

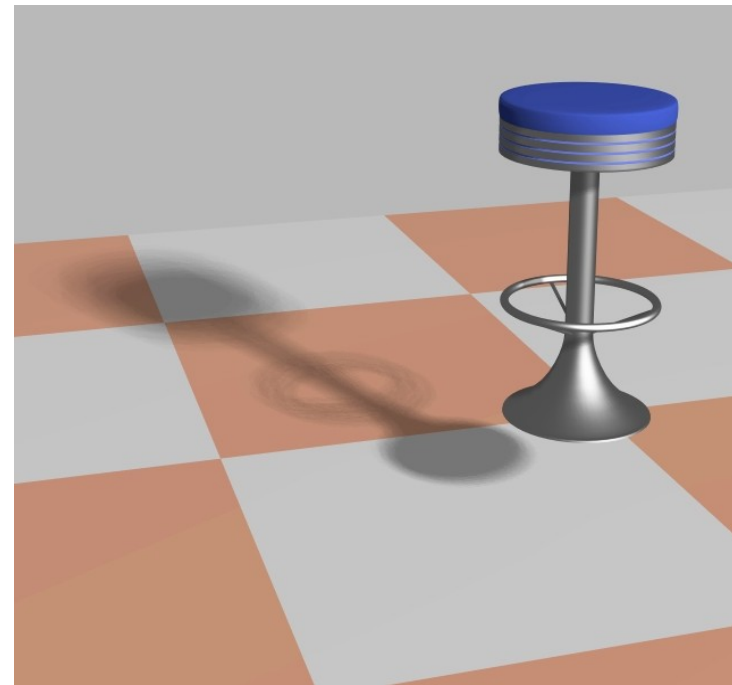
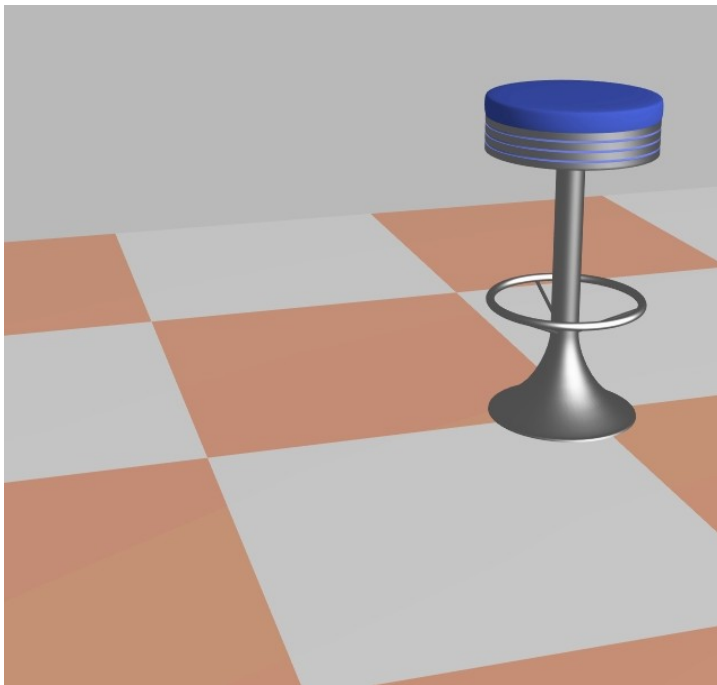
Real - Time Rendering

Shadows

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Juraj Starinský

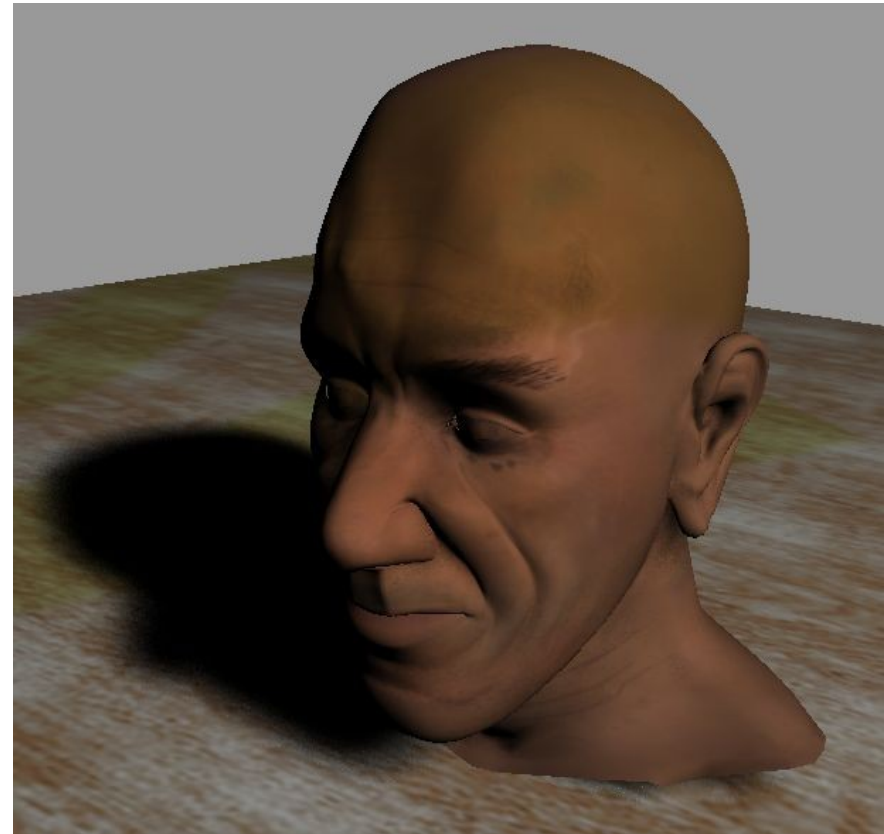
Why shadows ?

- Realism, atmosphere
- Spatial relationships
- Orientation
- Light position

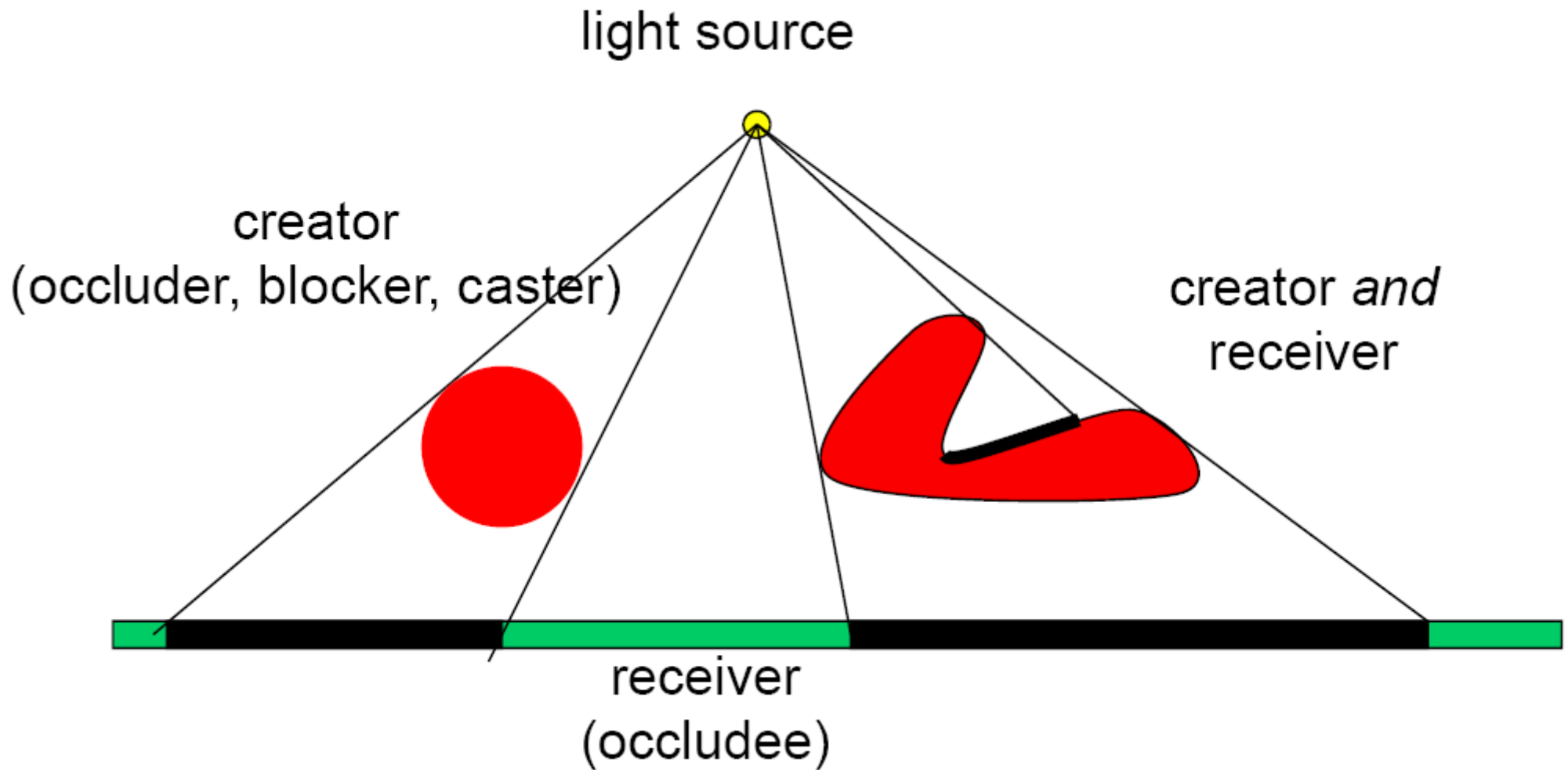


Overview

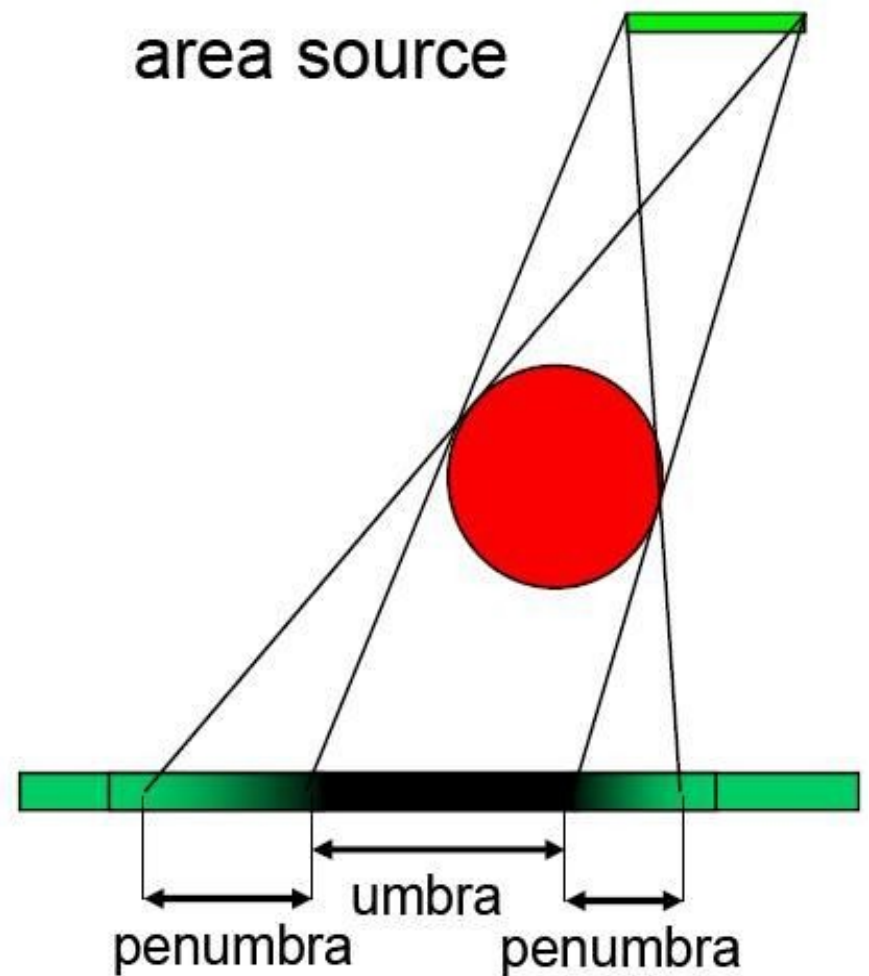
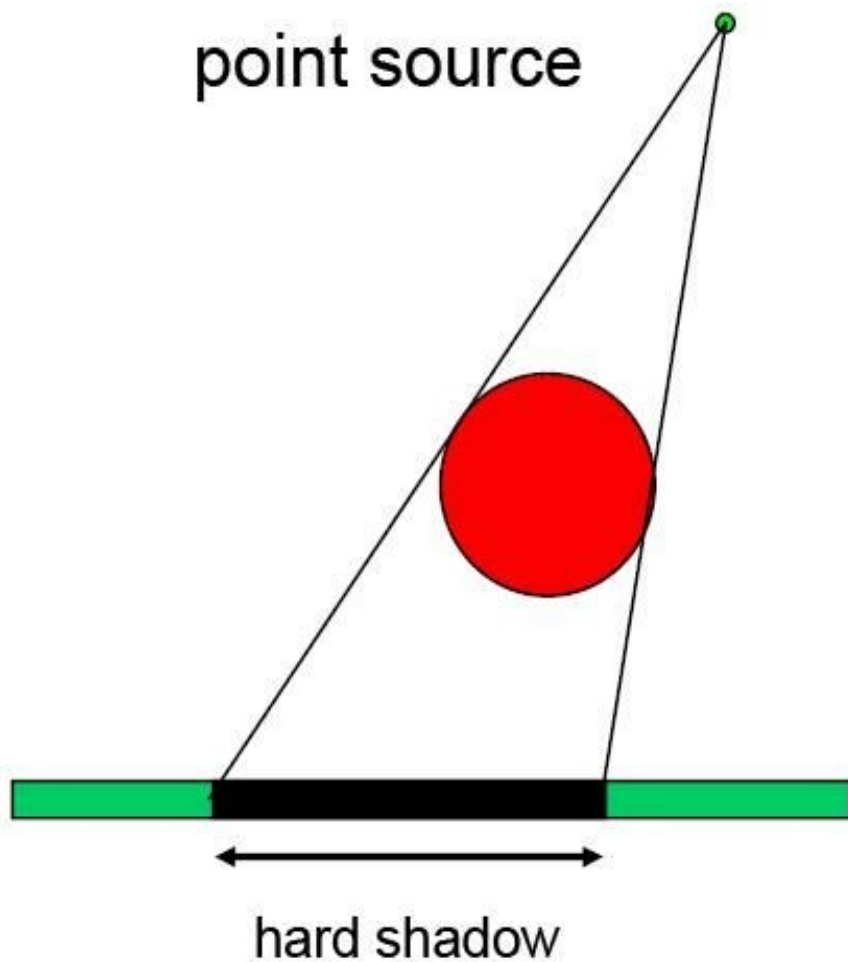
- Definitions
- Light maps
- Approximate shadows
- Planar shadows
- Projective shadows
- Shadow volumes
- Shadow maps



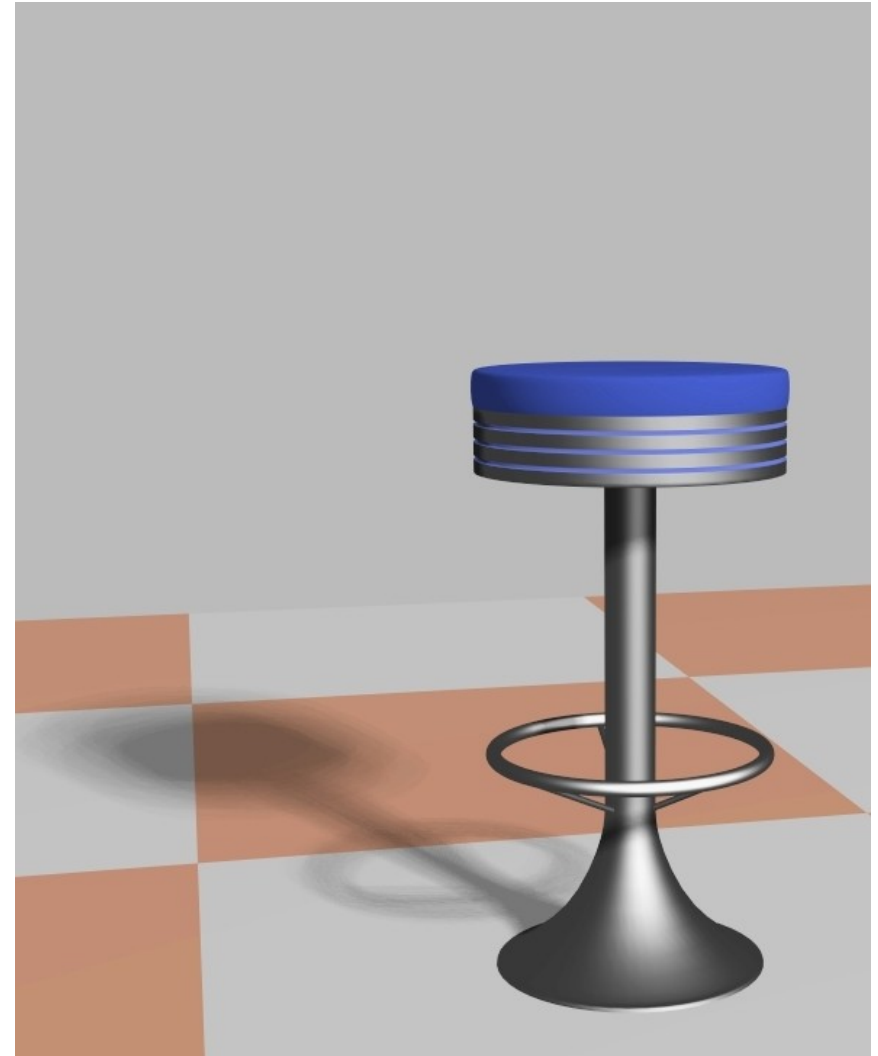
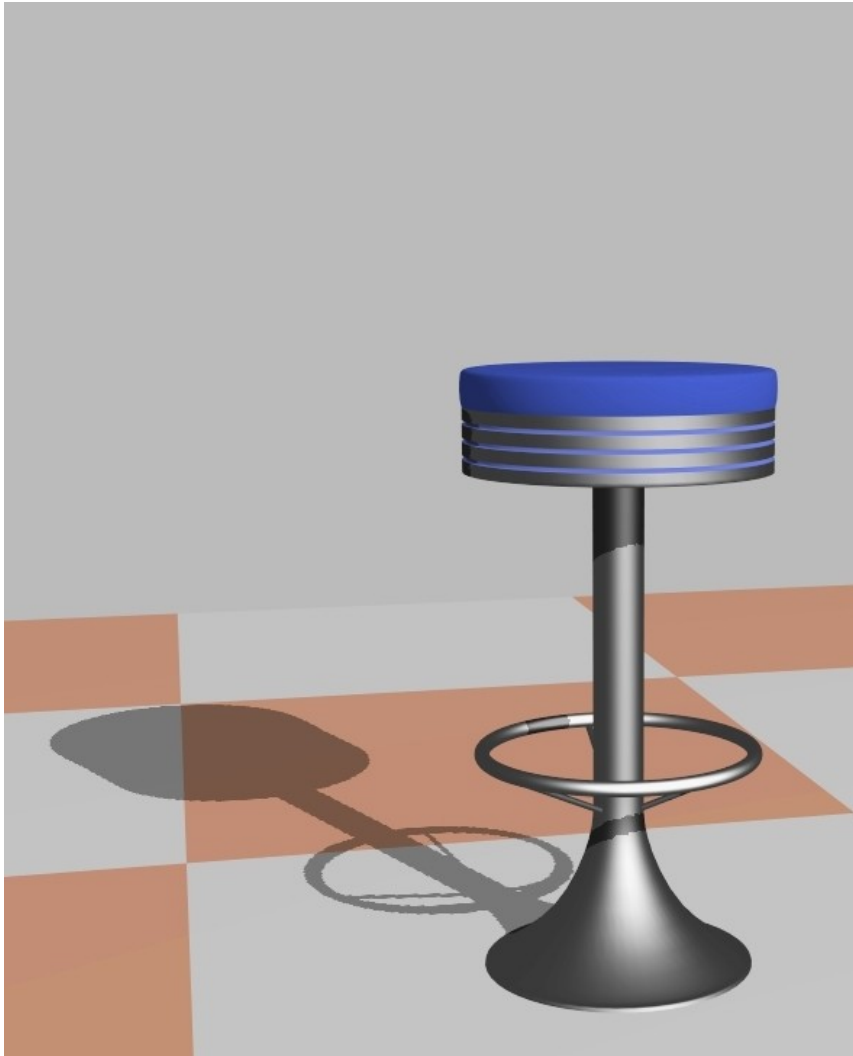
Definition



Hard vs. Soft shadows



Hard vs. Soft shadows



Light maps

- Static objects, lights
- Precomputed (quality)



Light maps

- Filtering

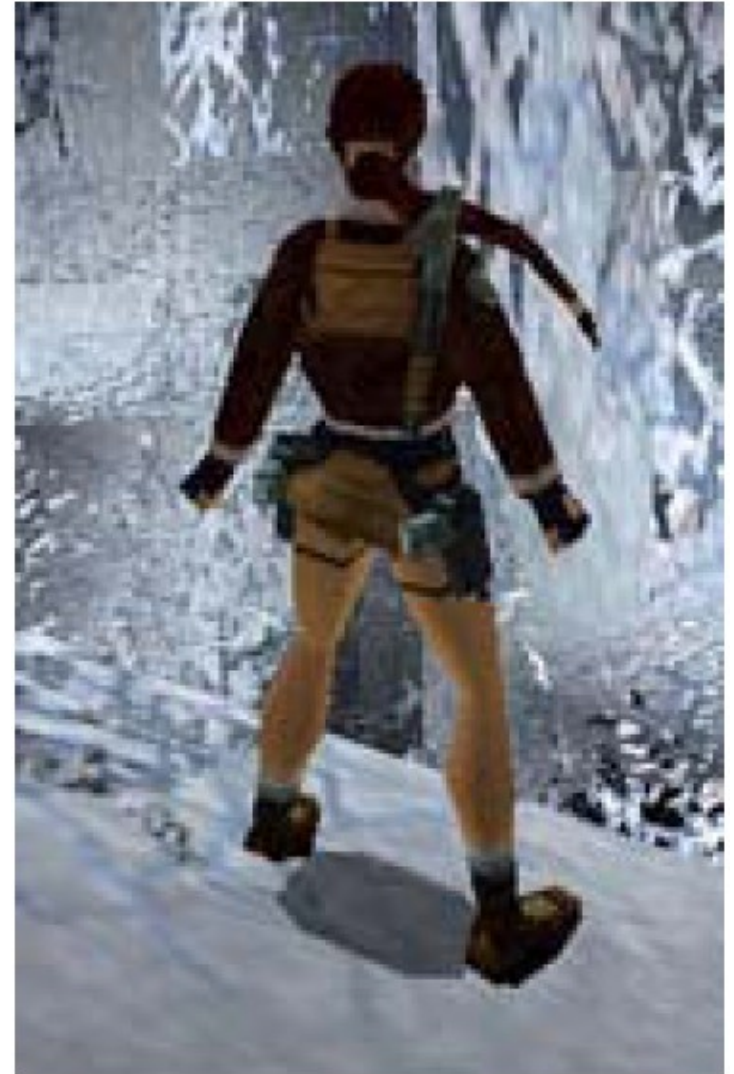


- # samples



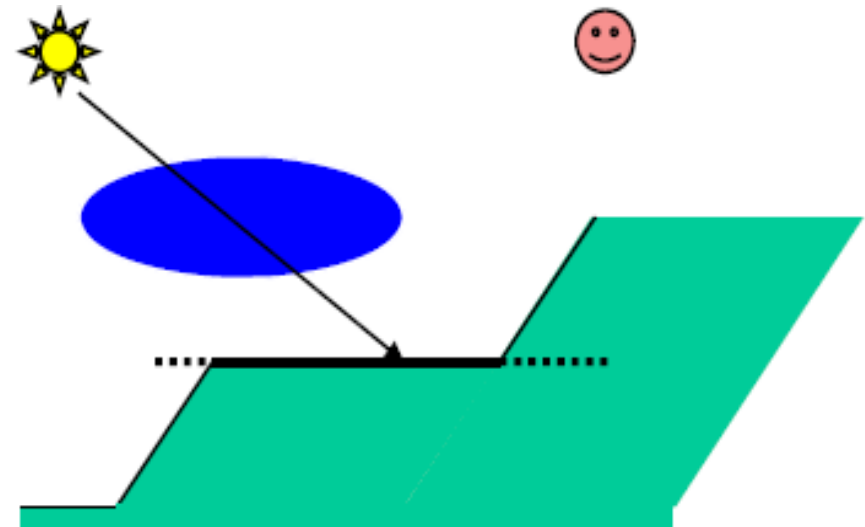
Approximate Shadows

- Better than nothing
- Minimal cost
- Shape not so important



Approximate Shadows (2)

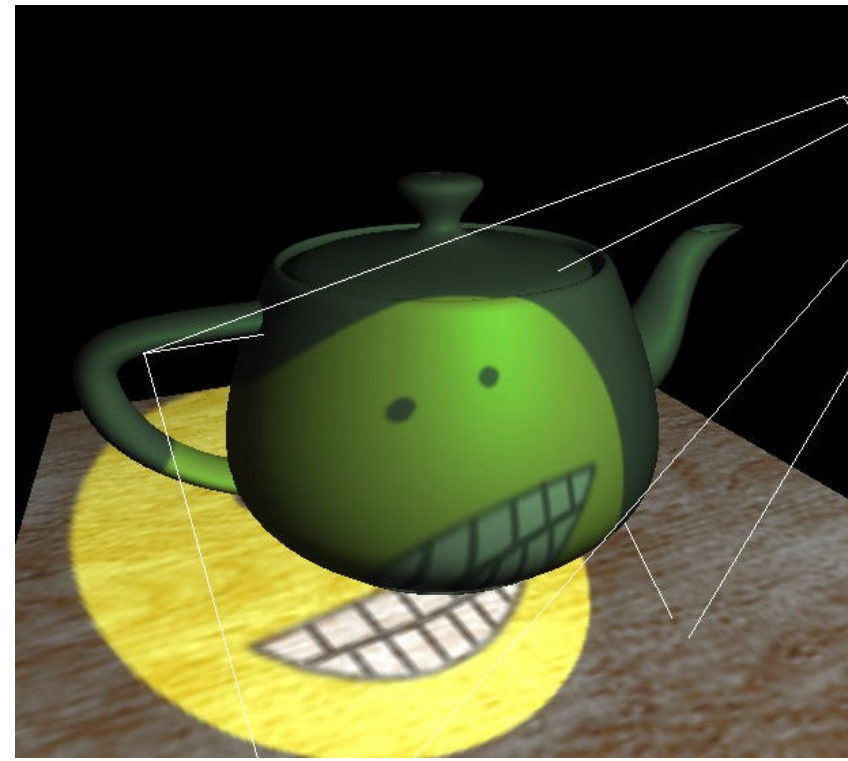
- Dark polygon (texture)
- Cast ray from light through object
- Blend into framebuffer
- Additional transformations



Projective Shadows

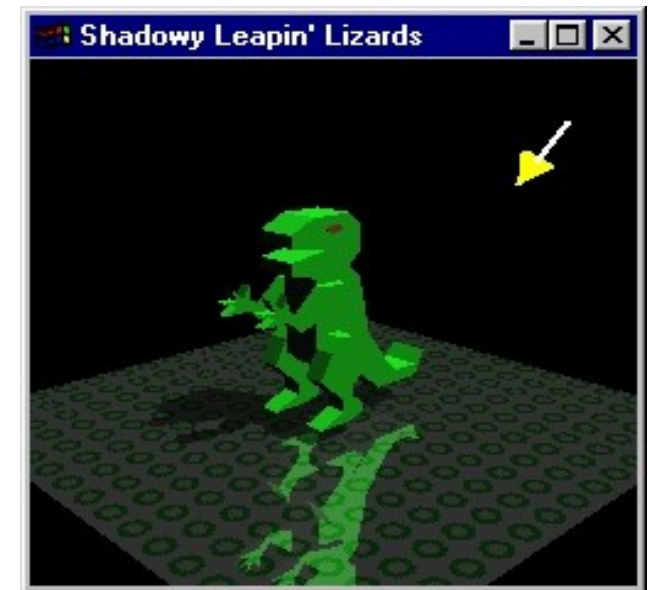
- Render scene from light position
 - All occluders as black, turn off depth test
- Project onto receiver polygons (ground, walls)
 - Projective texture mapping
 - Few, large receivers
- Split receivers and occluders
 - preprocessing
- Curved surfaces
- No self-shadowing
- Artifacts

7.04.2010



Planar Shadows

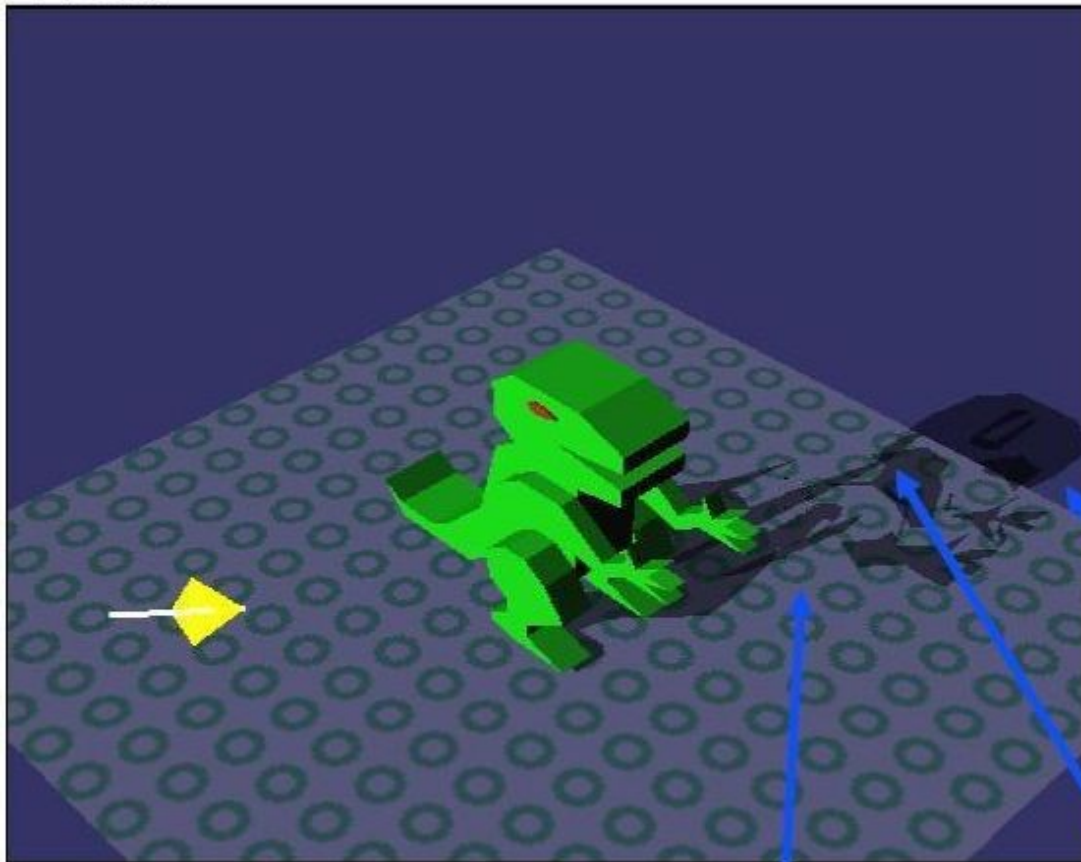
- Project occluder geometry to plane
 - Render over ground
 - Only planar receivers
 - No self-shadowing
-
- Planar soft shadows
 - Sample light source
 - Move plane up and down



Planar Shadows artifacts

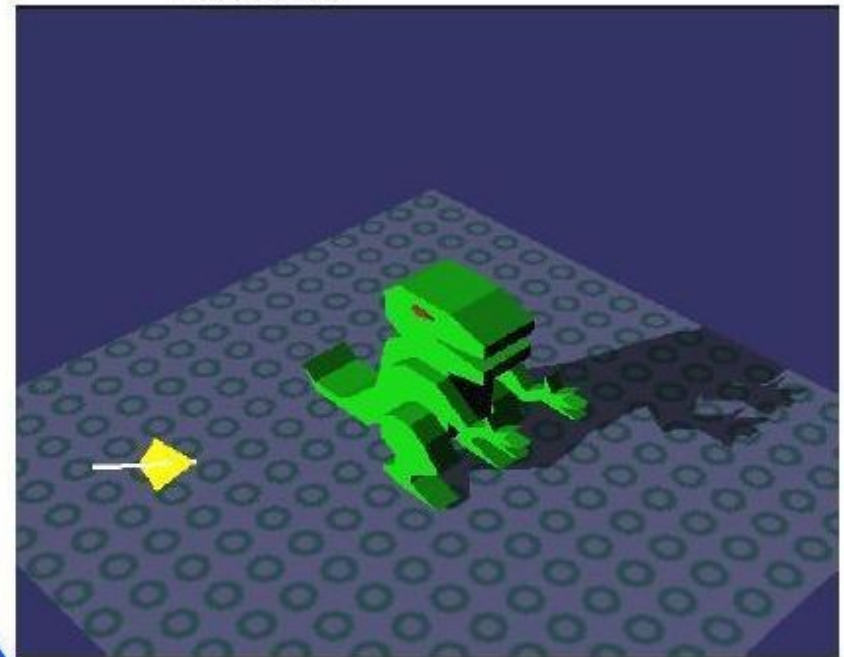
- Stencil buffer remove this artifacts

Bad



Z fighting

Good

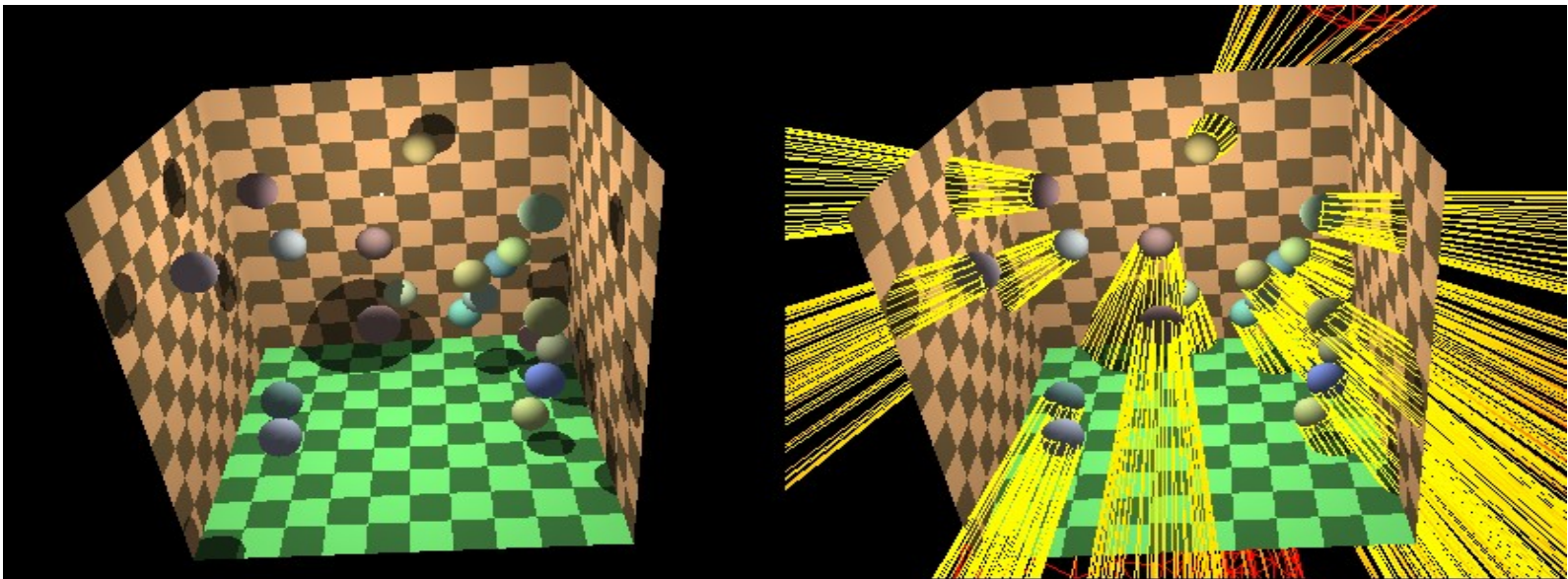


extends off
ground region

double blending

Shadow Volumes

- Create polygonal objects → shadowed volumes
 - View independent
 - Front/back faces → normals
 - Preprocessing / GPU
- Each triangle → 3 projecting quads

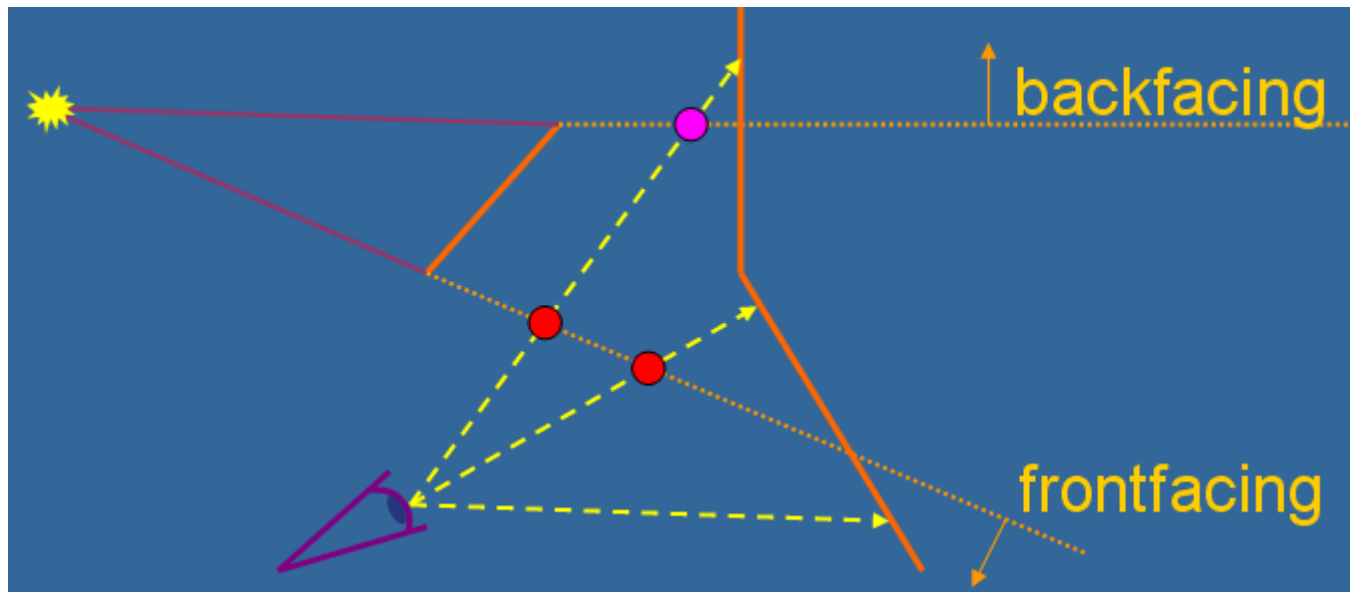


shadowed scene

wireframe shadow volumes

Shadow Volumes

- Test point $\rightarrow$ #polygons between it and the eye
- # frontfacing $>$ backfacing $\rightarrow$ shadow
- Stencil buffer



Shadow Volumes algorithm (z-pass)

1. Clear stencil buffer

Render scene with ambient light

2. Render front faces of shadow volumes (culling)

Turn off depth,color update (depth test on)

Visible polygons increment stencil buffer

3. Render back faces of shadow volumes (culling)

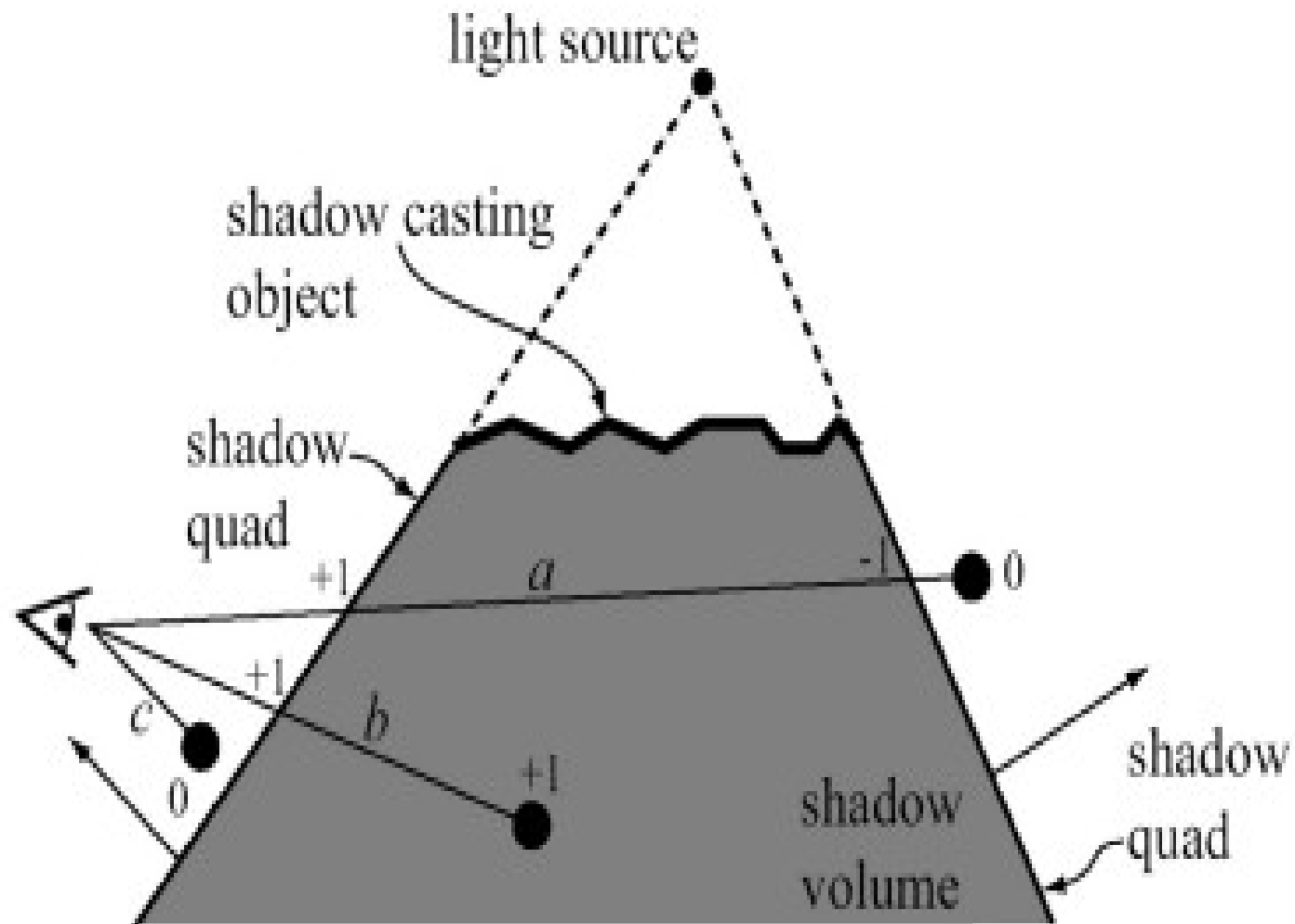
Turn off depth,color update (depth test on)

Visible polygons decrement stencil buffer

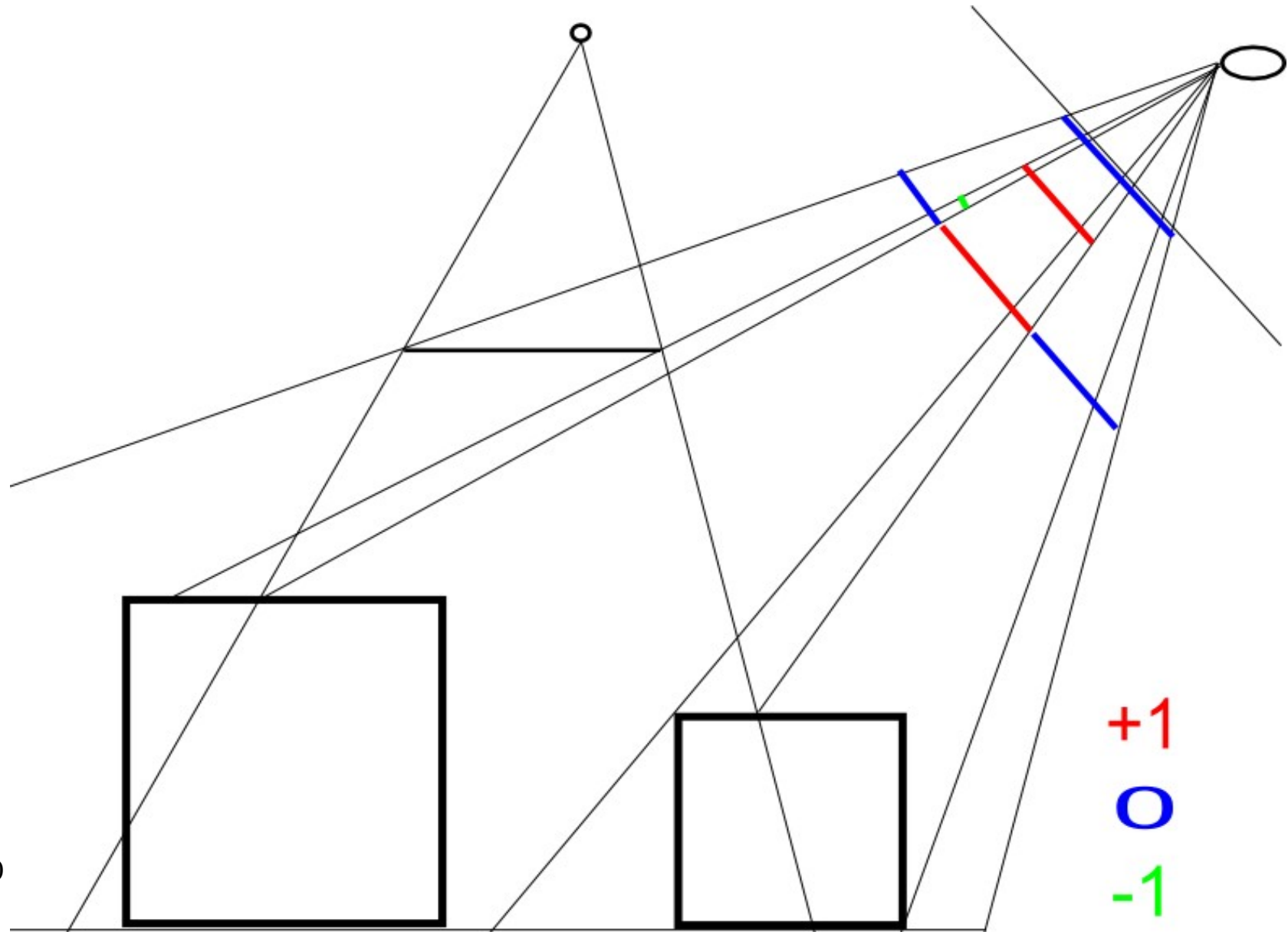
4. Render scene with diffuse & specular light

Update pixels where stencil = 0

Shadow Volumes algorithm



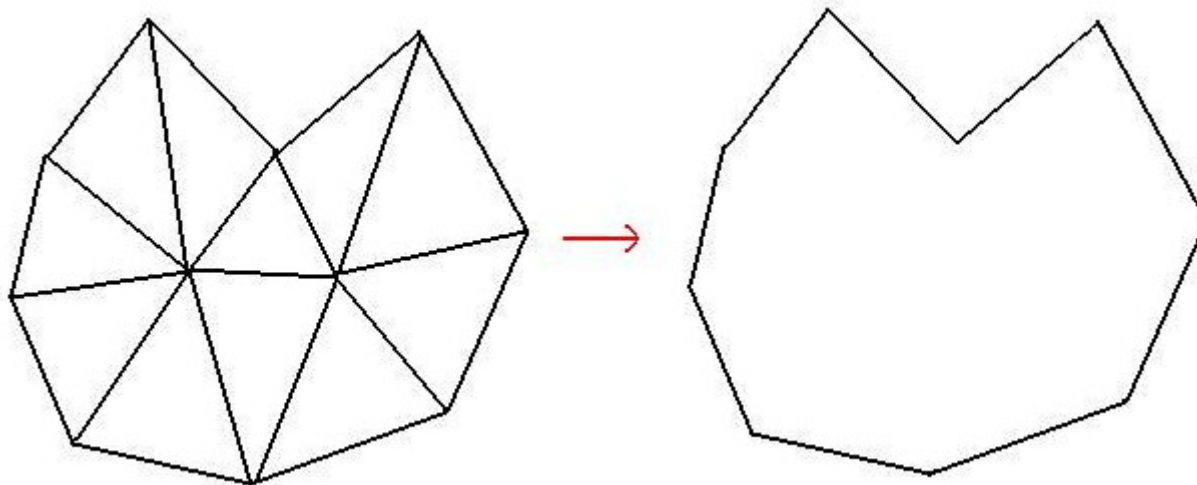
Shadow Volumes algorithm



Shadow Volumes

merging volumes

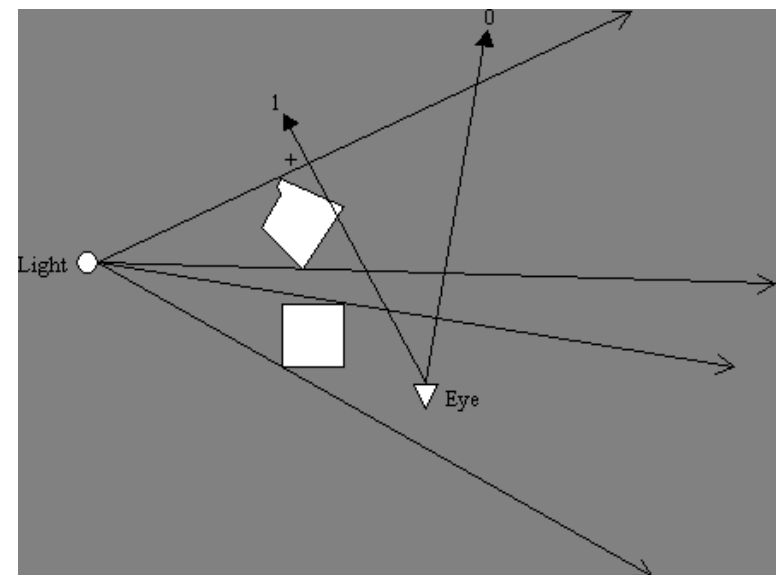
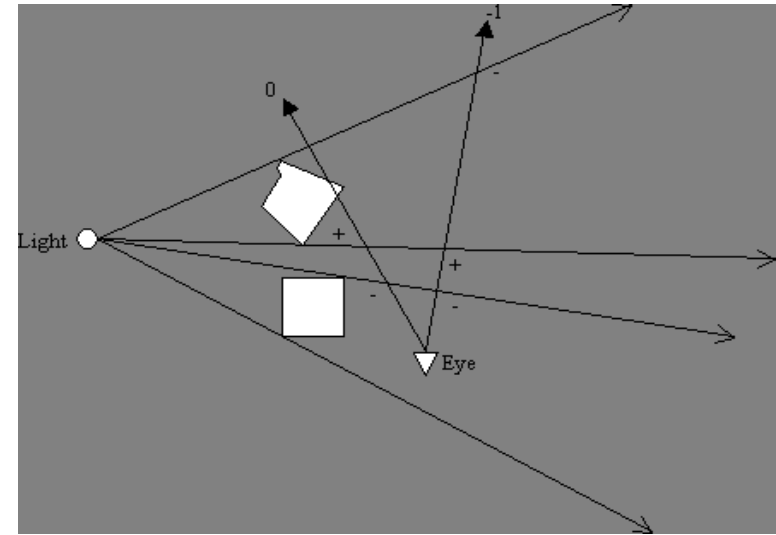
- Two polygons facing the light with common edge
 - Creates front/back facing quad
 - No contribution to stencil buffer
- Silhouette edges
 - Remove interior edges / mark silhouette
 - dot product (light vector, normal)



Shadow Volumes

special cases

- Inside shadow volume
 - Invert meaning of stencil test
- Near clip intersects shadow plane
 - Use z-fail test
 - Shadow volume → depth test fail
 - Back faces first → increment
 - Front faces → decrement
- Far clip (z-fail)
 - Cap shadow volumes



Shadow Volumes

z-pass vs. z-fail

- Z-pass
 - Faster (caps not necessary)
 - Light cap → z-test fails
 - Dark cap → fail, or background
 - Near clip plane → problem
- Z-fail
 - Slower → render caps
 - Far clip plane problem
 - Infinite shadows volumes

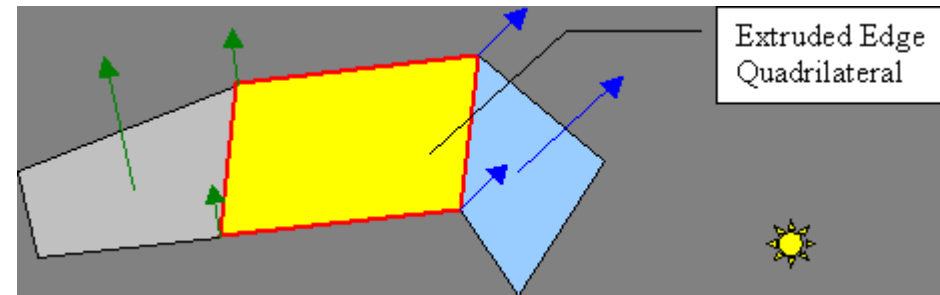
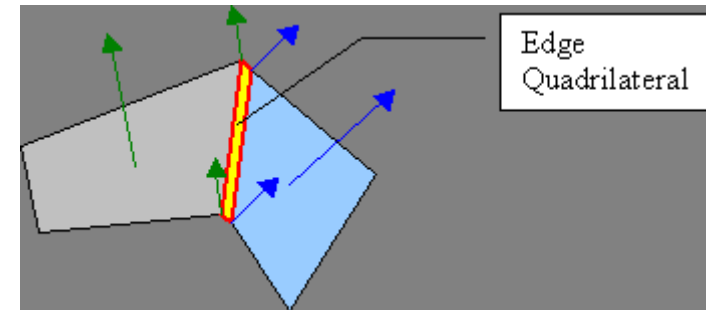
Shadow Volumes

z-pass vs. z-fail

- Combine both techniques
 - Viewport in shadow $\rightarrow$ z-fail
 - Otherwise $\rightarrow$ z-pass
- Far plane clipping
 - Far plane $\rightarrow$ infinity
 - Draw infinite vertices $\rightarrow$ homogeneous coord.

Shadow Volumes creation

- Vertex shader
 - Edge $\rightarrow$ degenerated quad
 - Use both normals
- Geometry shader
 - Generate new quads

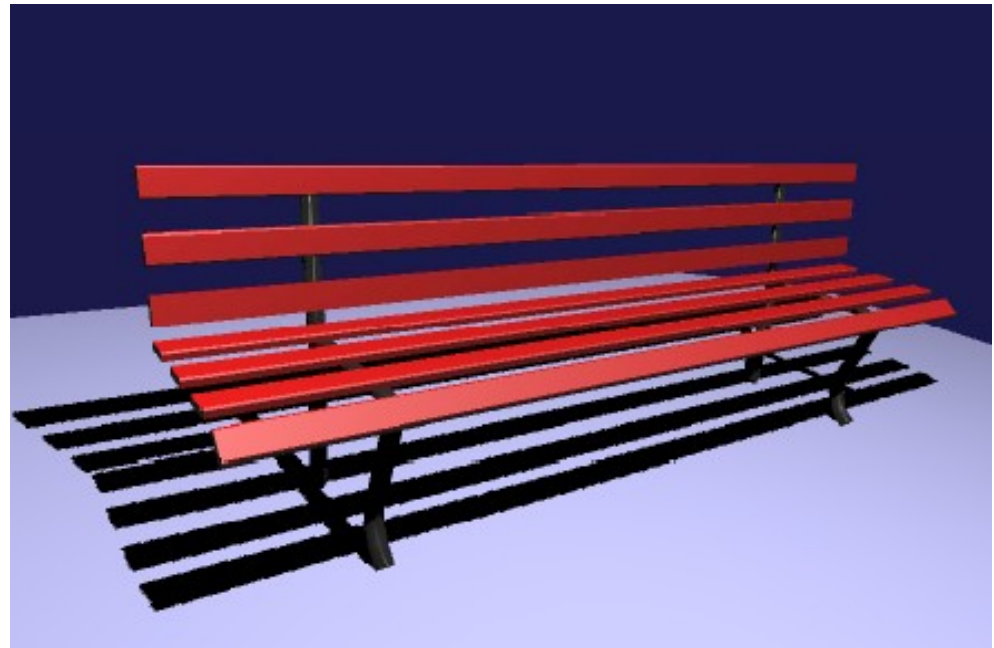


Shadow Volumes summary

- Pros
 - Robust
 - Self-shadowing
 - GPU
- Cons
 - Geometry limited
 - Stencil polygons
 - Multi-pass
 - Hard shadows

Shadow Maps

- Image space - 2 pass algorithm
- Object with holes
- Curved shadows, curved surfaces
- ARB_shadow



Shadow Maps

- Render scene from light position
 - Depth buffer $\rightarrow$ shadow map
 - Distance D of objects to light
- Render scene normally
 - For each pixel, calculate distance S to the light
 - Transform fragments to light space
 - Compare with shadow map (light space)
 - If $S > D \rightarrow$ shadow

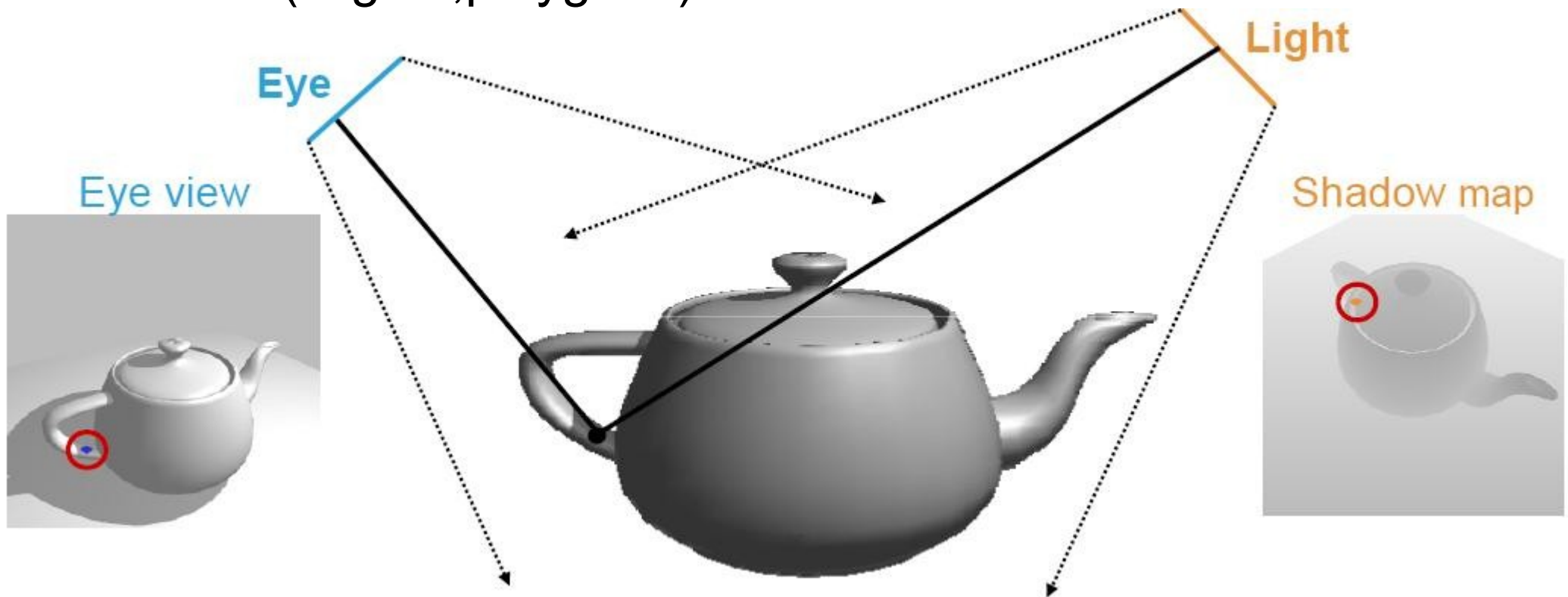
Shadow Maps

- Pros

- Supported self-shadowing
- Cost is linear
(#lights, polygons)

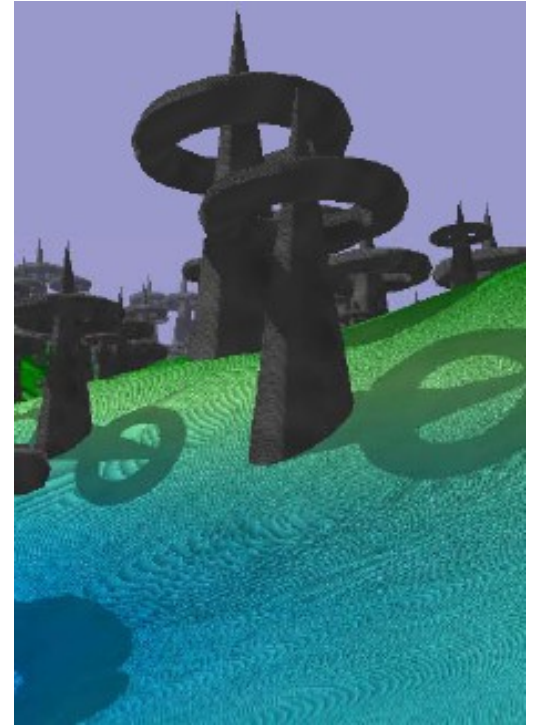
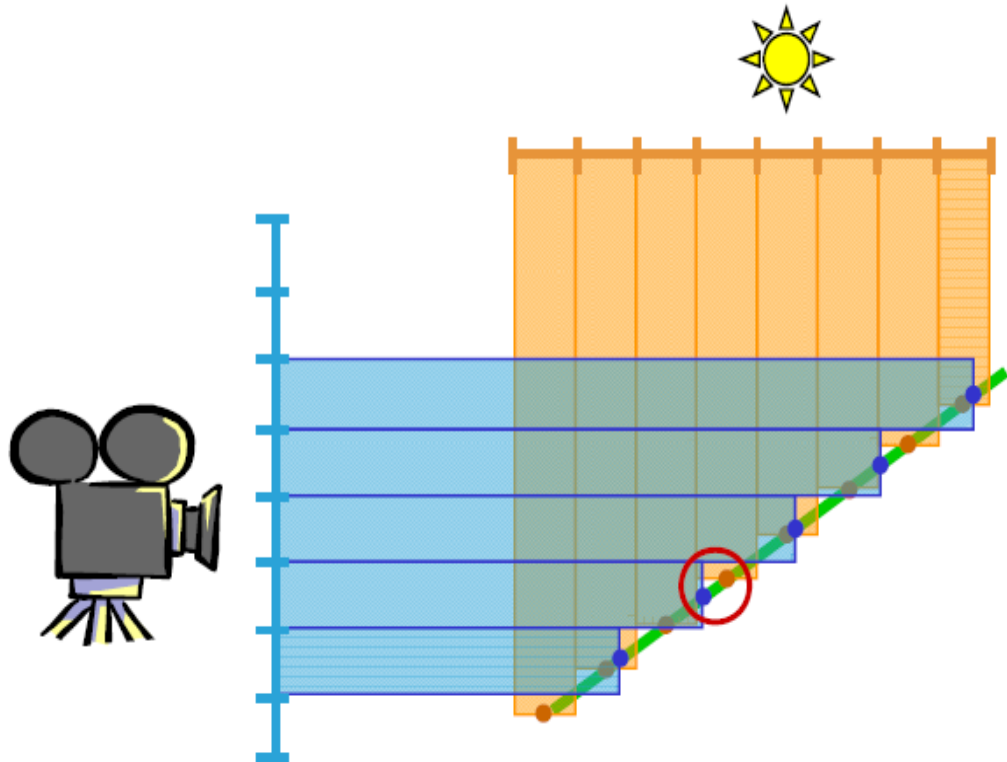
- Cons

- Self-shadowing aliasing
- Shadow map resolution



Shadow Maps

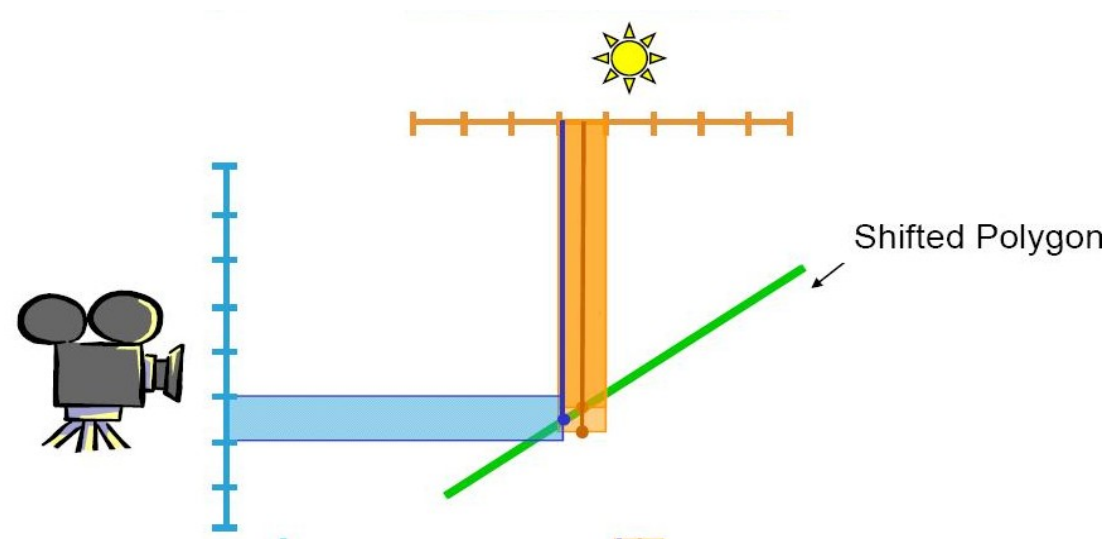
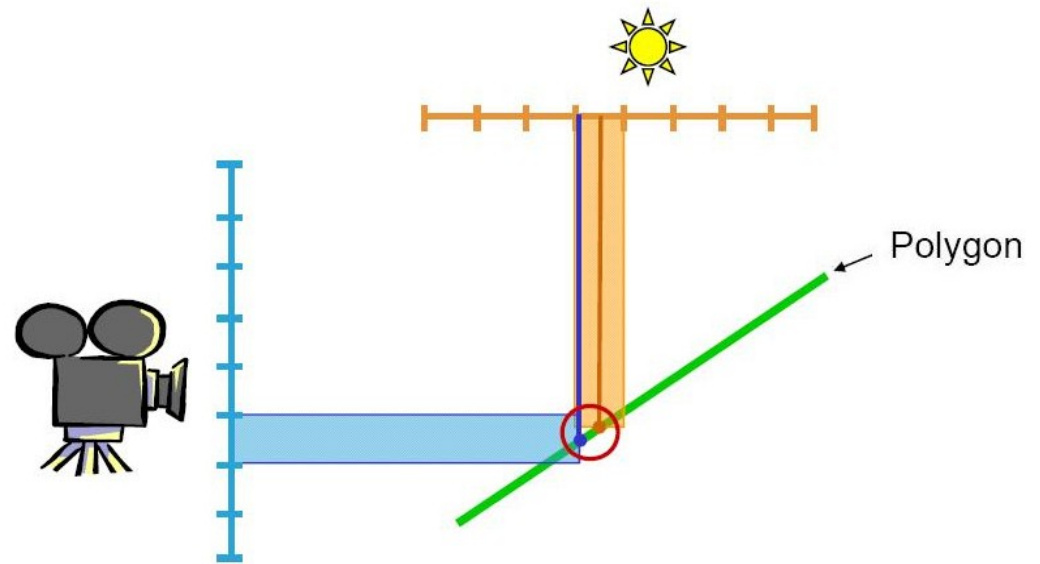
Incorrect self-shadowing



Shadow Maps

Incorrect self-shadowing

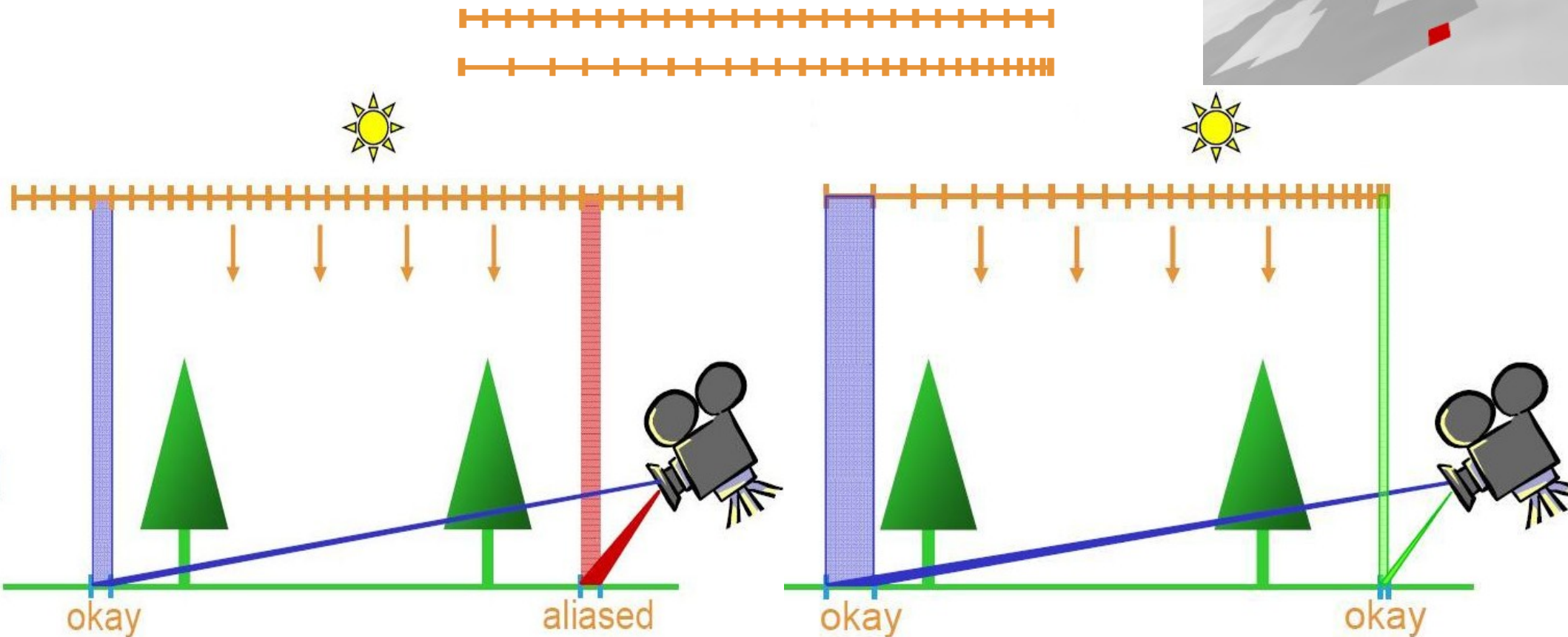
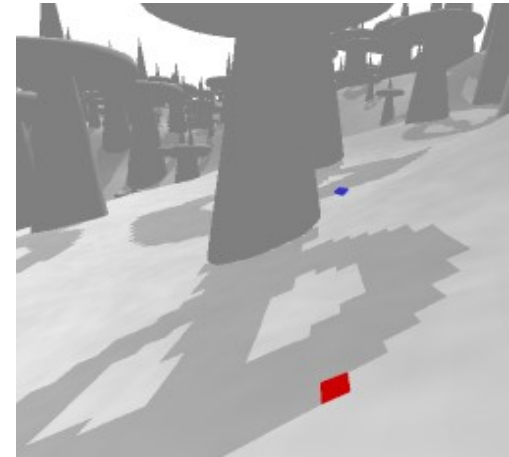
- `glPolygonOffset`
- Epsilon (shader)
- Bias
 - Constant
 - Slope-scale



Shadow Maps

Perspective aliasing

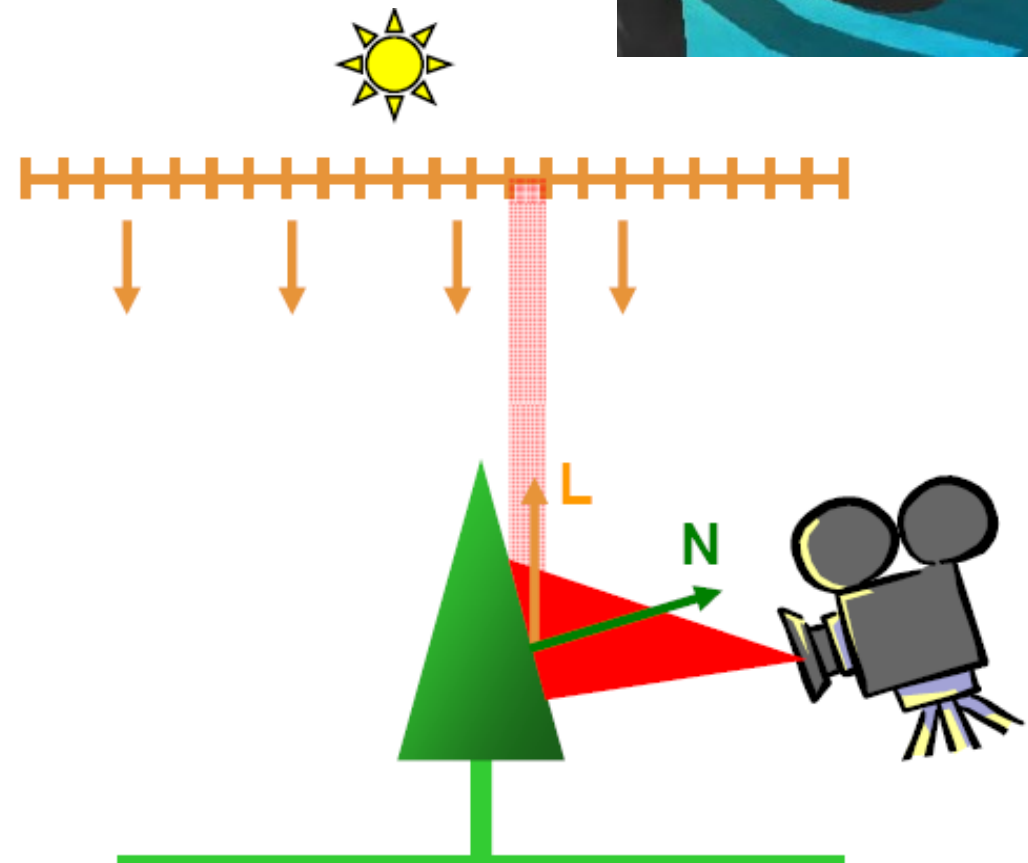
- (In)Sufficient resolution (near/far)
- Redistribute values in shadow map



Shadow Maps

Projective aliasing

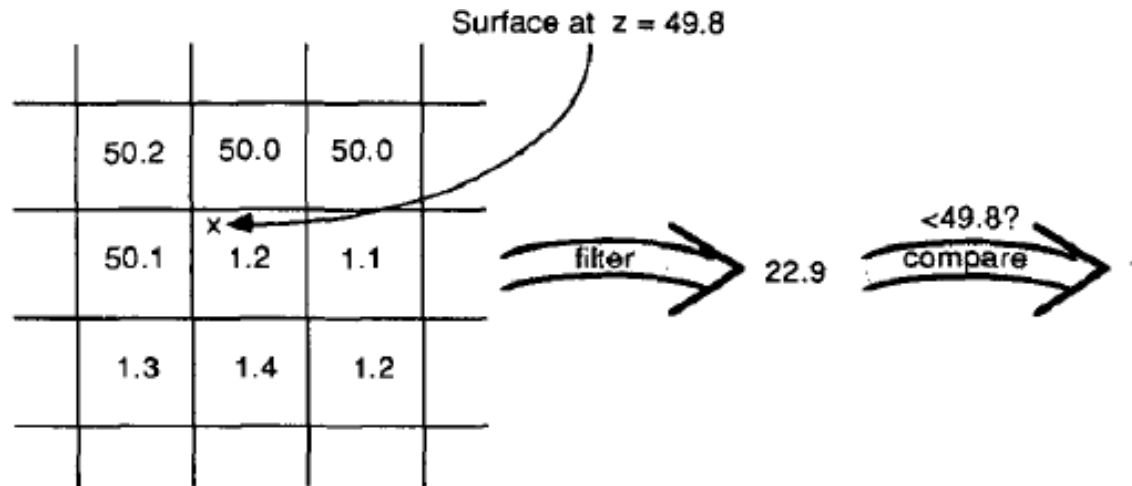
- Diffuse light $\rightarrow$ small intensity
- Ambient light $\rightarrow$ small intensity
- Specular light $\rightarrow$ ok
- Blur shadows
 - Separate texture



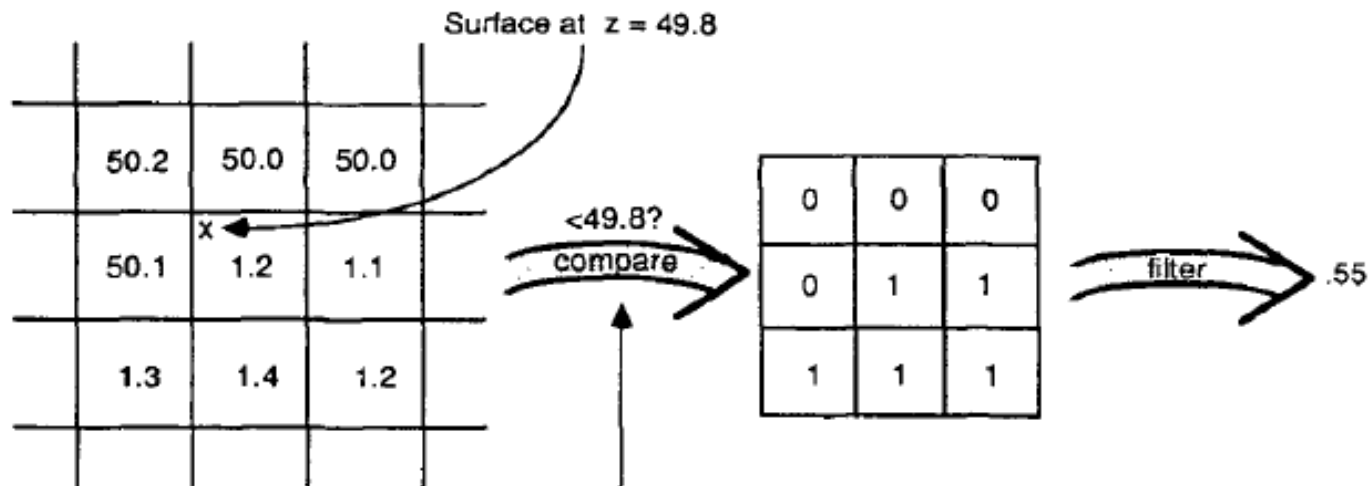
Shadow Maps

- Resolution mismatch
 - Perspective shadow maps
- Percentage closer filtering
 - Built in HW
 - Filter lookup result
- Demo

Percentage closer filtering



a) Ordinary texture map filtering. Does not work for depth maps.



Sample Transform Step

b) Percentage closer filtering.

References

- Real-time rendering slides
- <http://www.cg.tuwien.ac.at/courses/Realtime/>
- GeForce 8 and 9 Series GPU Programming
- <http://en.wikipedia.org/wiki/>
- <http://flickr.com/photos/buou/2126755136/>
- http://vr.kaist.ac.kr/_r011.htm
- http://www.vis.uni-stuttgart.de/eng/teaching/lecture/ws04/seminar_spiele/bsp/
- http://developer.nvidia.com/object/hwshadowmap_paper.html
- <http://www.sgi.com/products/software/opengl/examples/glut/examples/>
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- http://www.devmaster.net/articles/shadow_techniques/
- <http://www.gamedev.net/reference/articles/article1990.asp>
- <http://www.gamedev.net/reference/articles/article1873.asp>
- <http://graphics.pixar.com/library/ShadowMaps/paper.pdf>

Questions ?