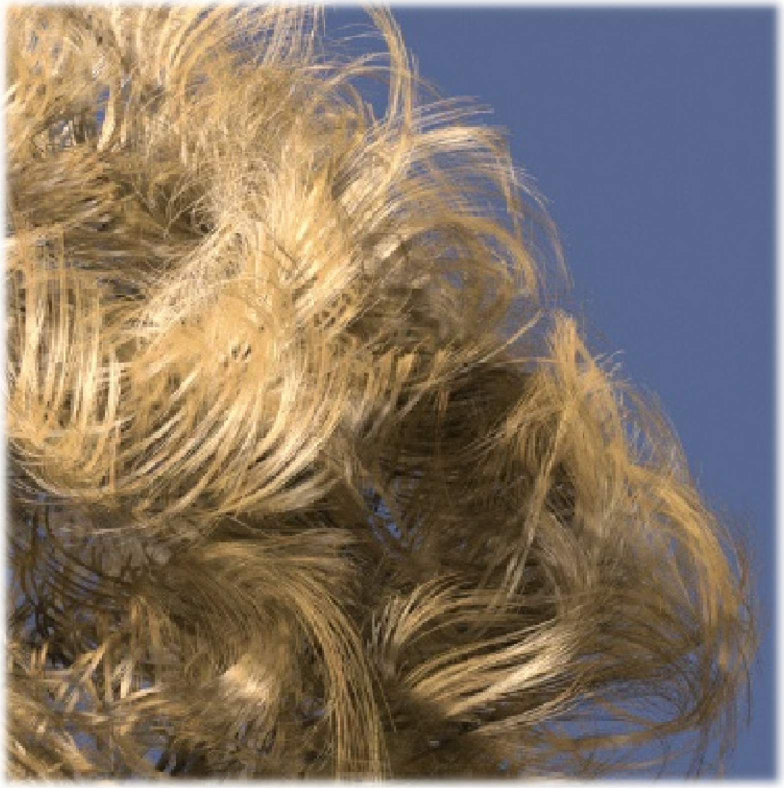


Why Are Shadows Important?

- Realism



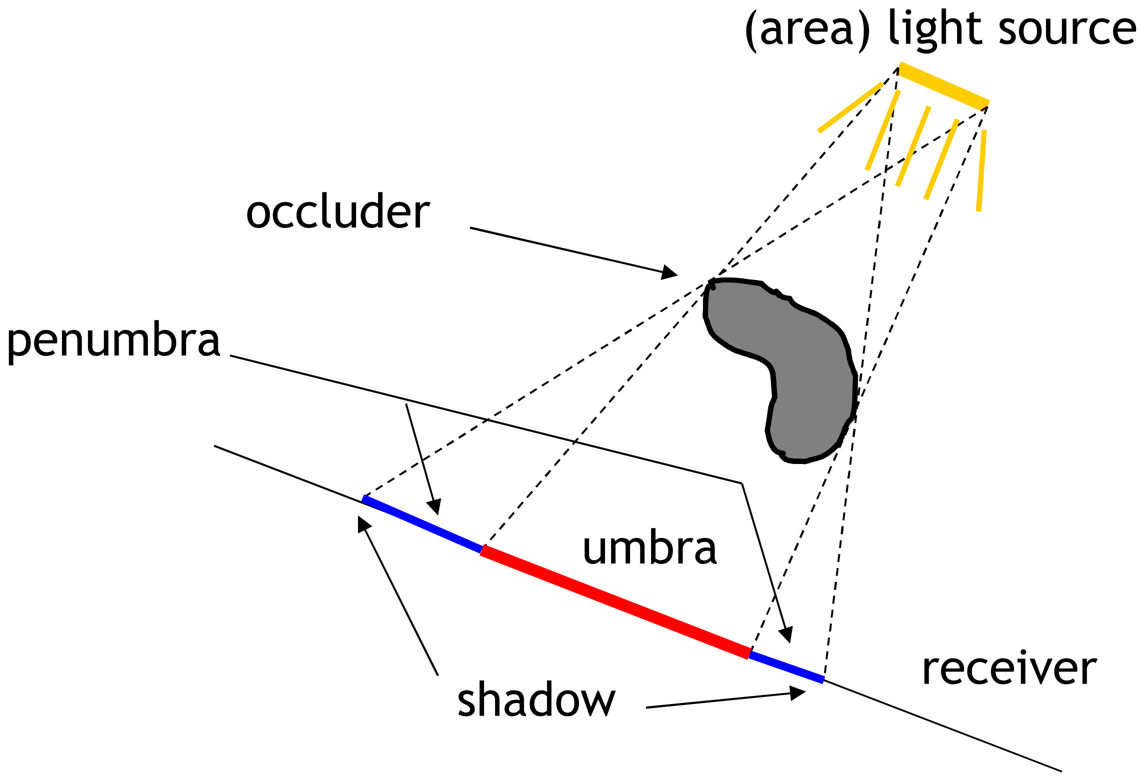
Without self-shadowing



With self-shadowing

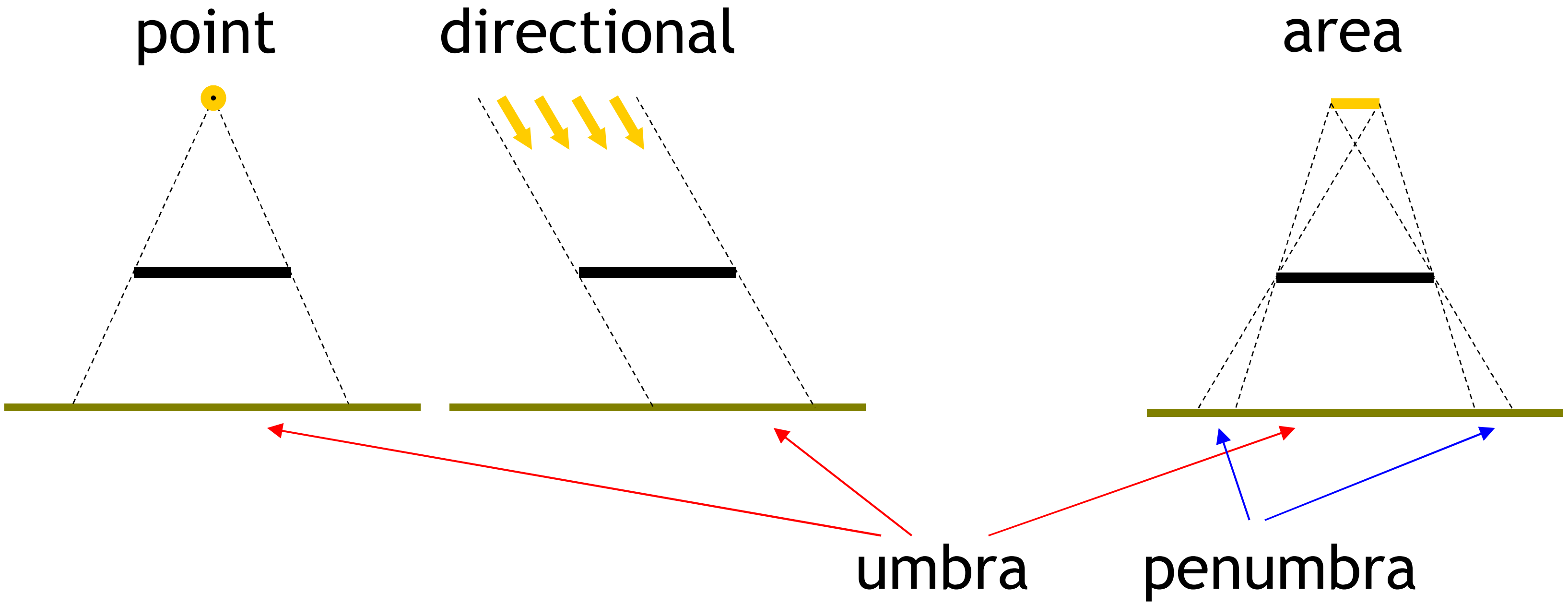
Terminology

- Umbra: fully shadowed region
- Penumbra: partially shadowed region

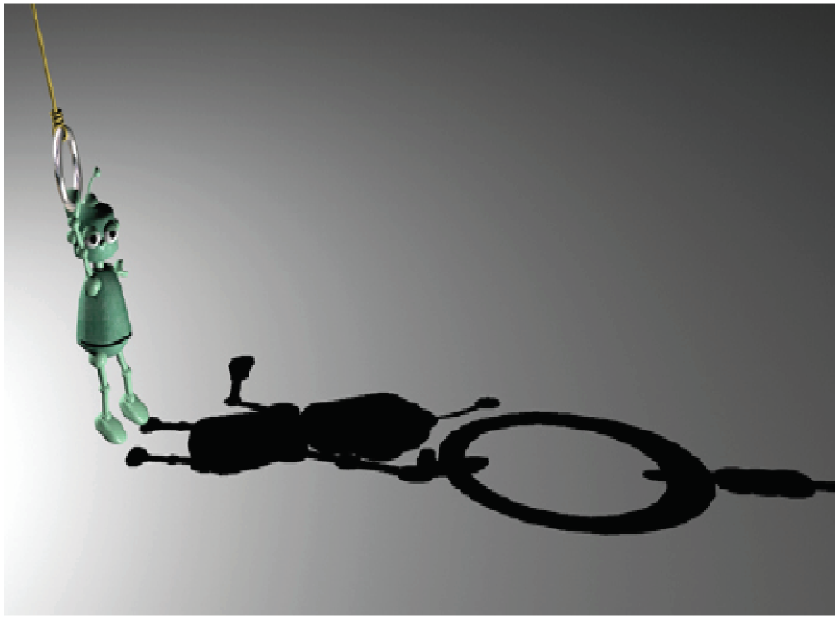


Hard and Soft Shadows

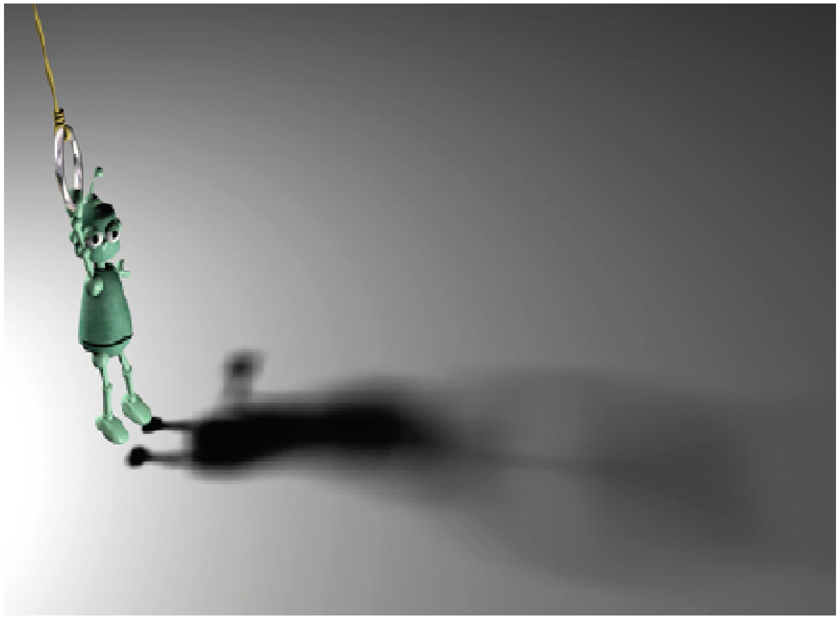
- Point and directional lights lead to hard shadows, no penumbra
- Area light sources lead to soft shadows, with penumbra



Hard and Soft Shadows



Hard shadow from point light source



Soft shadow from area light source

Shadows for Interactive Rendering

- In this course: hard shadows only
  - Soft shadows hard to compute in interactive graphics
- Two most popular techniques:
  - Shadow mapping
  - Shadow volumes
- Many variations, subtleties
- Active research area

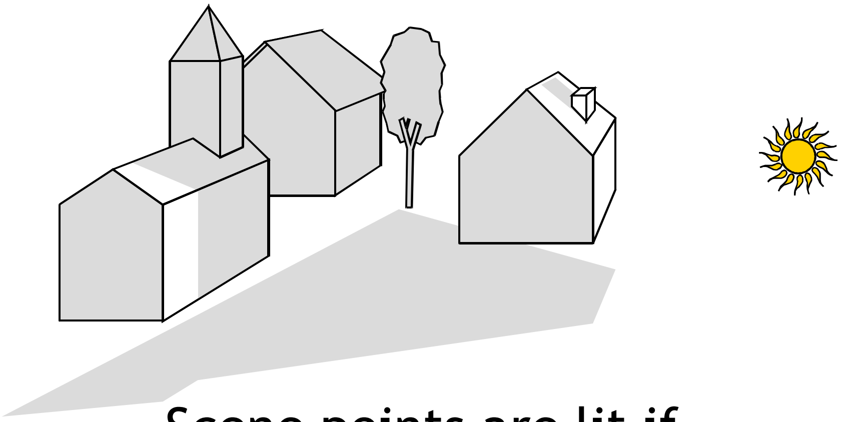
Lecture Overview

- Shadows
- Shadow mapping

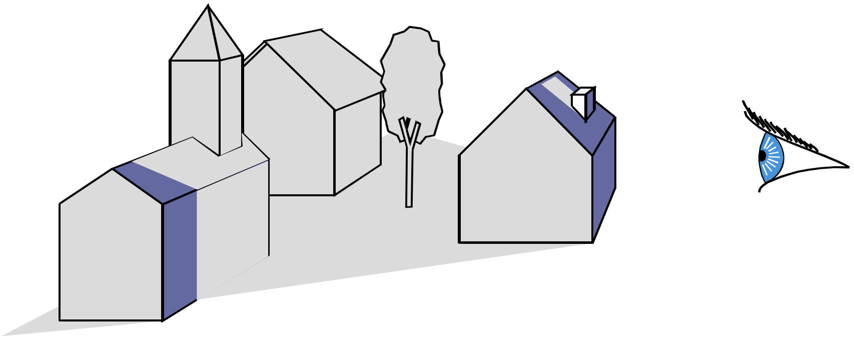
Shadow Mapping

Main Idea

- A scene point is lit by the light source if visible from the light source
- Determine visibility from light source by placing a camera at the light source position and rendering the scene from there



Scene points are lit if visible from light source

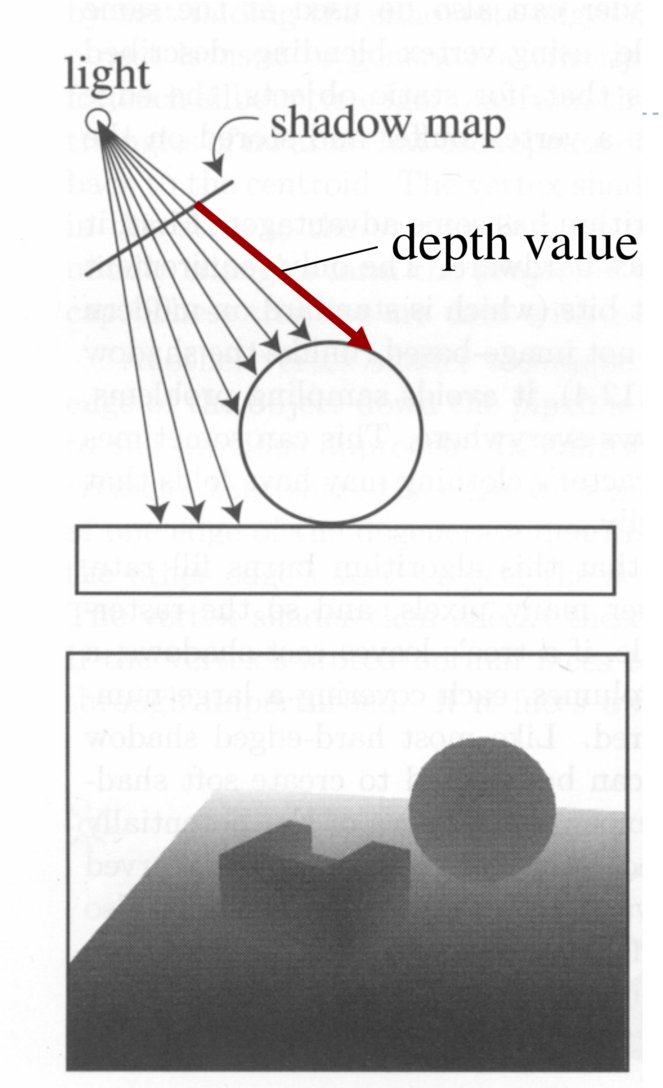


Determine visibility from light source by placing camera at light source position

Two Pass Algorithm

First Pass

- Render scene by placing camera at light source position
- Store depth image (*shadow map*)

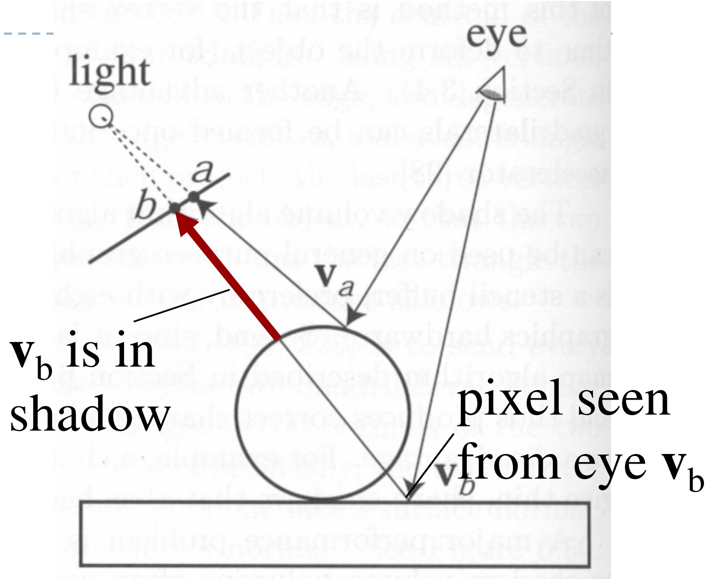


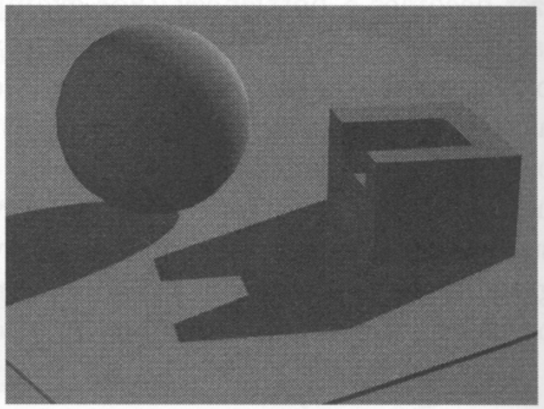
Depth image as seen from light source

Two Pass Algorithm

Second Pass

- Render scene from camera position
- At each pixel, compare distance to light source with value in shadow map
  - If distance is larger, pixel is in shadow
  - If distance is smaller or equal, pixel is lit





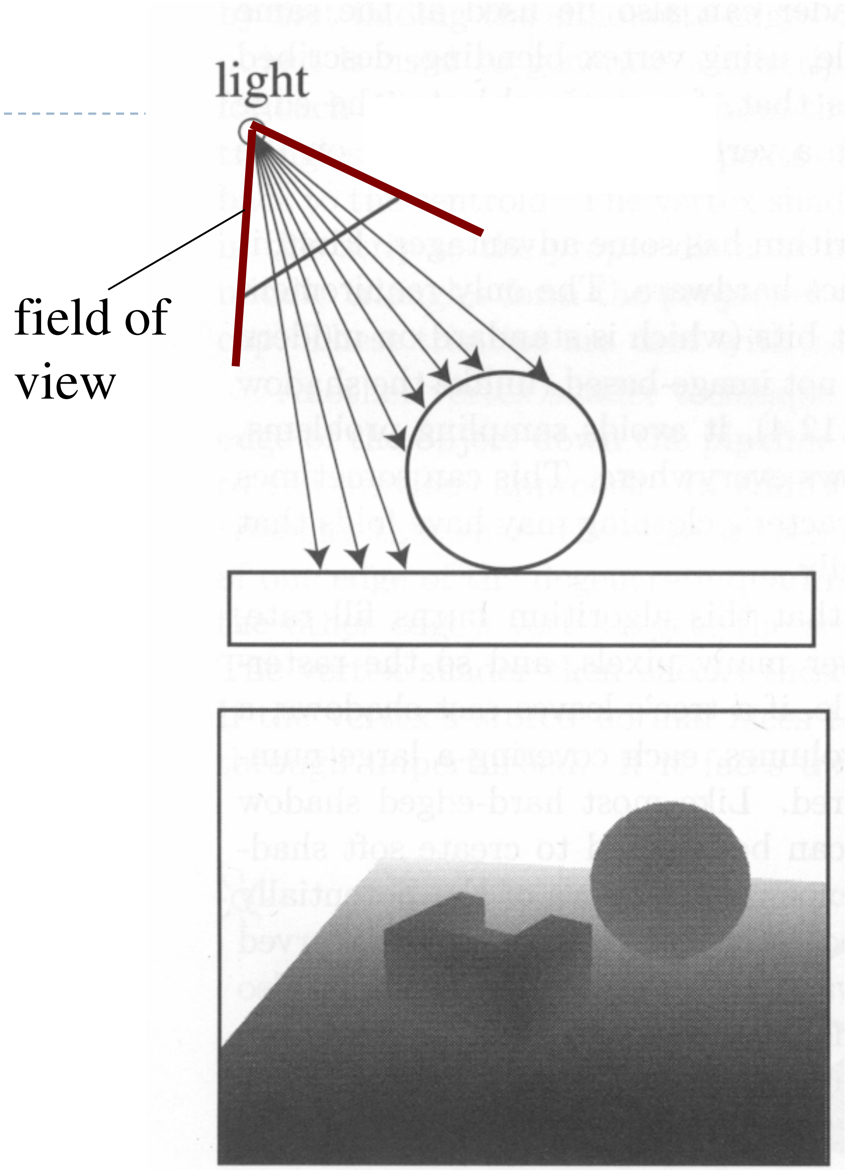
Final image with shadows

Issues With Shadow Maps

- Limited field of view of shadow map
- Z-fighting
- Sampling problems

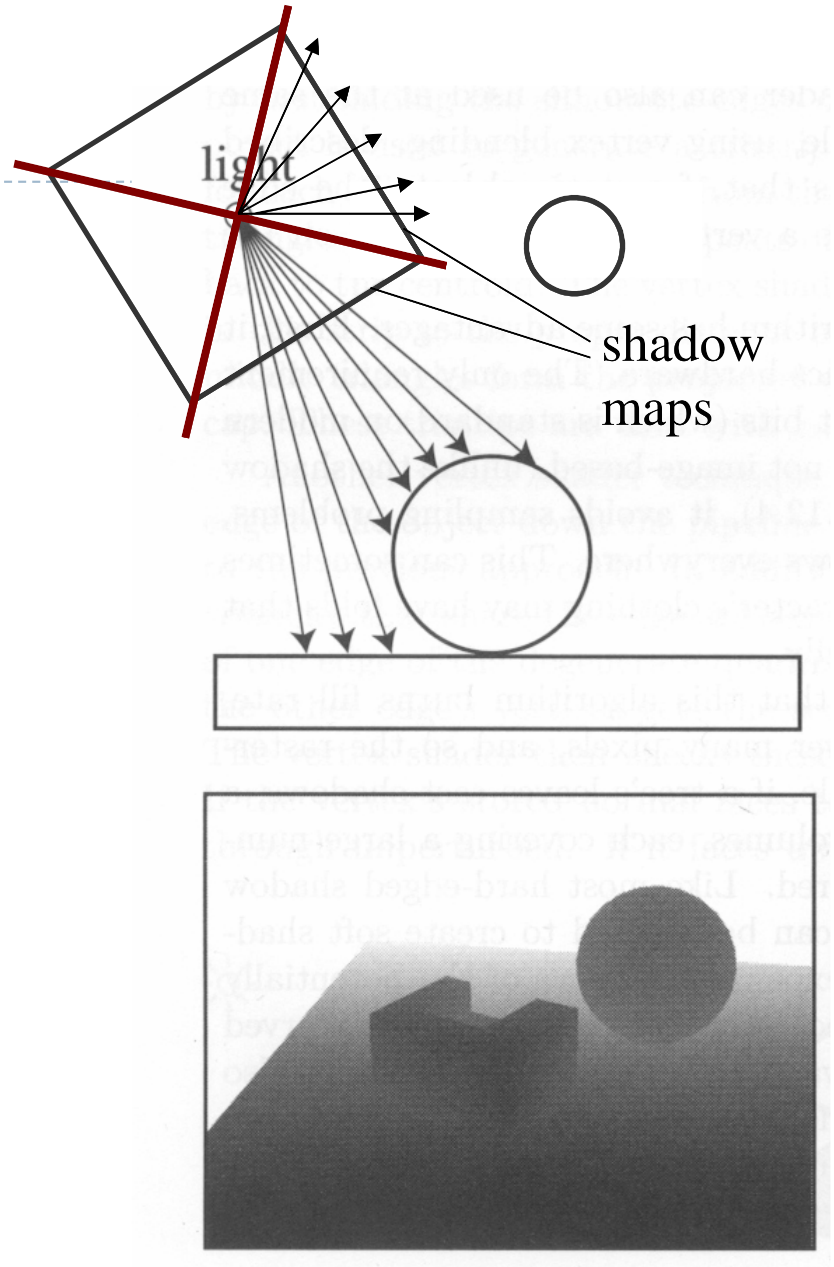
Limited Field of View

- What if a scene point is outside the field of view of the shadow map?



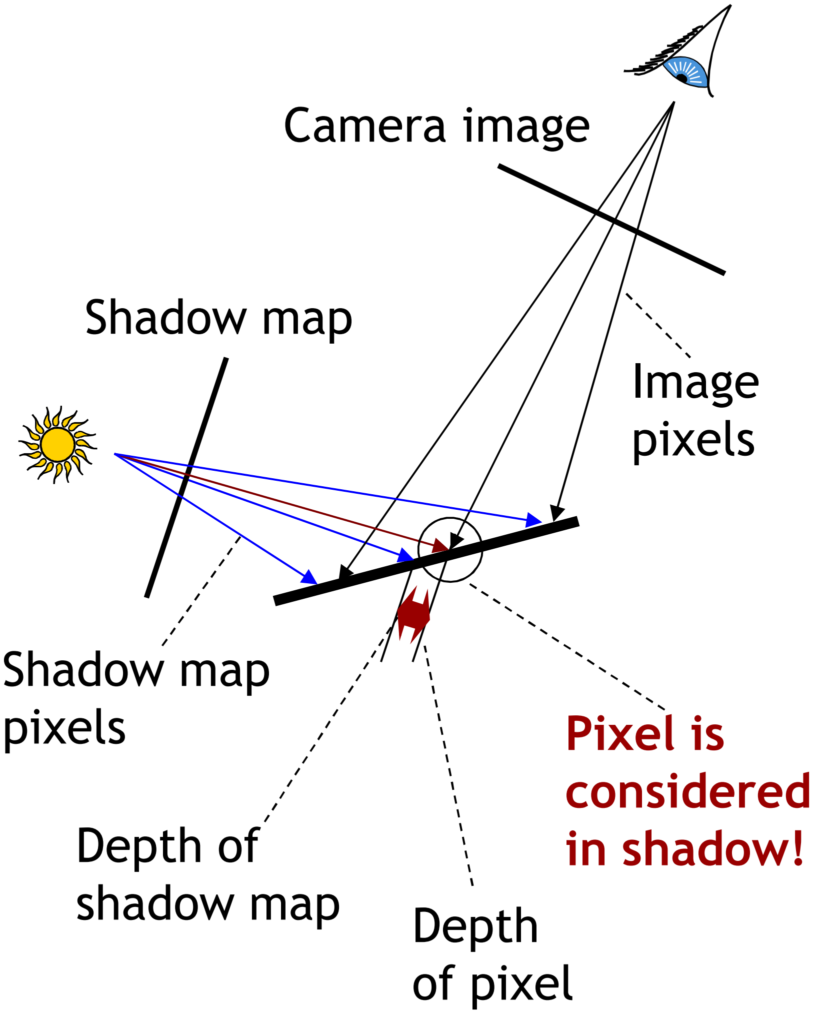
Limited Field of View

- What if a scene point is outside the field of view of the shadow map?
  → Use six shadow maps, arranged in a cube
- Requires a rendering pass for each shadow map



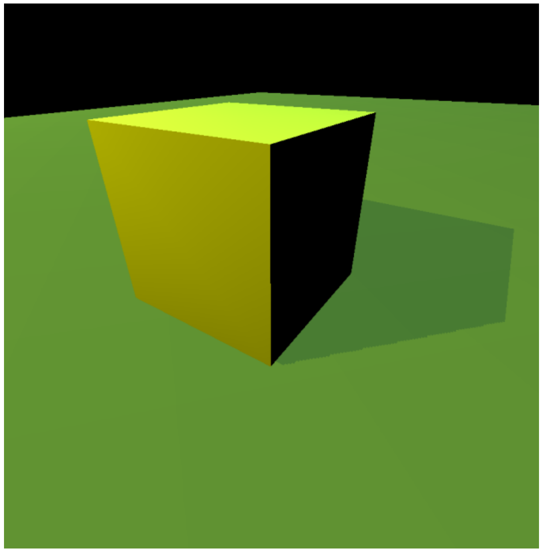
Z-Fighting

- Depth values for points visible from light source are equal in both rendering passes
- Because of limited resolution, depth of pixel visible from light could be larger than shadow map value
- Need to add bias in first pass to make sure pixels are lit

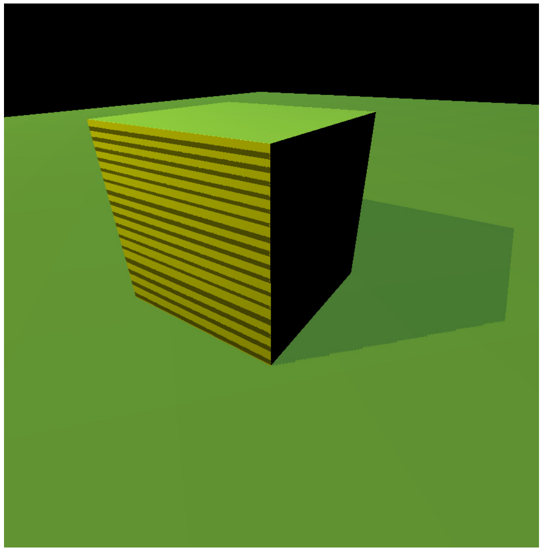


Solution: Bias

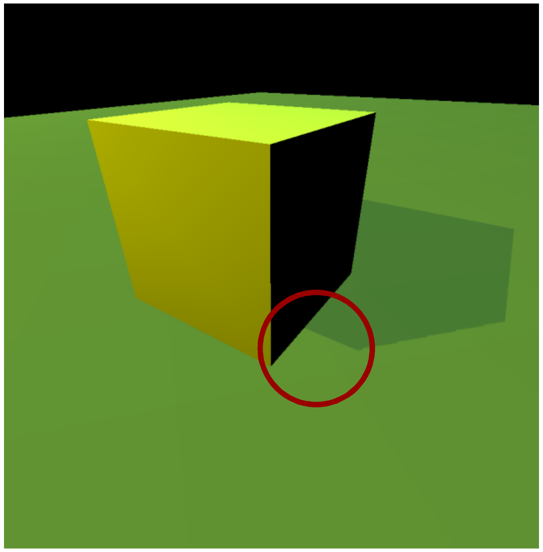
- Add bias when rendering shadow map
  - Move geometry away from light by small amount
- Finding correct amount of bias is tricky



Correct bias



Not enough bias

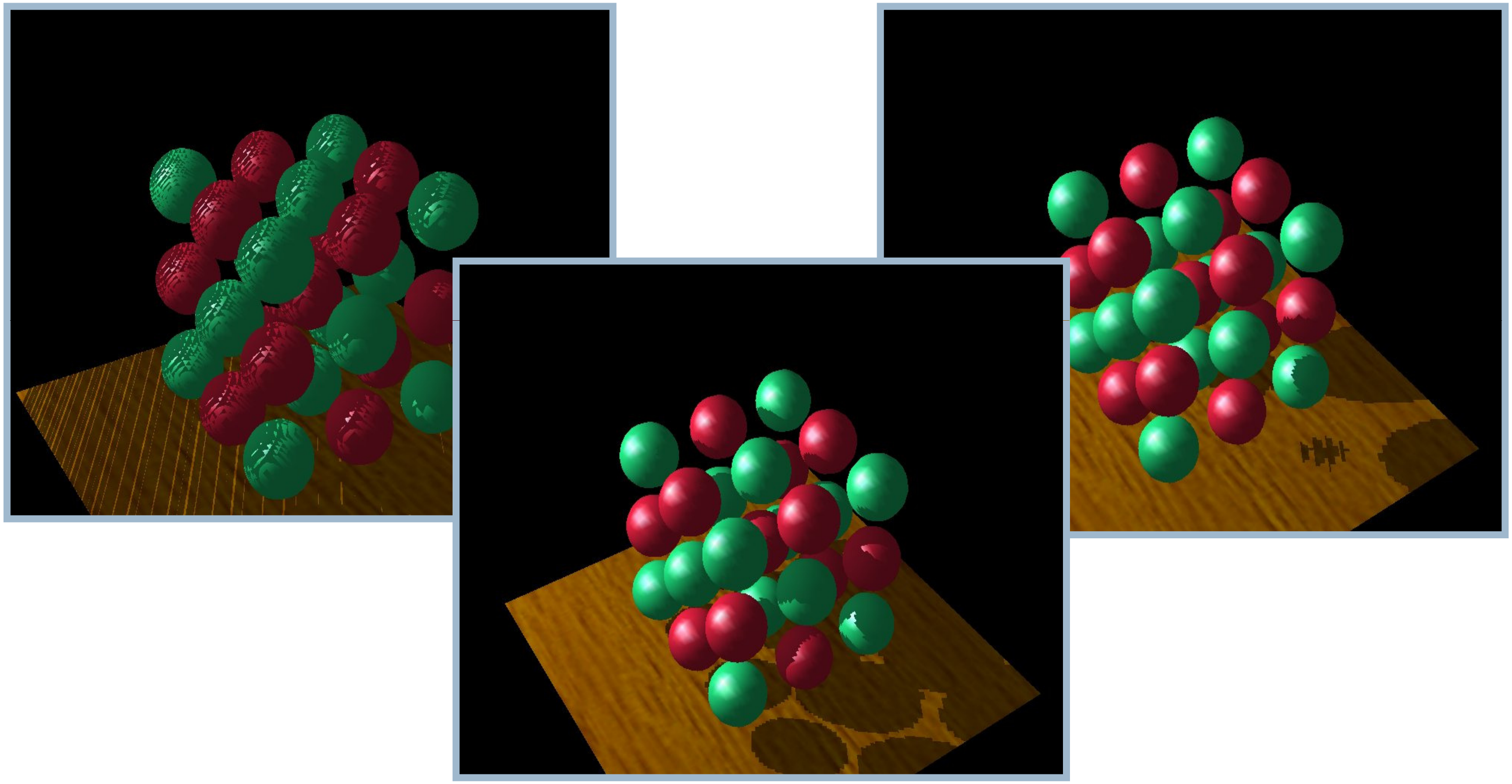


Too much bias

Bias Adjustment

Not enough

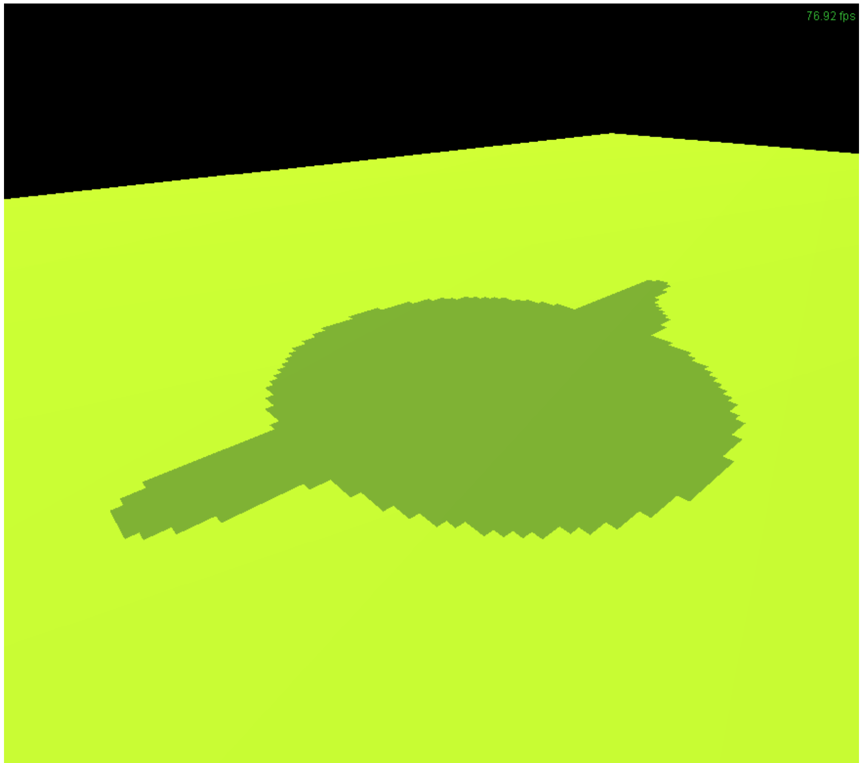
Too much

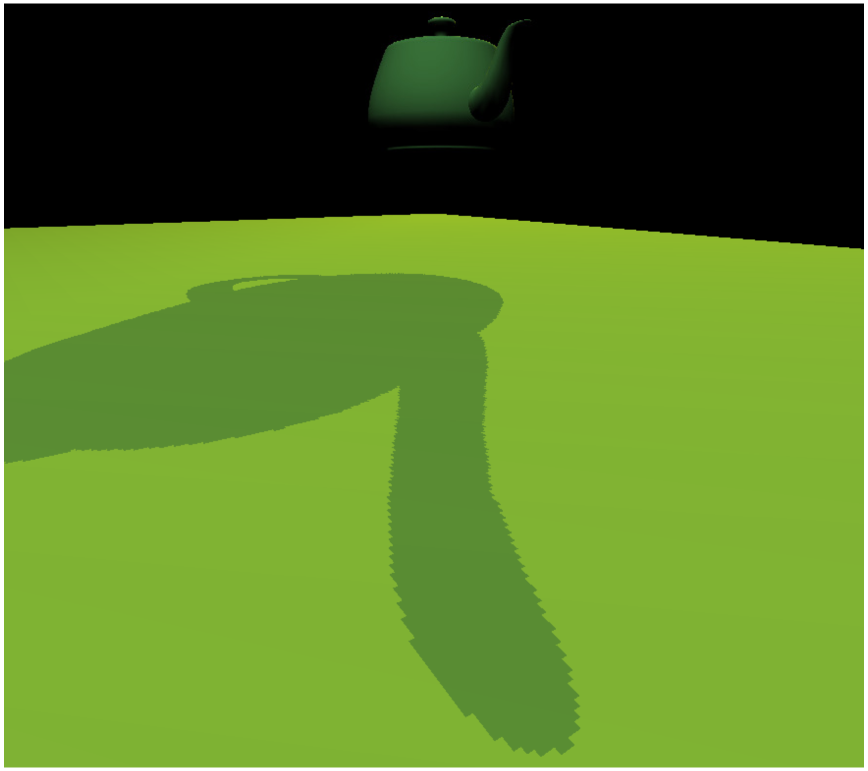


Just right

Sampling Problems

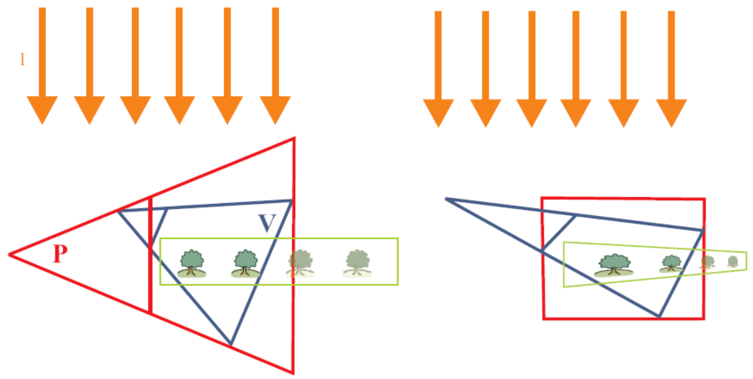
- Shadow map pixel may project to many image pixels
  → Stair-stepping artifacts





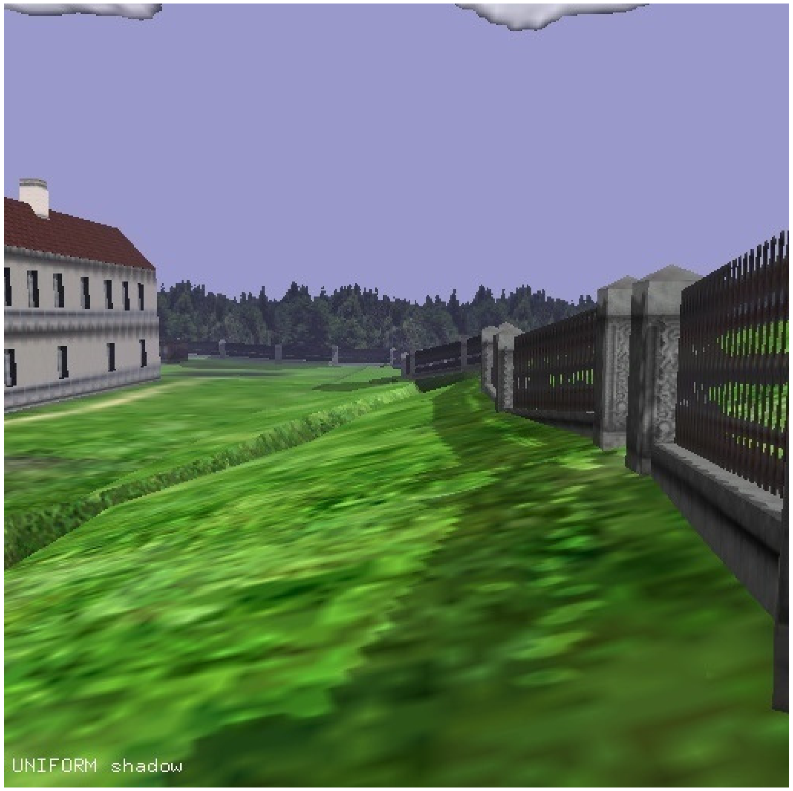
Solutions

- Increase resolution of shadow map
  - Not always sufficient
- Split shadow map into several tiles
- Tweak projection for shadow map rendering
  - Light space perspective shadow maps (LiSPSM) http://www.cg.tuwien.ac.at/research/vr/lispsm/

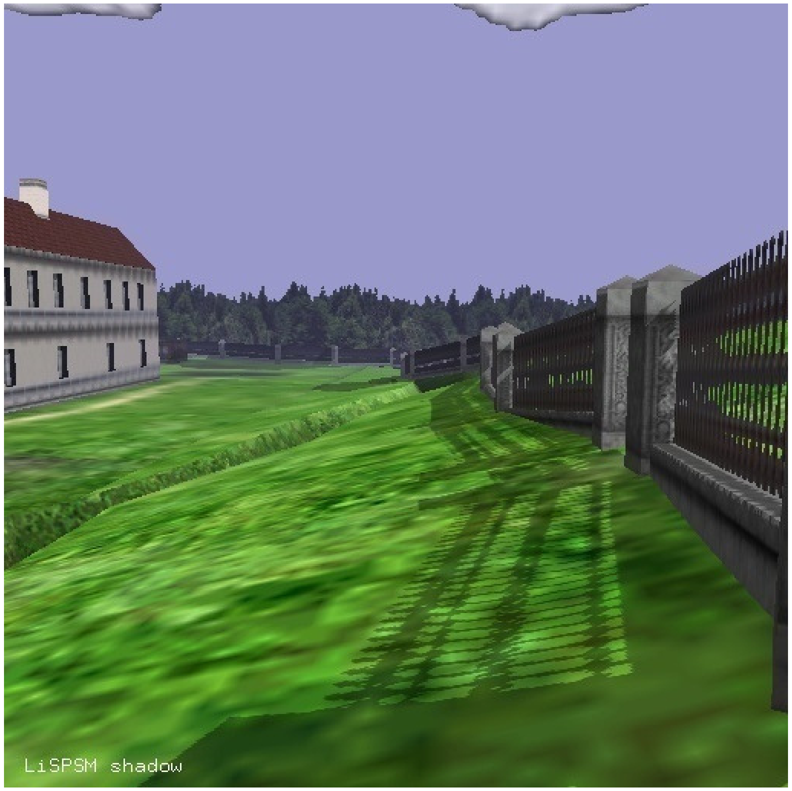


- Combination of splitting and LiSPSM
  - Basis for most serious implementations

LiSPSM



Basic shadow map



Light space perspective shadow map

Video

Next Lecture

- Shadow Maps cont'd
- Procedural Modeling