Rendering Fake Soft Shadows with Smoothies

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Clarification

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Real-Time Soft Shadows

SIGGRAPH2004

Goals:

- Interactive framerates
- Hardware-accelerated
- Good image quality
- Dynamic environments

NVIDIA

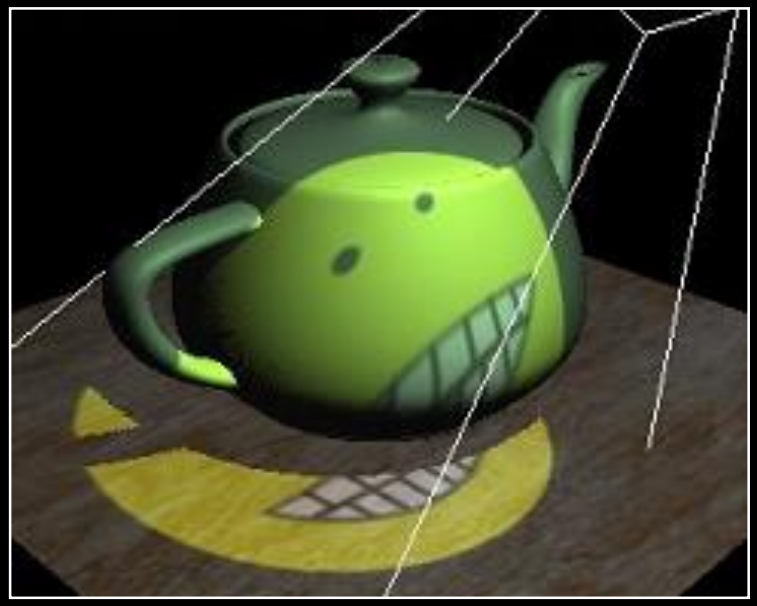
Challenge:

- How to balance quality and performance?

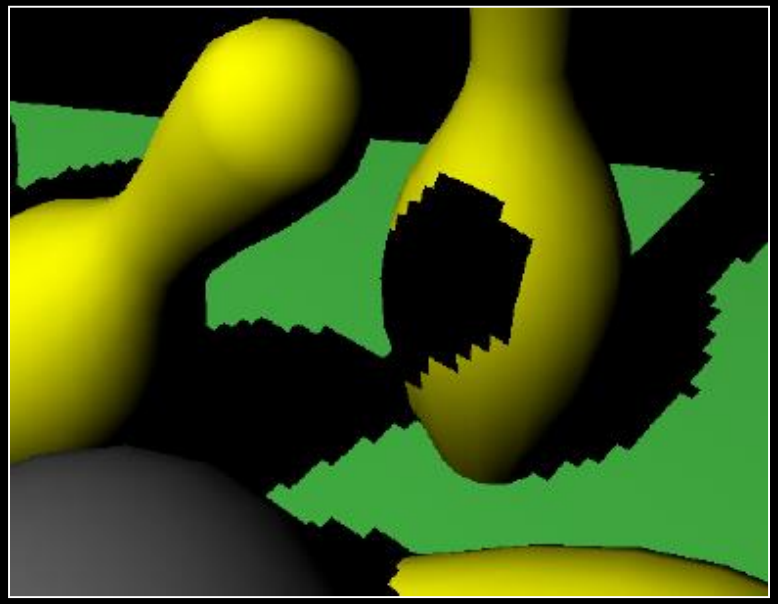
Ordinary Shadow Maps

Image-space algorithm:

- Fast and simple
- Supported in hardware
- Aliasing artifacts



NVIDIA



Sen et al. [SIGGRAPH 2003]

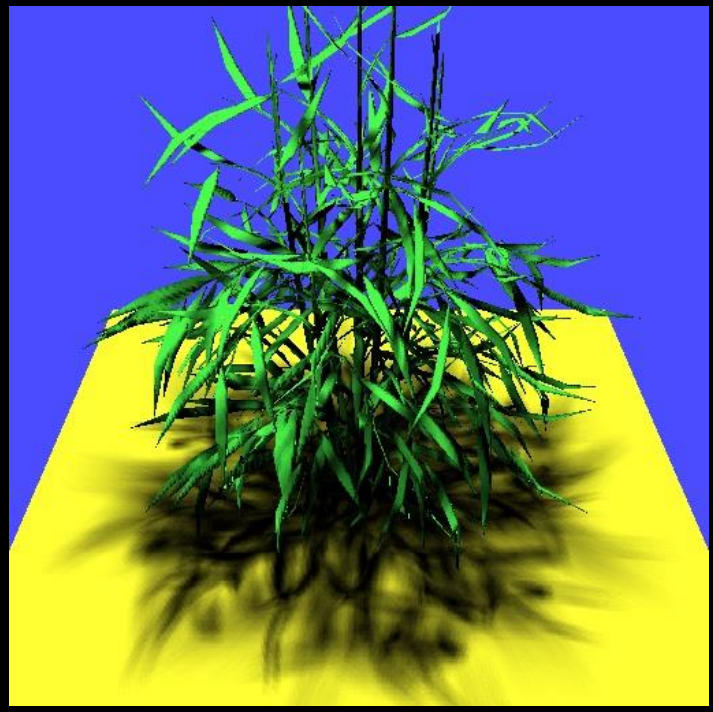
Soft Shadow Maps

Techniques:

- Filtering
- Stochastic sampling
- Image warping

Examples:

- Percentage closer filtering (Reeves et al., SIG1987)
- Deep shadow maps (Lokovic and Veach, SIG2000)

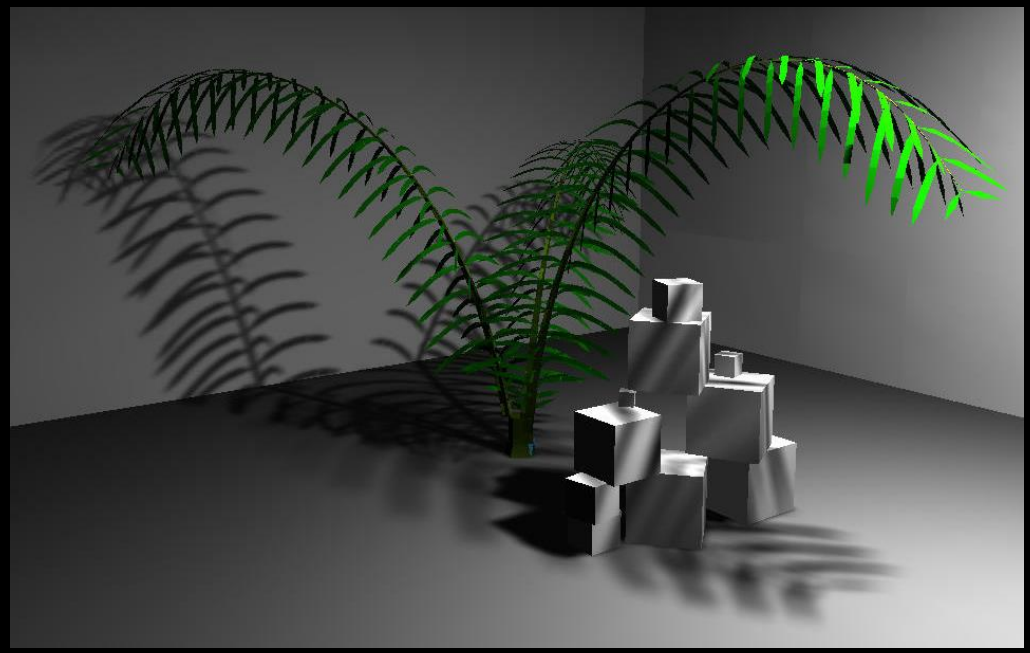


Agrawala et al. [SIGGRAPH 2000]

But: need dense sampling to minimize artifacts

Soft Shadow Maps (cont.)

Approximations



Soler and Sillion

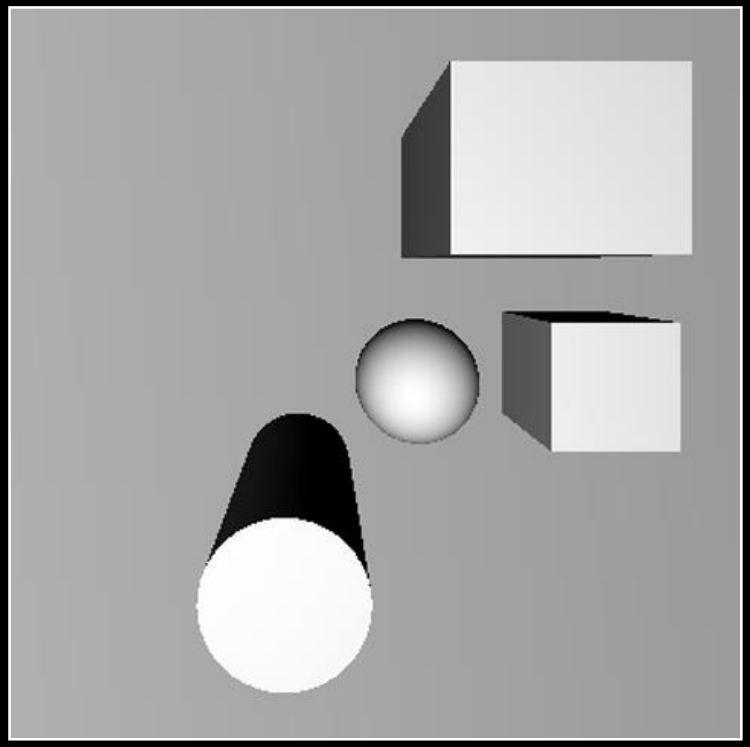
Examples:

- Convolution (Soler and Sillion, SIGGRAPH 1998)
- Linear lights (Heidrich et al., EGRW 2000)

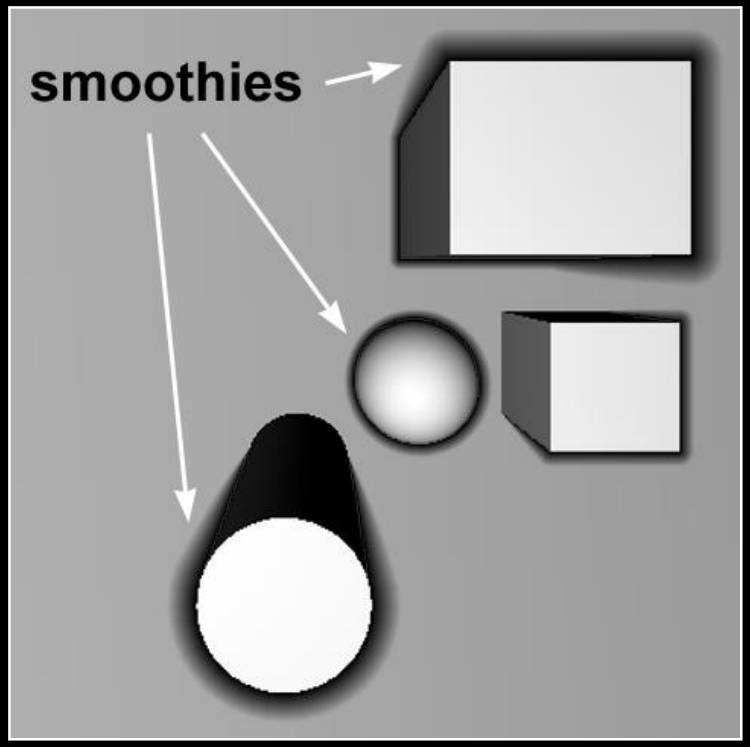
Idea

Extend basic shadow map approach

Extra primitives (smoothies) soften shadows



light's view (blockers only)

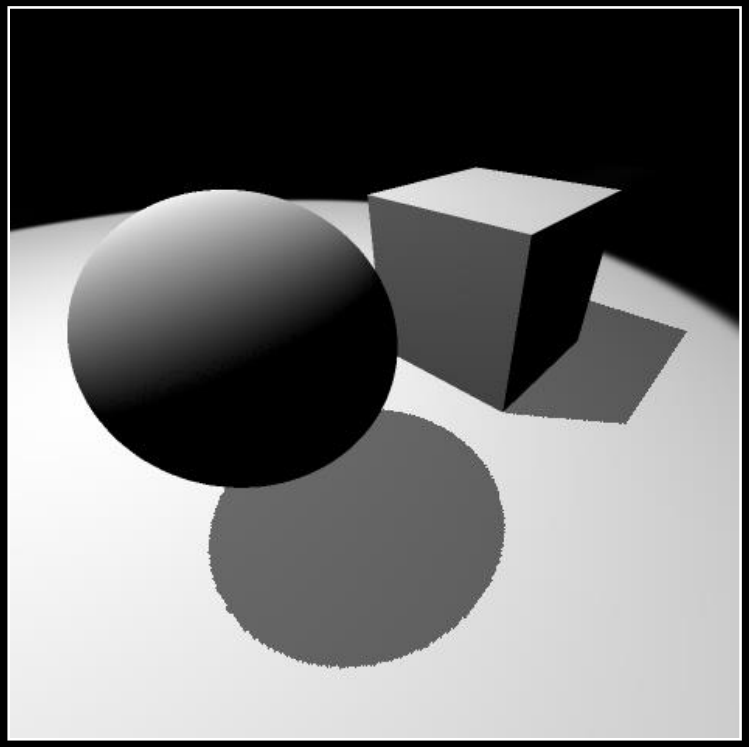


light's view (blockers + smoothies)

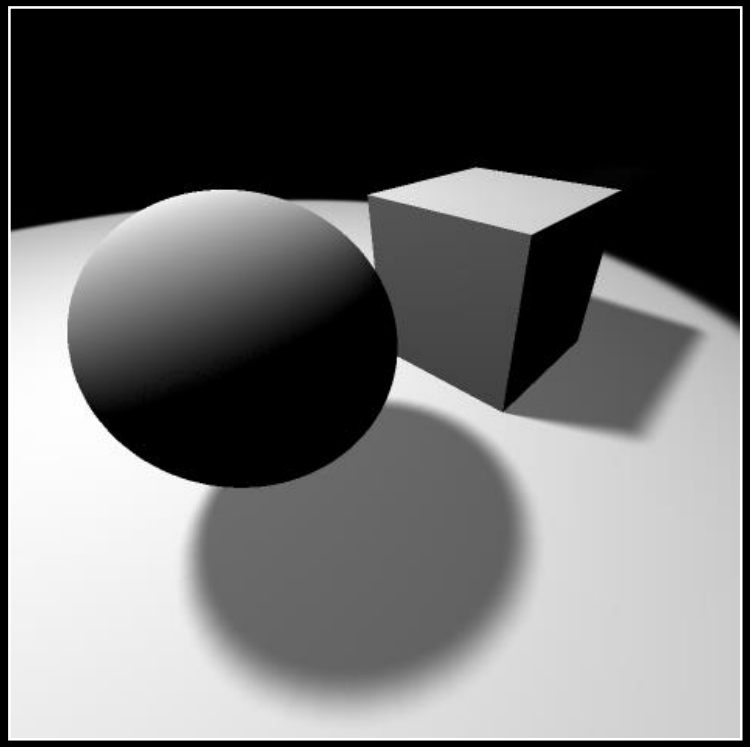
Fake Soft Shadows

Shadows not geometrically correct

Shadows appear qualitatively like soft shadows



Hard shadows

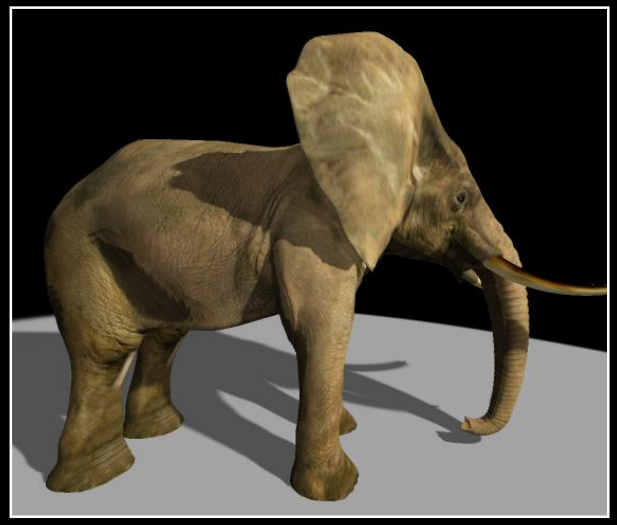


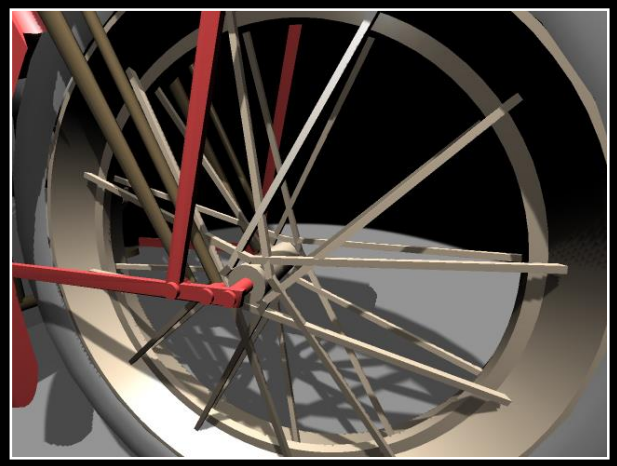
Fake soft shadows

Smoothie Algorithm

Properties:

- Creates soft shadow edges
- Hides aliasing artifacts
- Efficient (object / image space)
- Hardware-accelerated
- Supports dynamic scenes





References

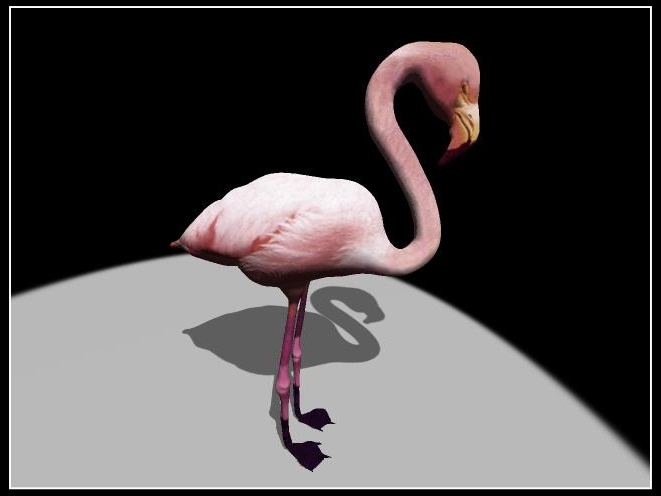
SIGGRAPH2004

Rendering Fake Soft Shadows with Smoothies

- E. Chan and F. Durand [EGSR 2003]

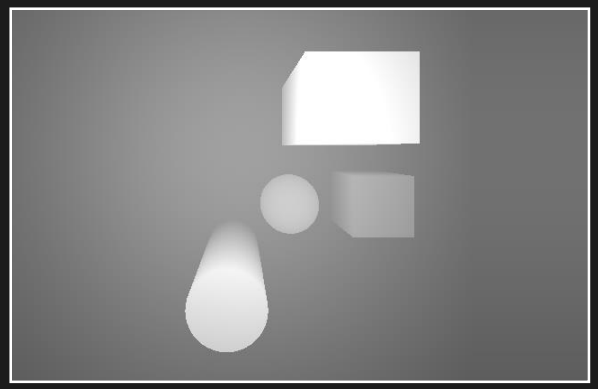
Penumbra Maps

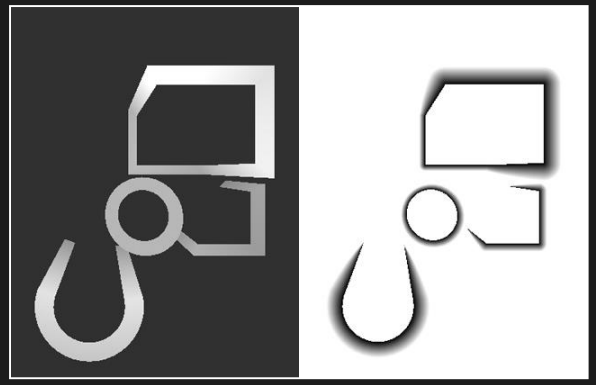
- C. Wyman and C. Hansen [EGSR 2003]

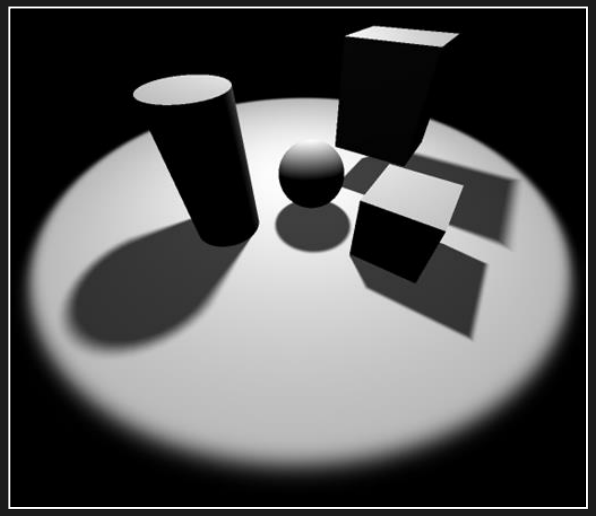


Algorithm

Algorithm Overview



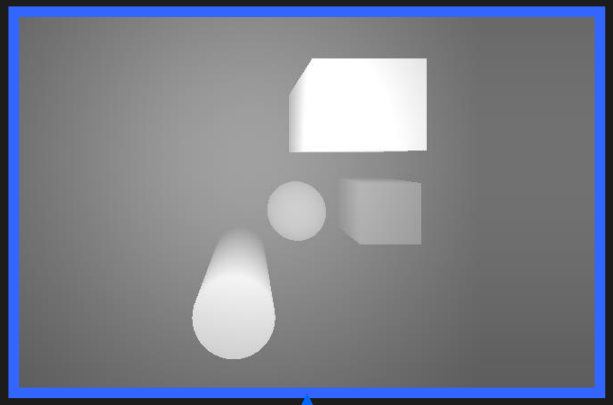


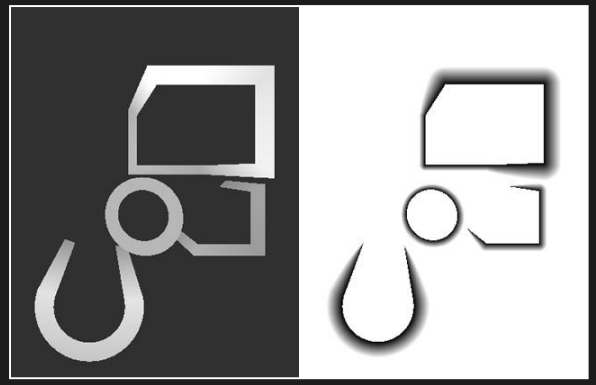


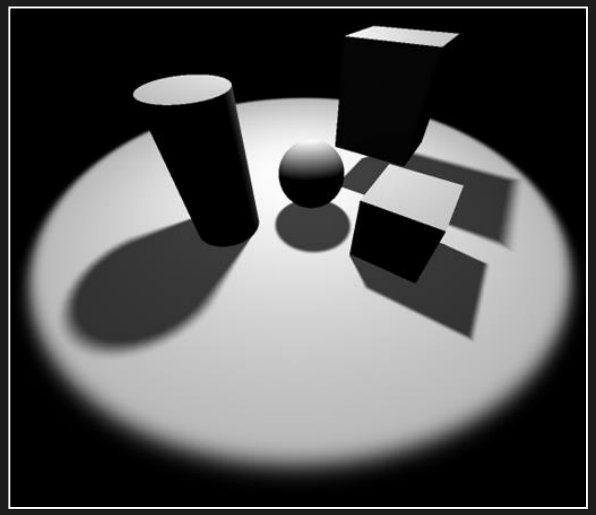
Focus on concepts

Implementation details later

Algorithm Overview



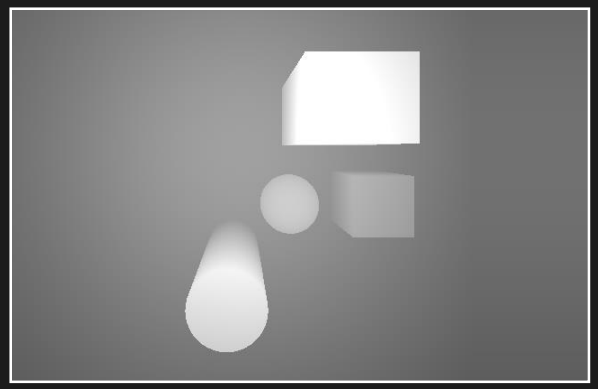


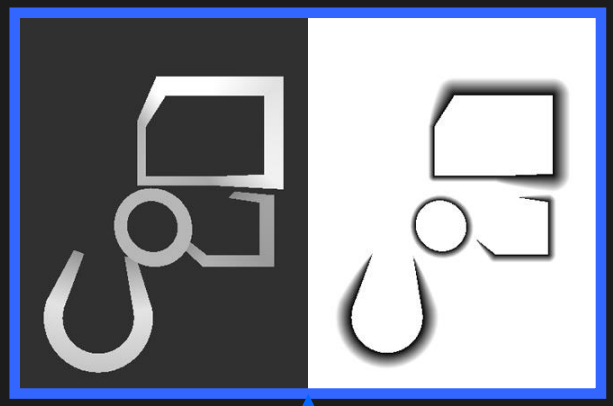


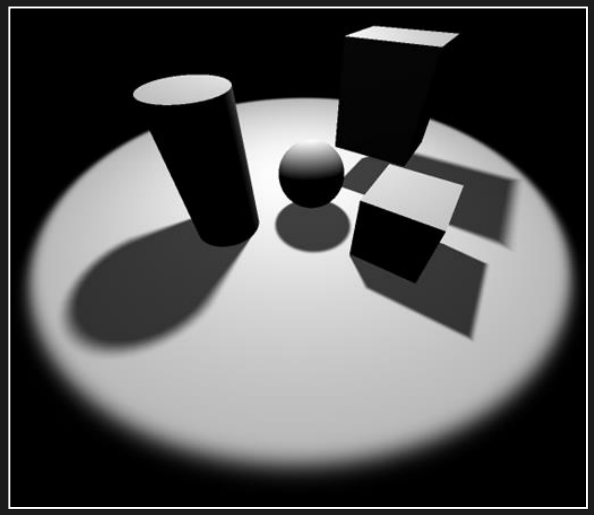
Step 1

Create depth map

Algorithm Overview



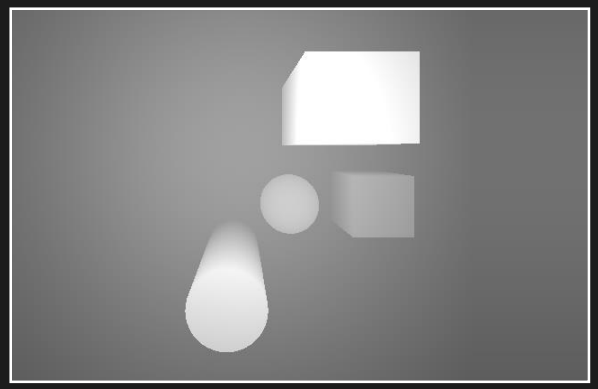


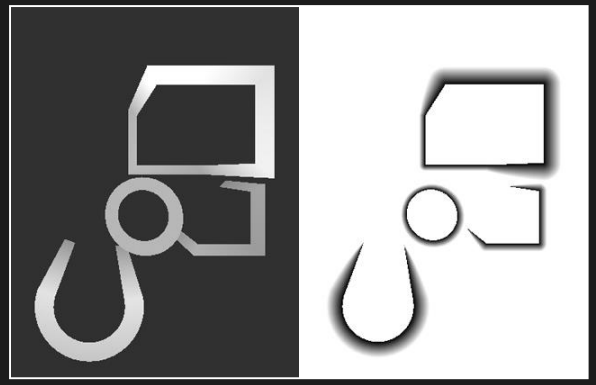


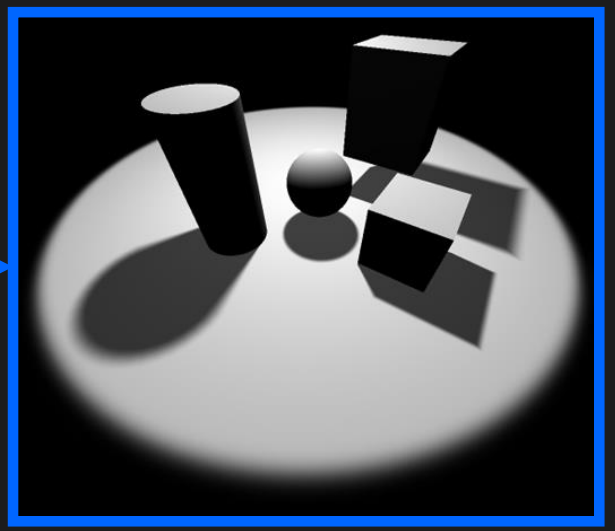
Step 2

Create smoothie buffer

Algorithm Overview





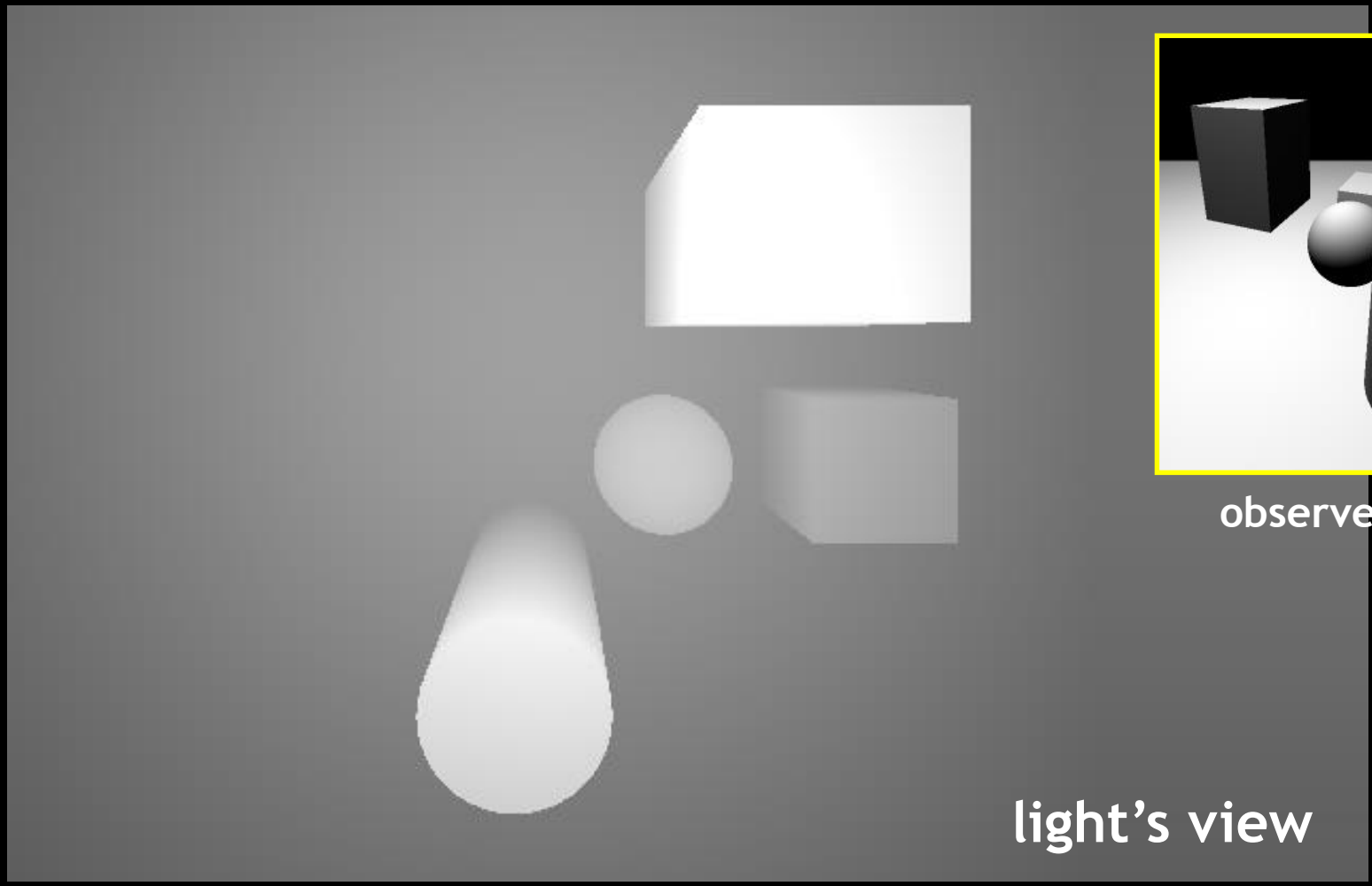


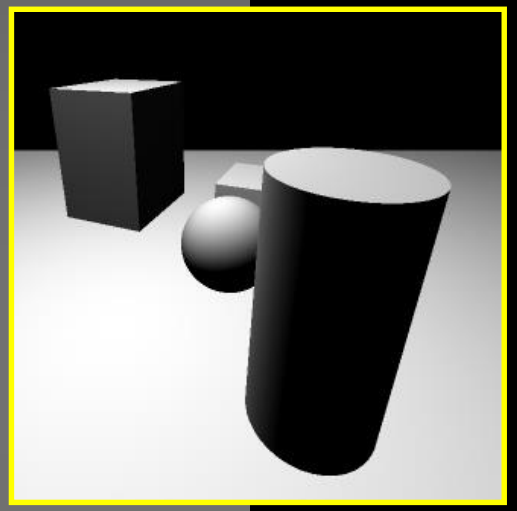
Step 3

Render scene + shadows

Create Shadow Map

Render blockers into depth map



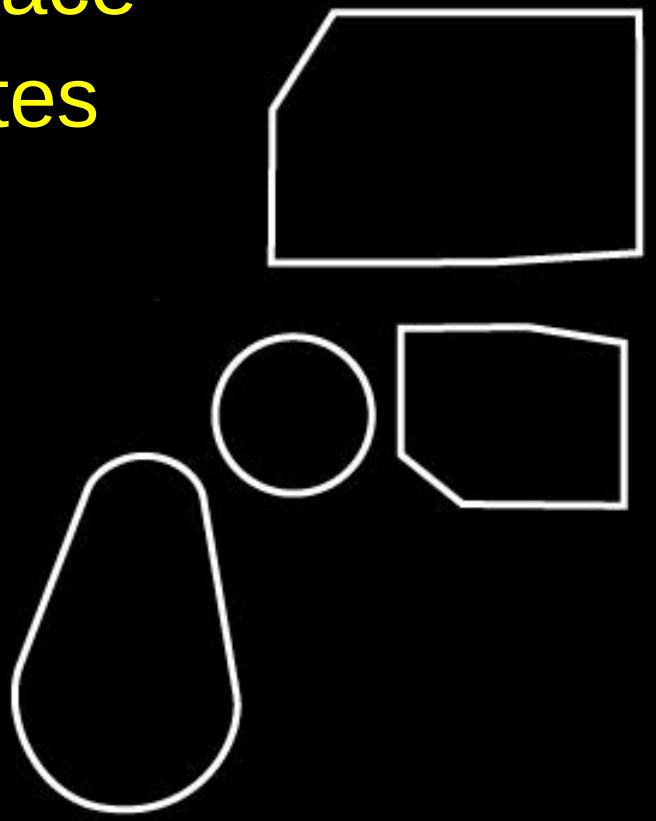


observer's view

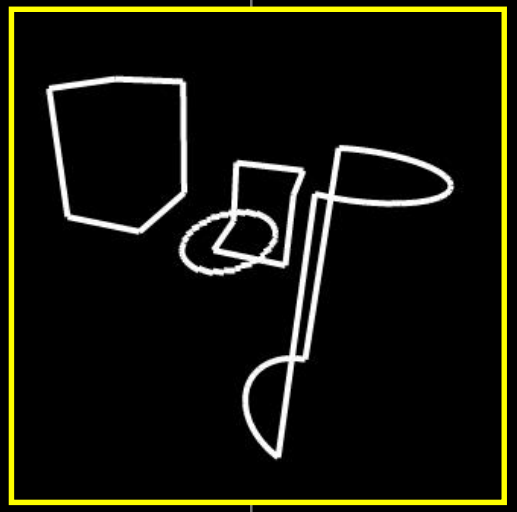
Find Silhouette Edges

Find blockers' silhouette edges in object space

object-space silhouettes



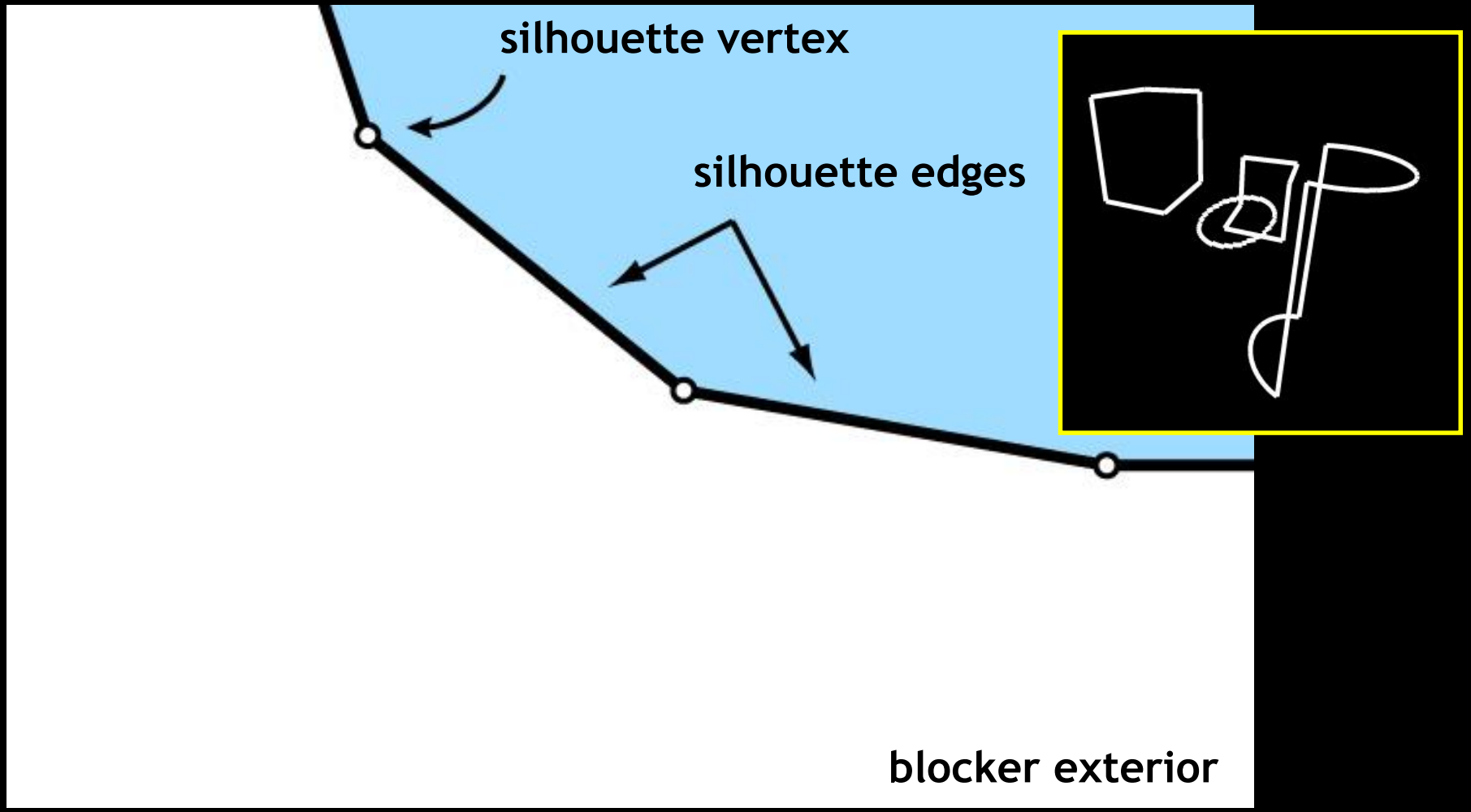
light's view



observer's view

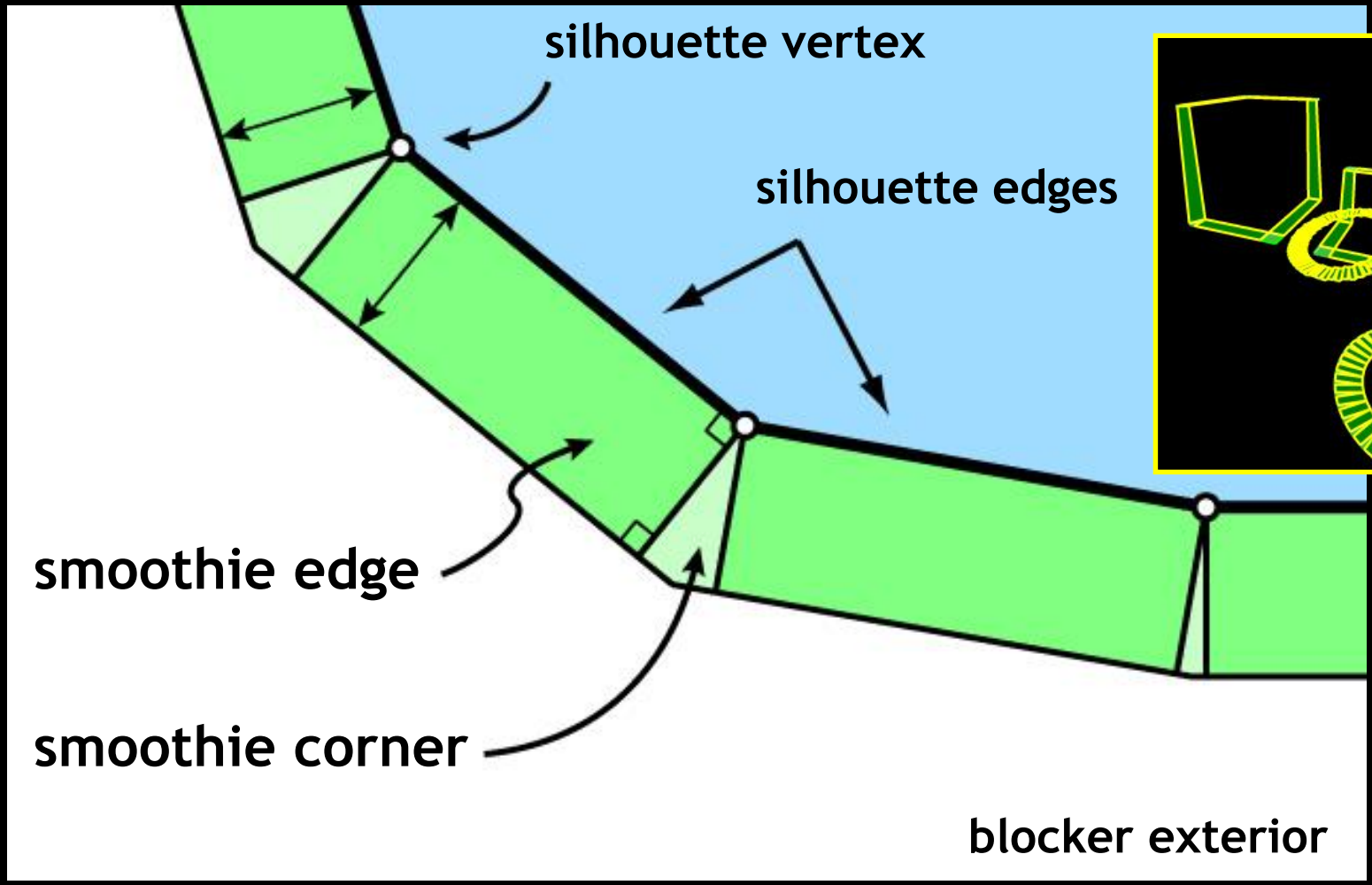
Construct Smoothies

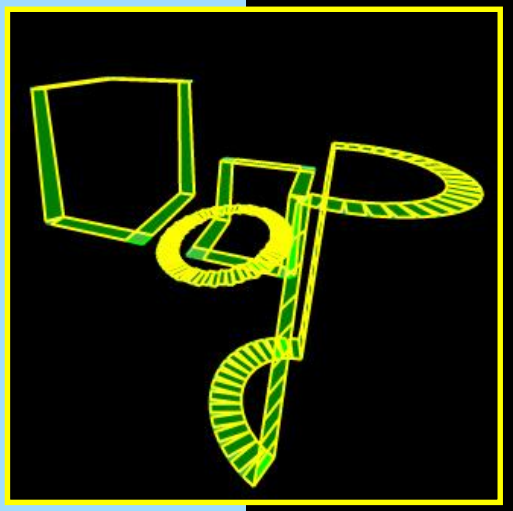
Blocker only:



Construct Smoothies

Blocker + smoothies:



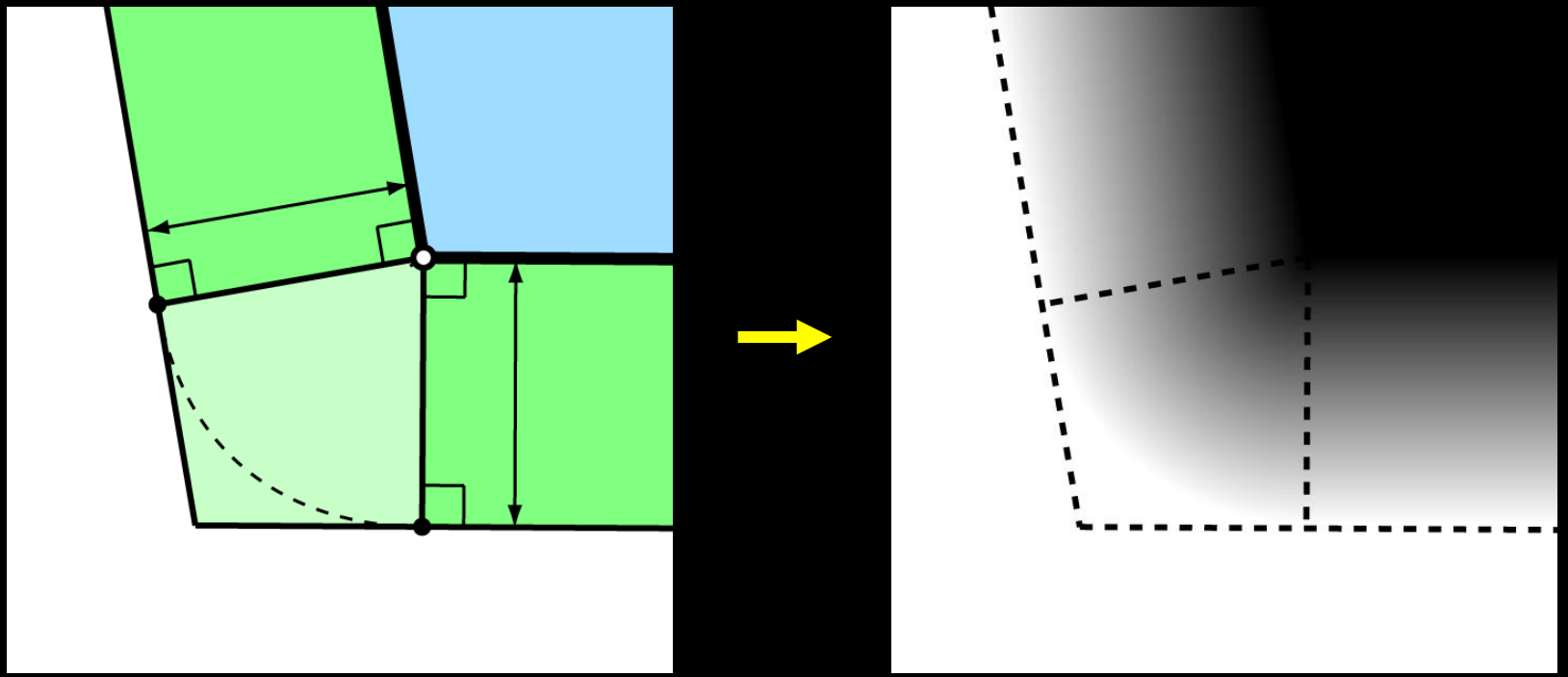


Construct Smoothies

SIGGRAPH2004

Smoothie edges are fixed-width rectangles in screen space

Smoothie corners connect adjacent smoothie edges



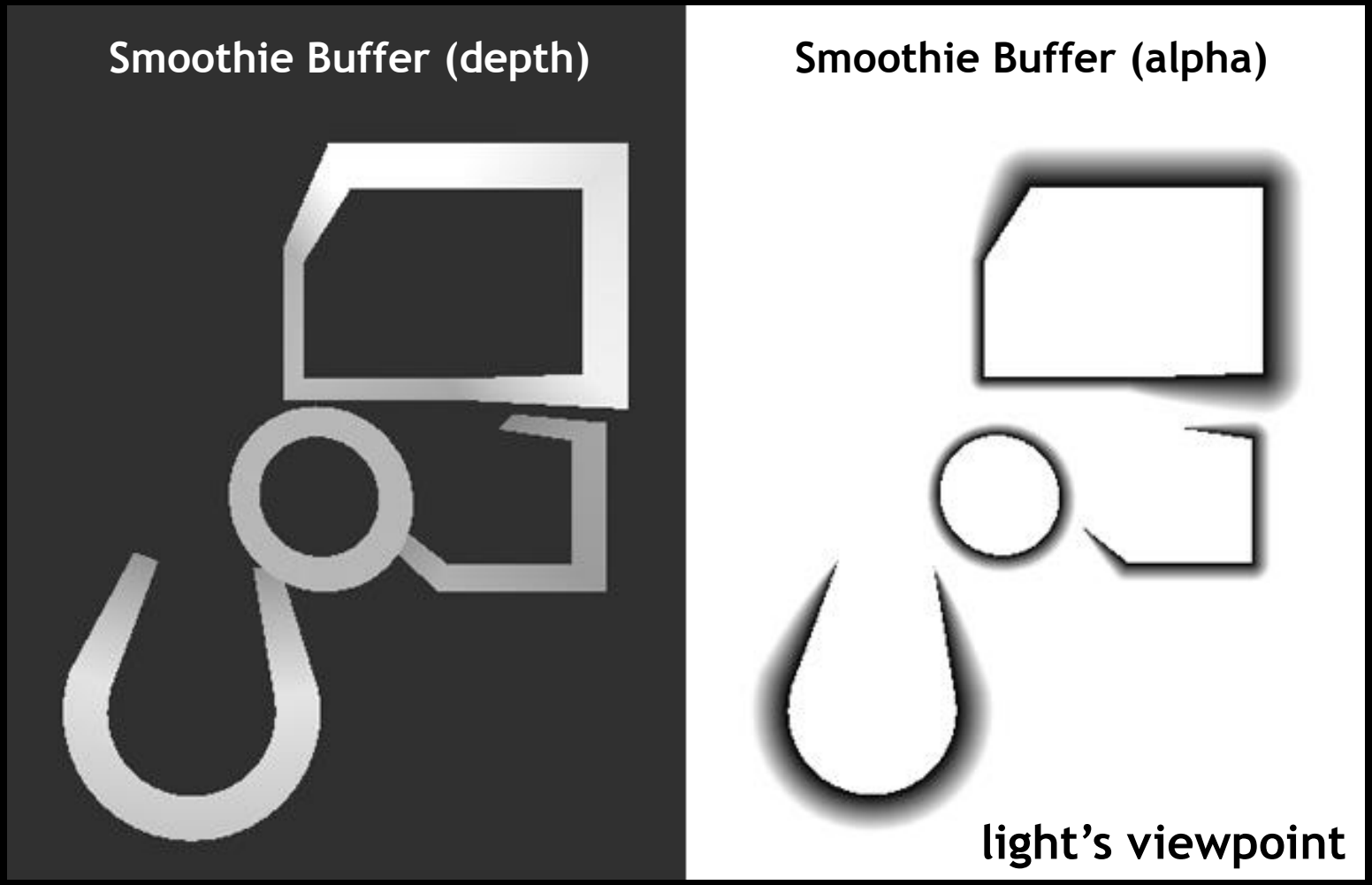
geometry

shading

Render Smoothies

SIGGRAPH2004

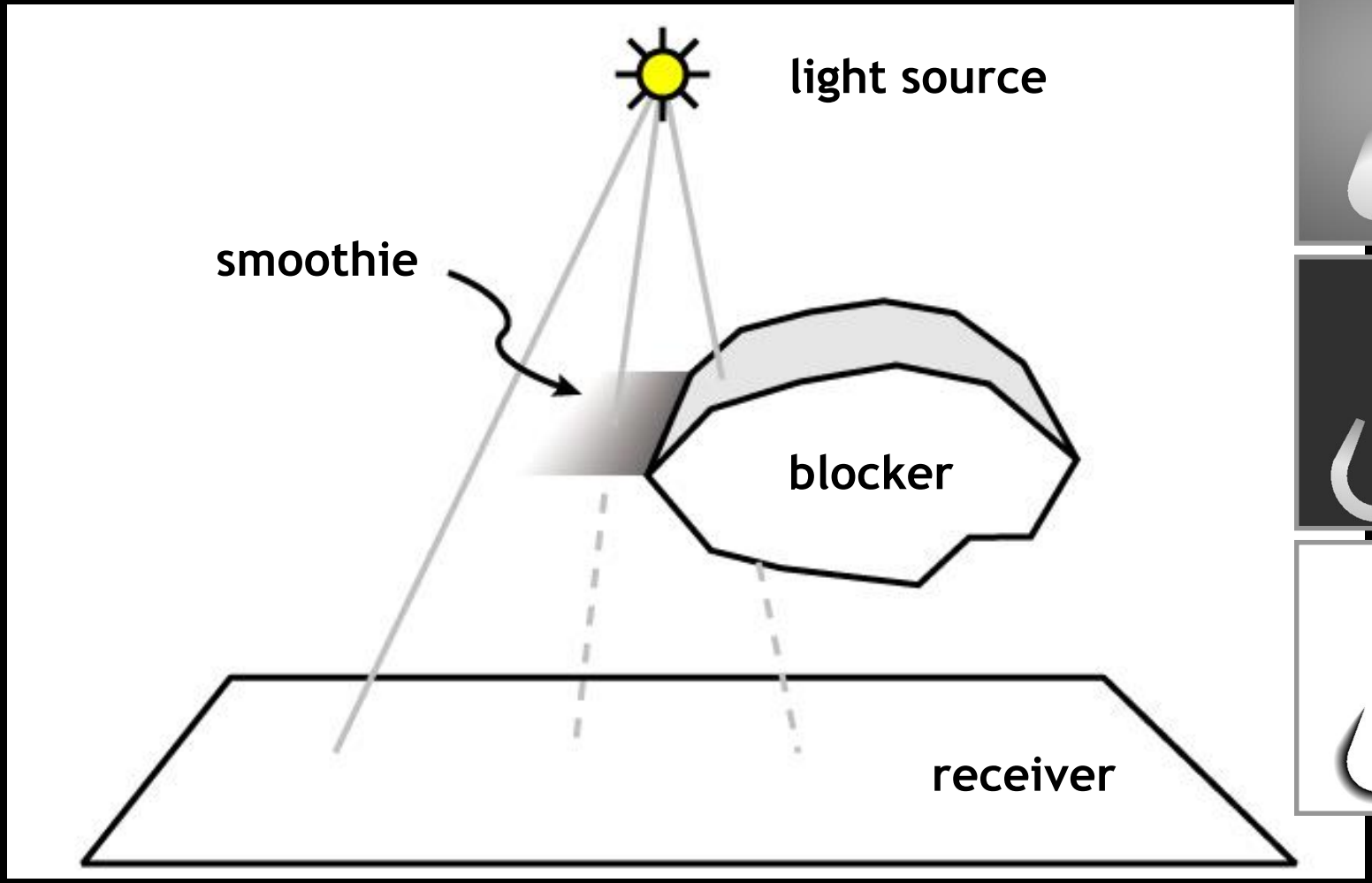
Store depth and alpha values into smoothie buffer



Compute Shadows

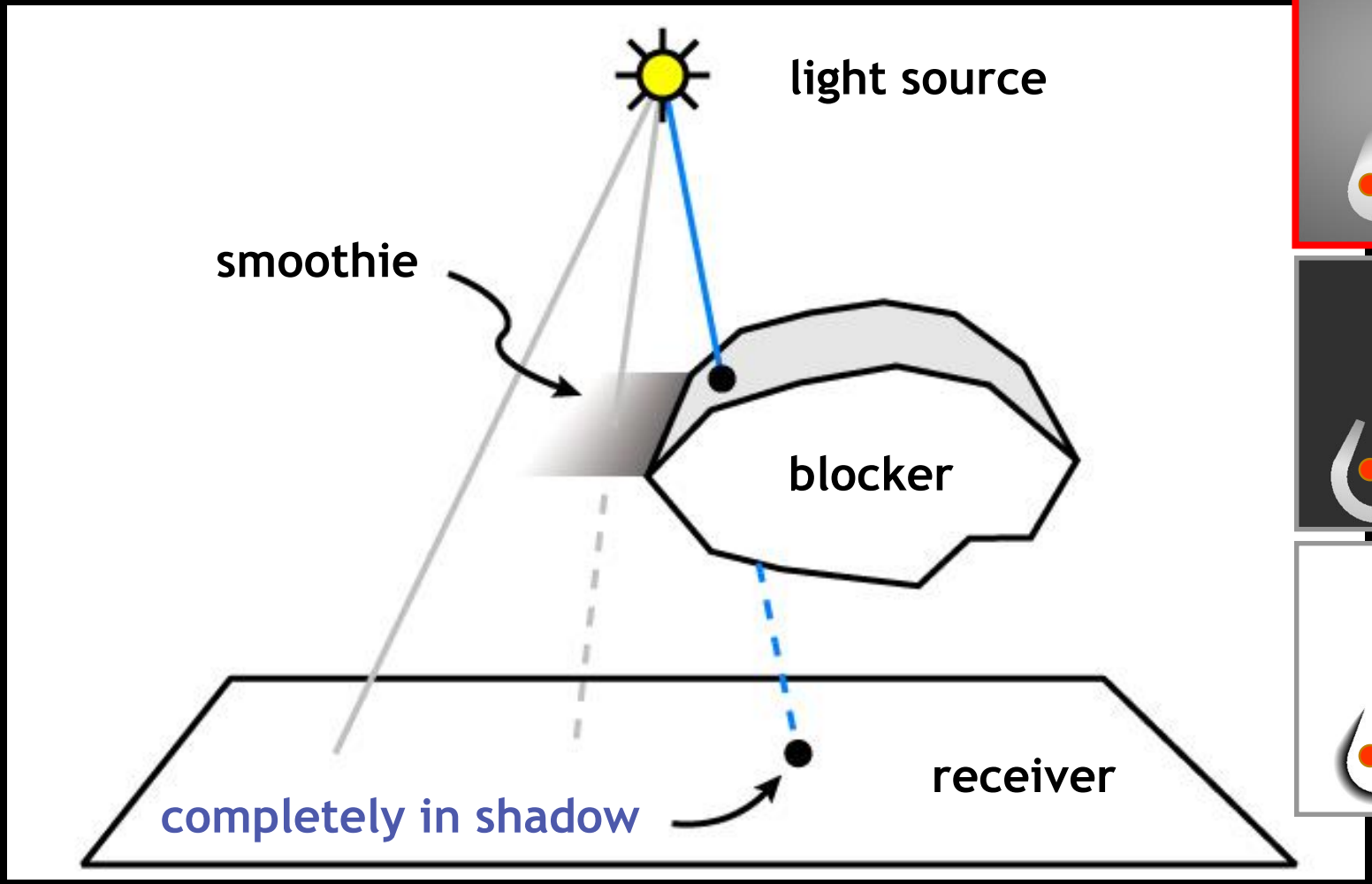
SIGGRAPH2004

Compute intensity using depth comparisons



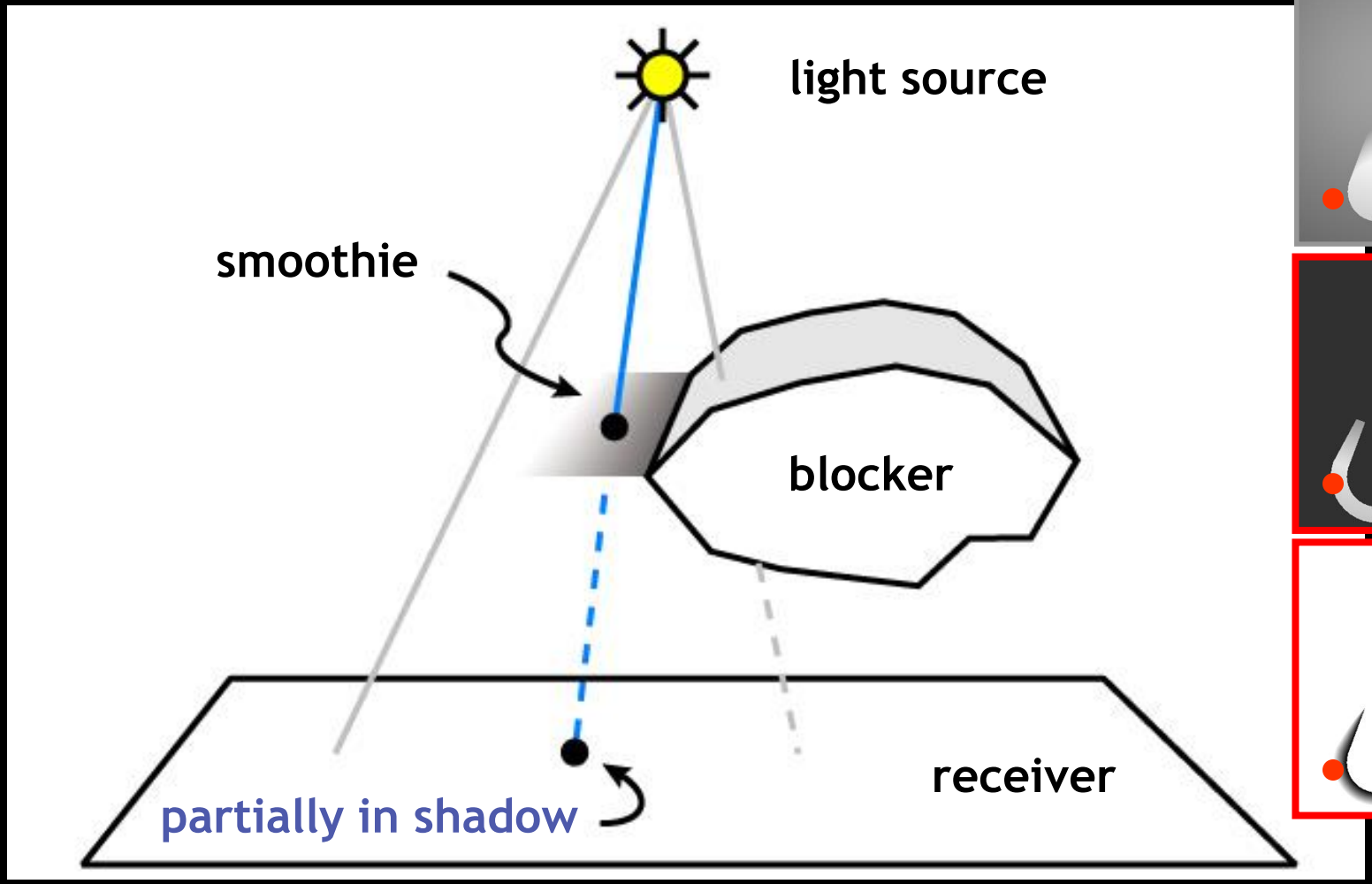
Compute Shadows (1 of 3)

Image sample behind blocker (intensity = 0)



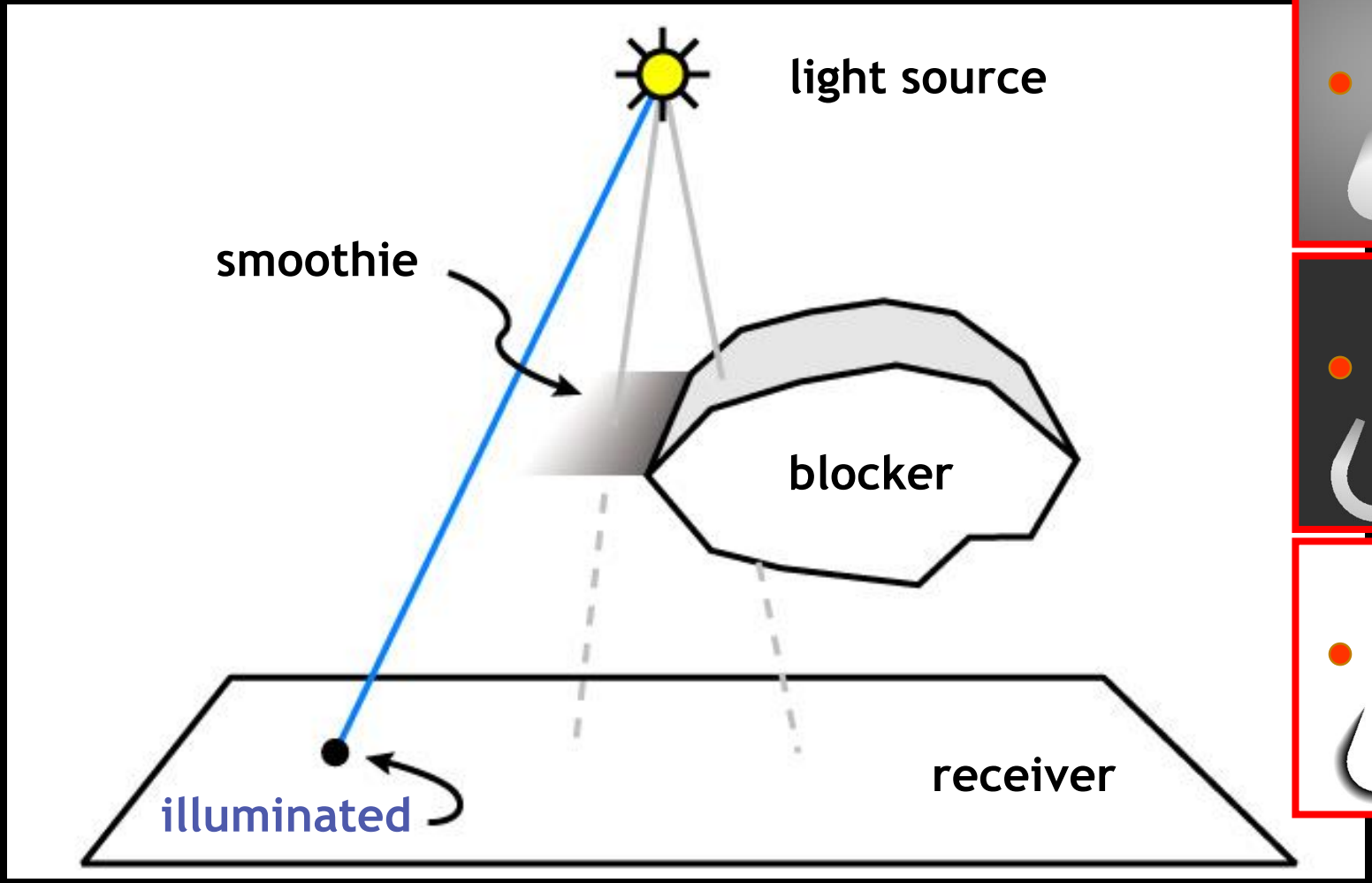
Compute Shadows (2 of 3)

Image sample behind smoothie (intensity = α)



Compute Shadows (3 of 3)

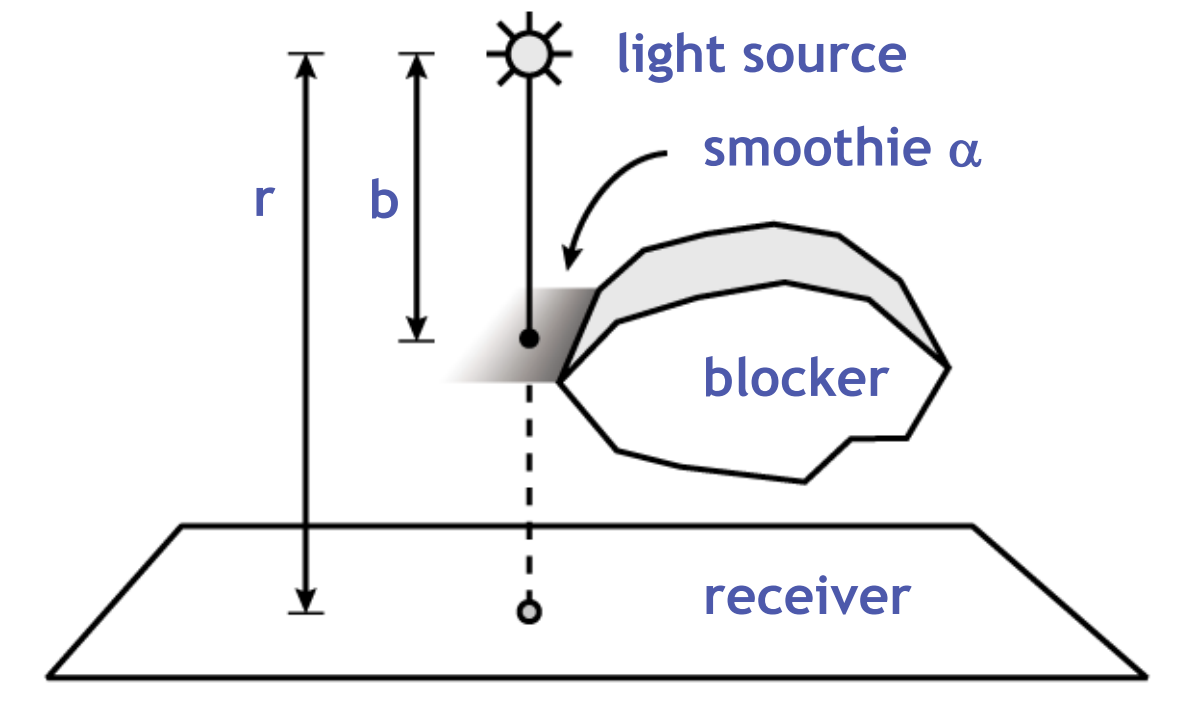
Image sample illuminated (intensity = 1)



Computing Alpha Values

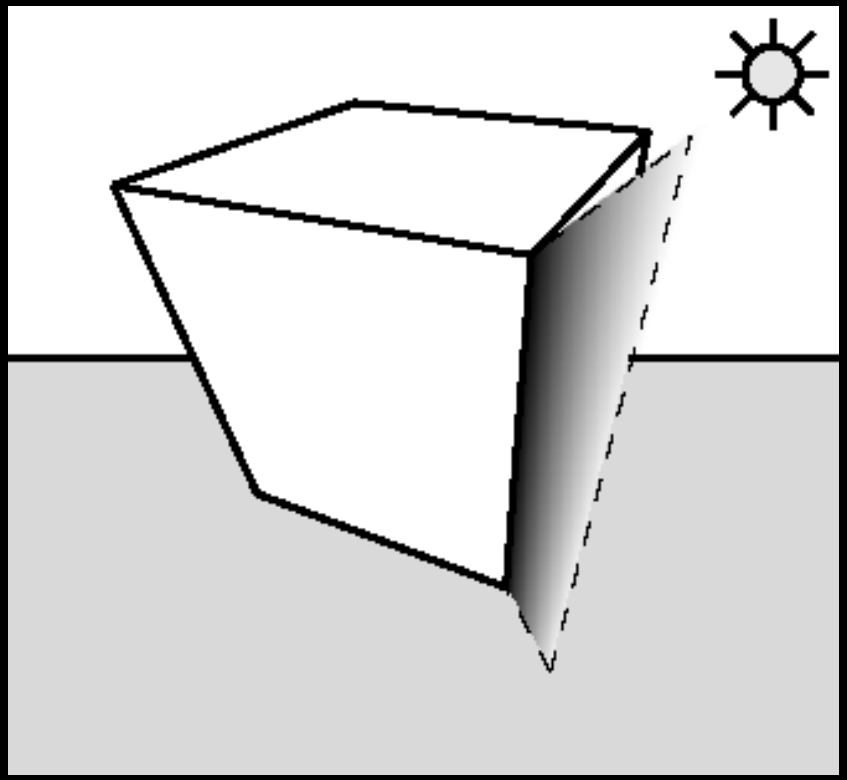
Intuition:

- Alpha defines penumbra shape
- Should vary with ratio b/r

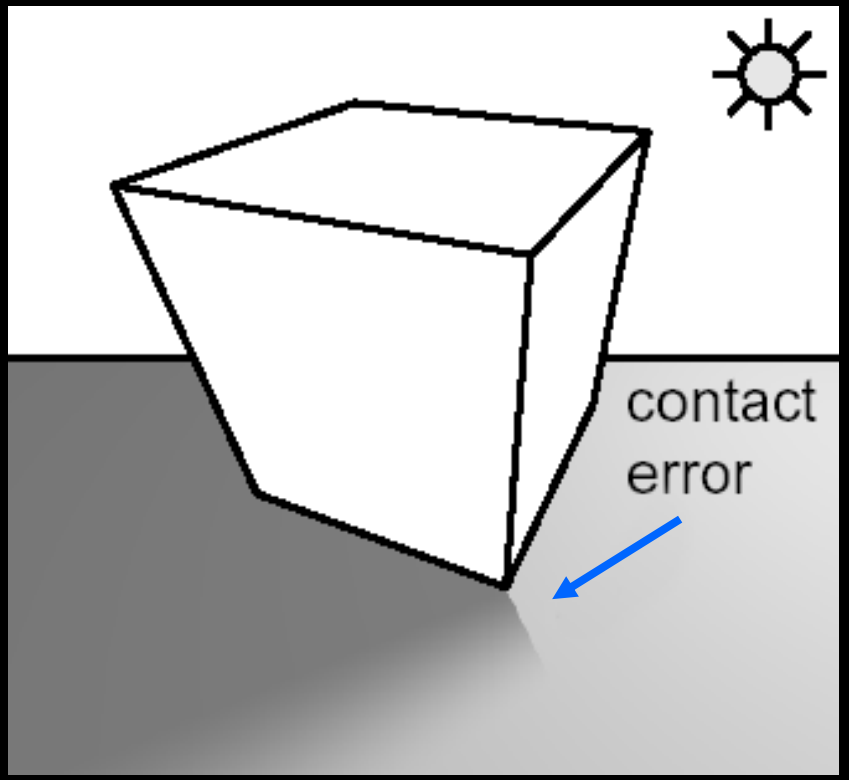


Without Alpha Remapping

Linearly interpolated alpha → undesired results!



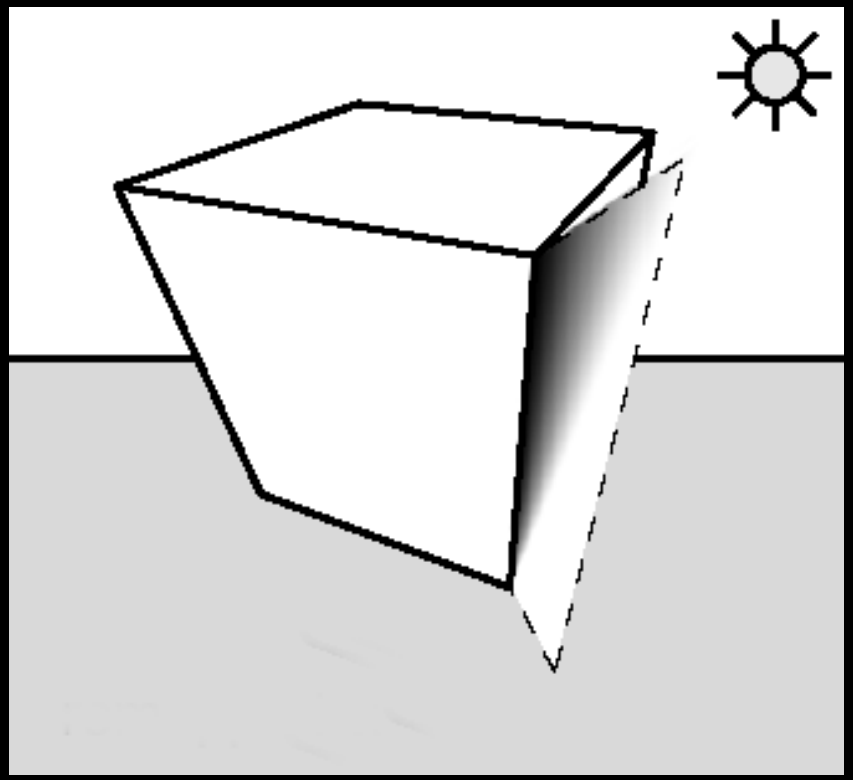
smoothie



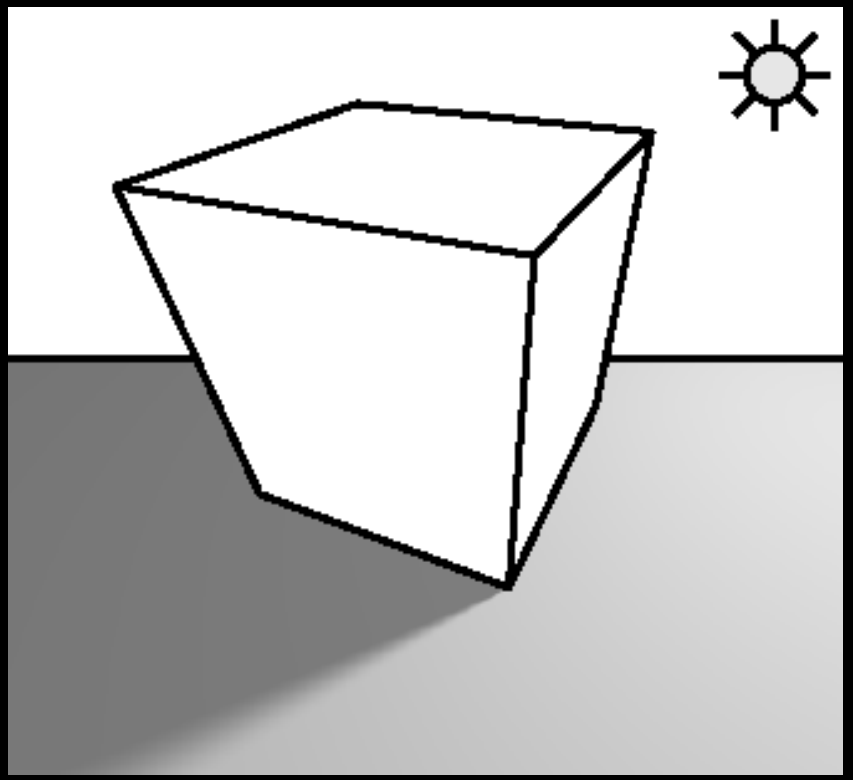
contact problem

With Alpha Remapping

Remap alpha at each pixel using ratio b/r: $\alpha' = \alpha \,/\, (1 - b/r)$



smoothie

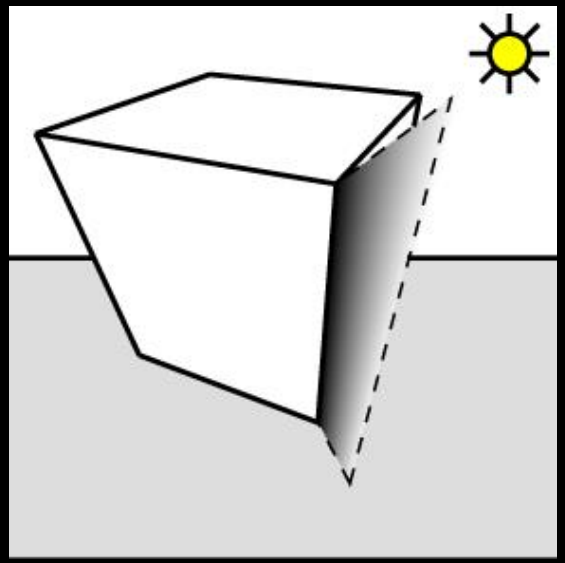


fixed contact problem

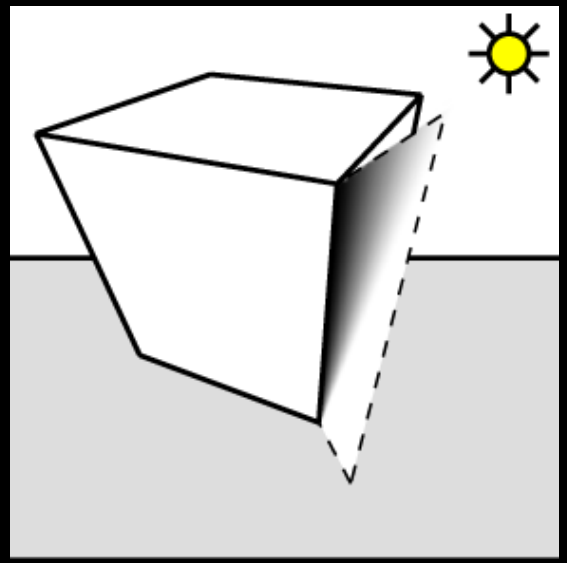
Computing Alpha Values

1. Linearly interpolate alpha
2. Remap alpha at each pixel using ratio b/r:

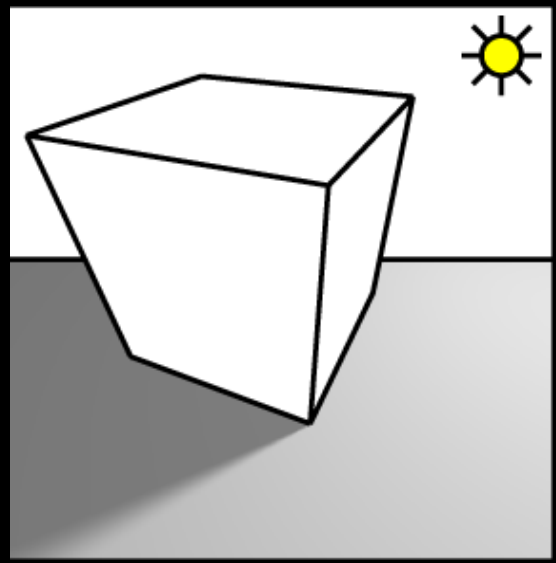
$$\alpha' = \alpha \,/\, (1 - b/r)$$



original α

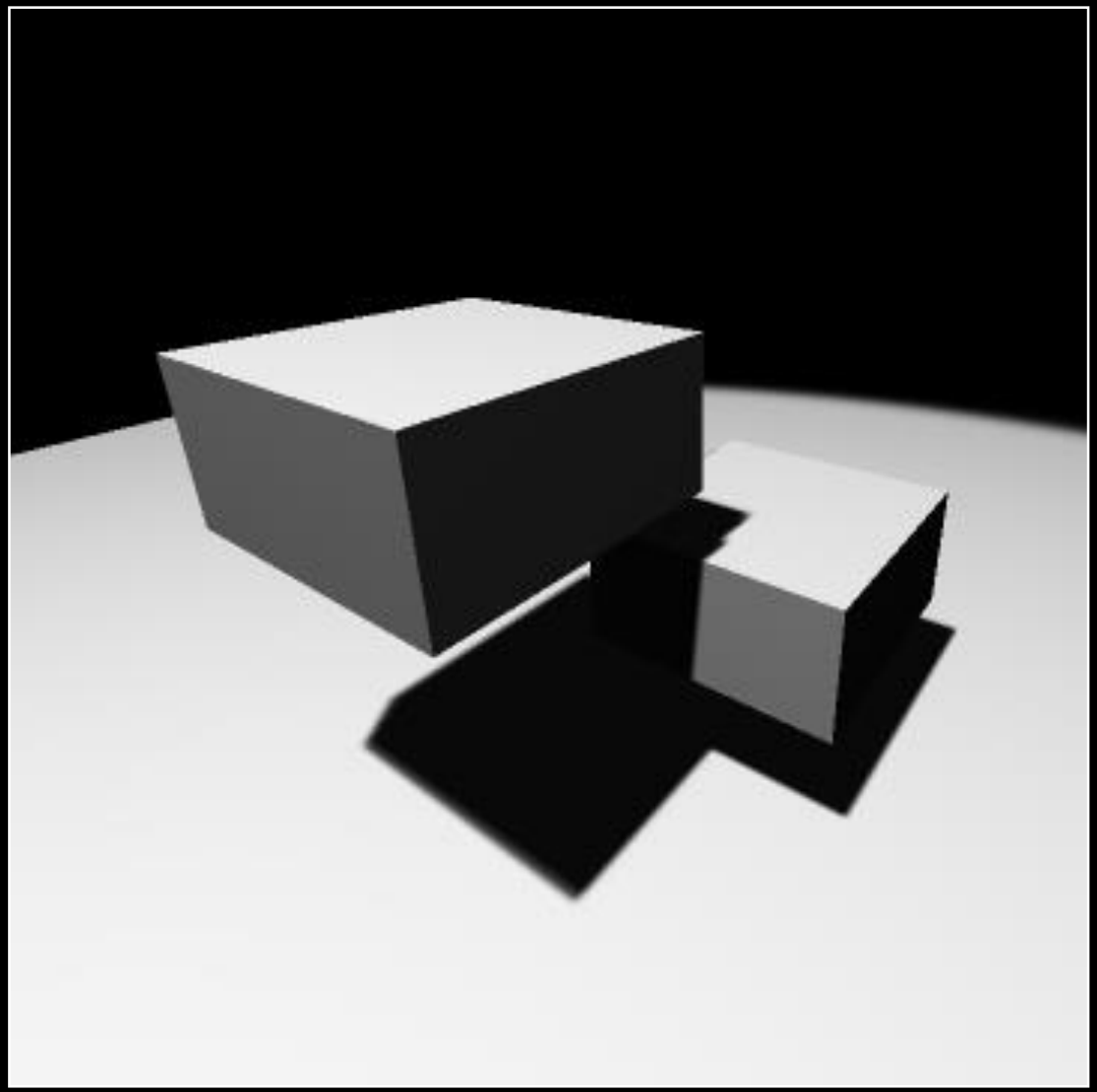


remapped α

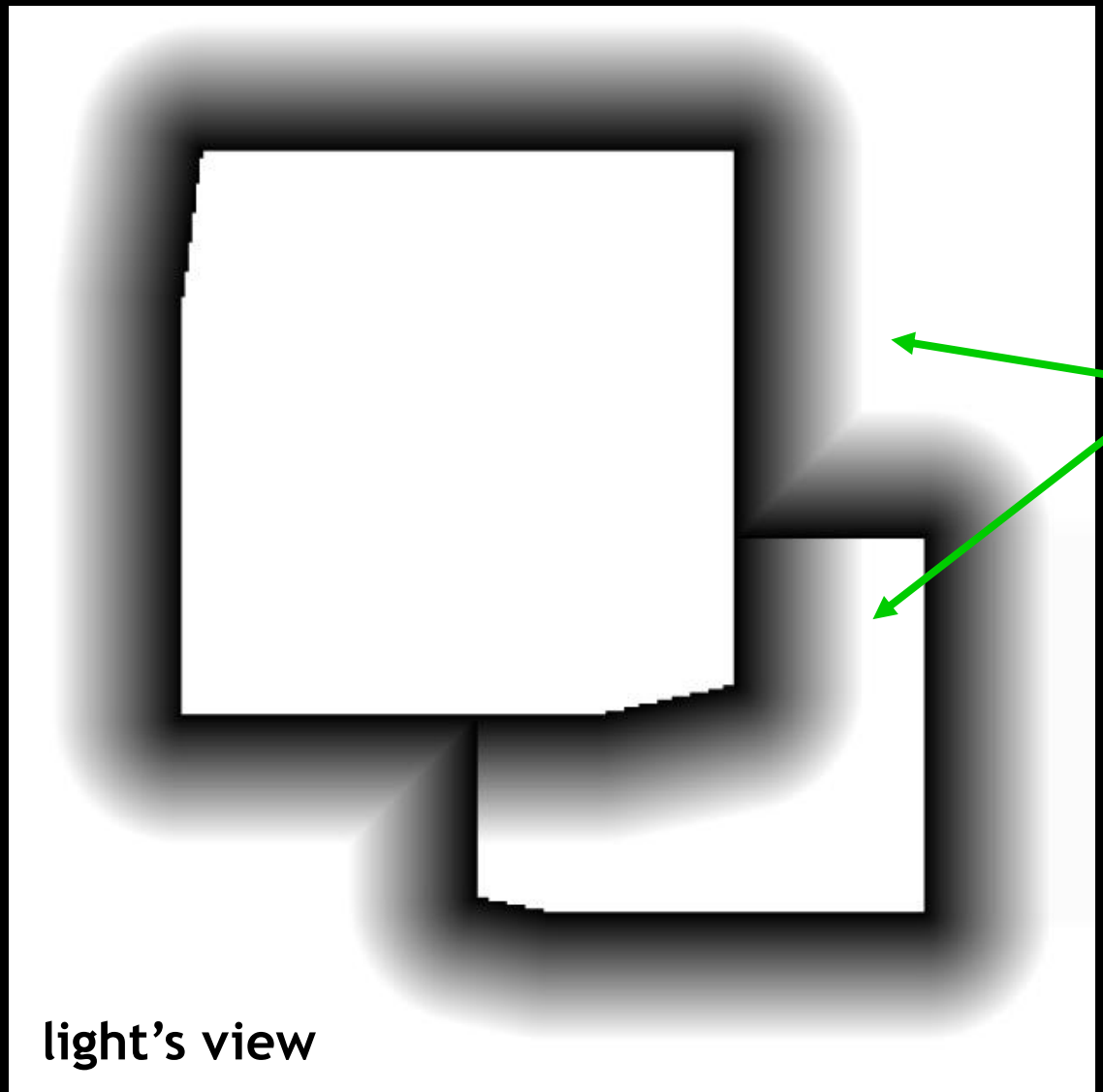


result

Multiple Objects



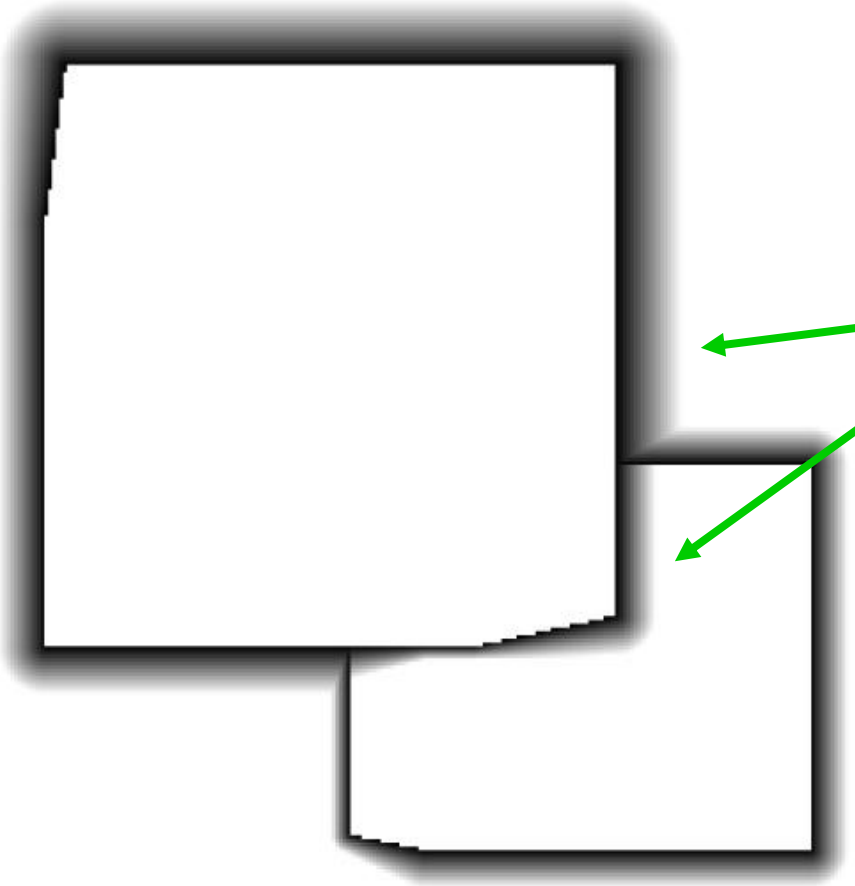
Multiple Receivers



Smoothie buffer
(linearly-interpolated α)

same thickness

Multiple Receivers

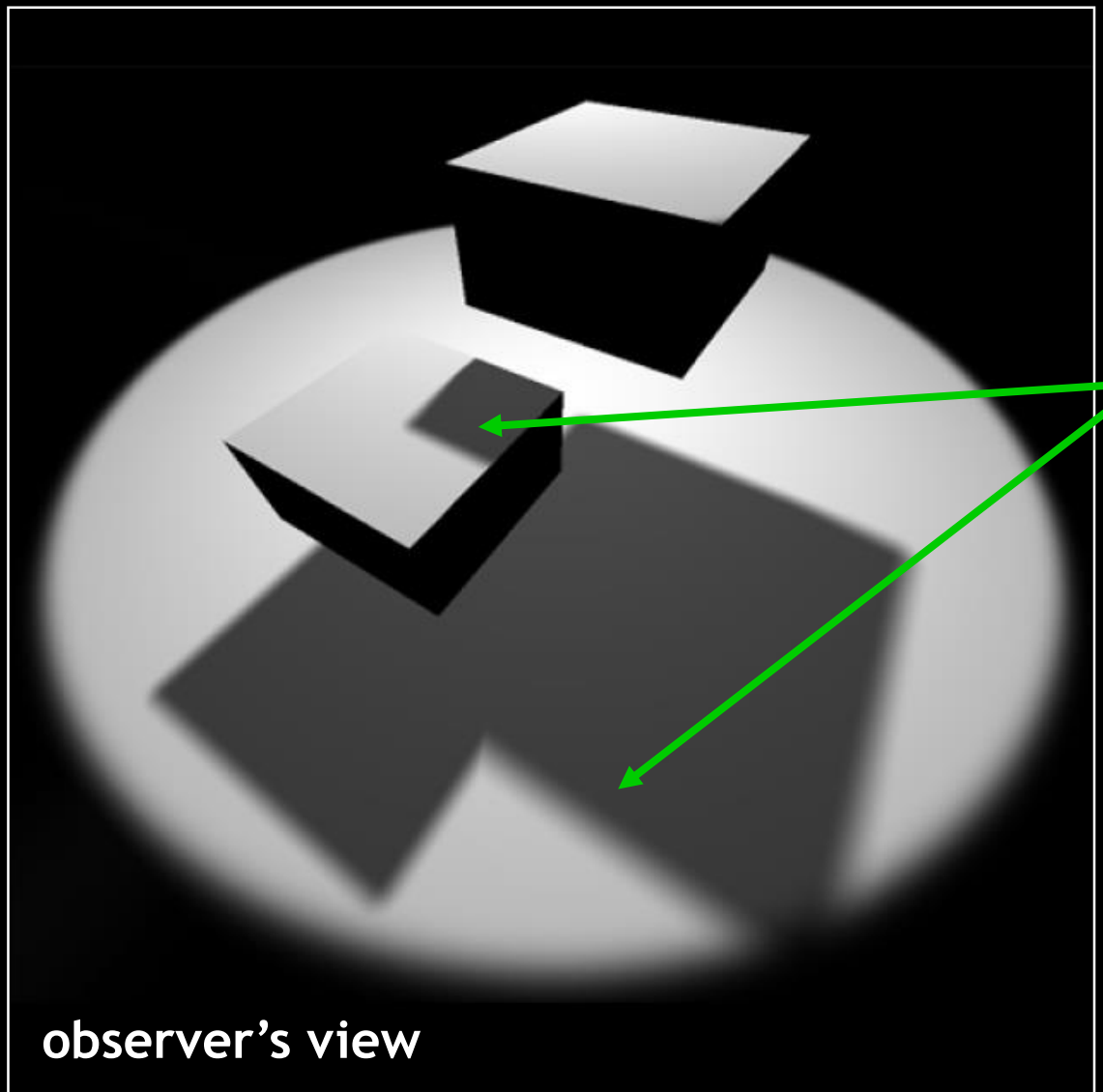


light's view

Smoothie buffer
(remapped α)

different thickness

Multiple Receivers

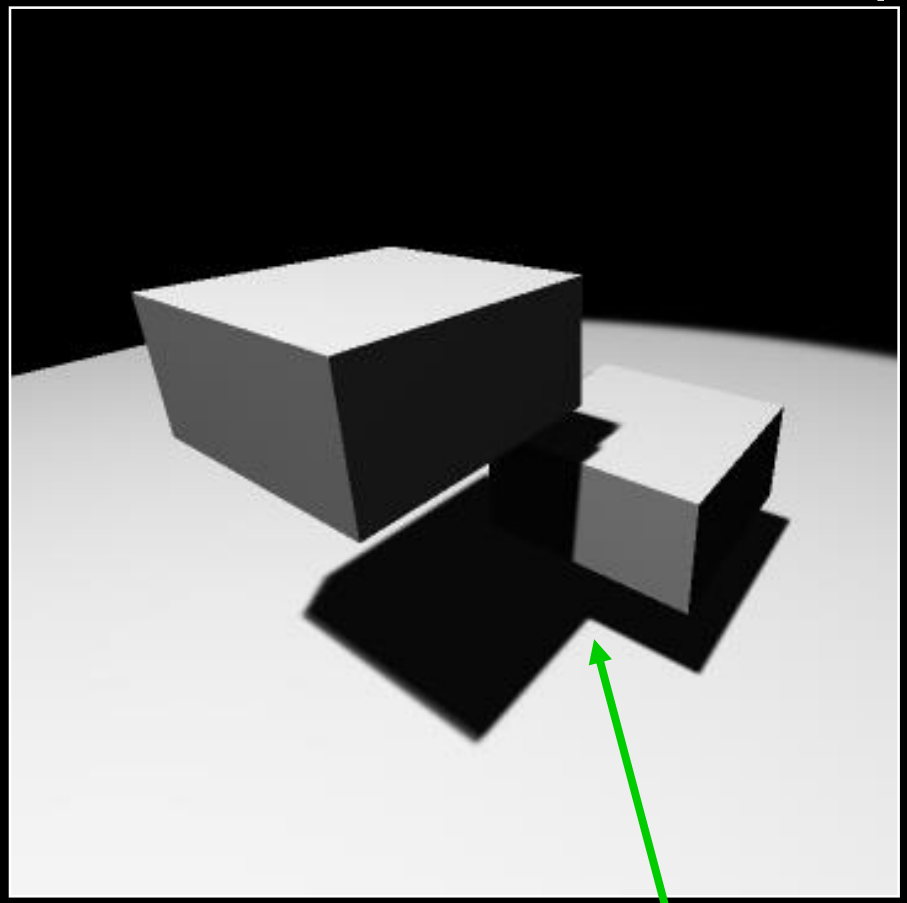


Final image

different thickness

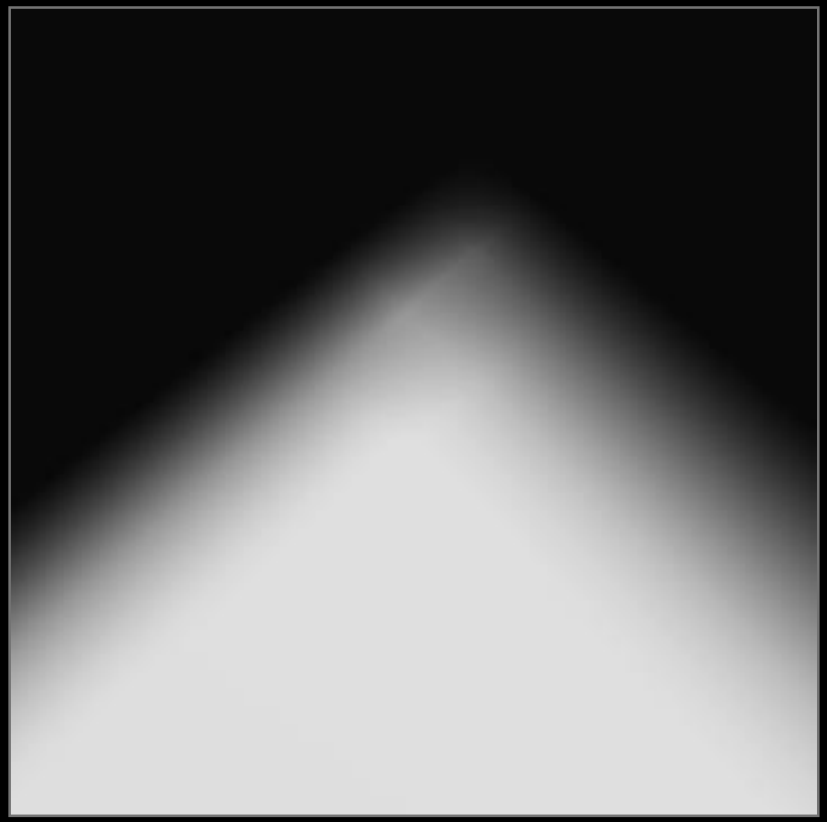
Multiple Blockers

What happens when smoothies overlap?

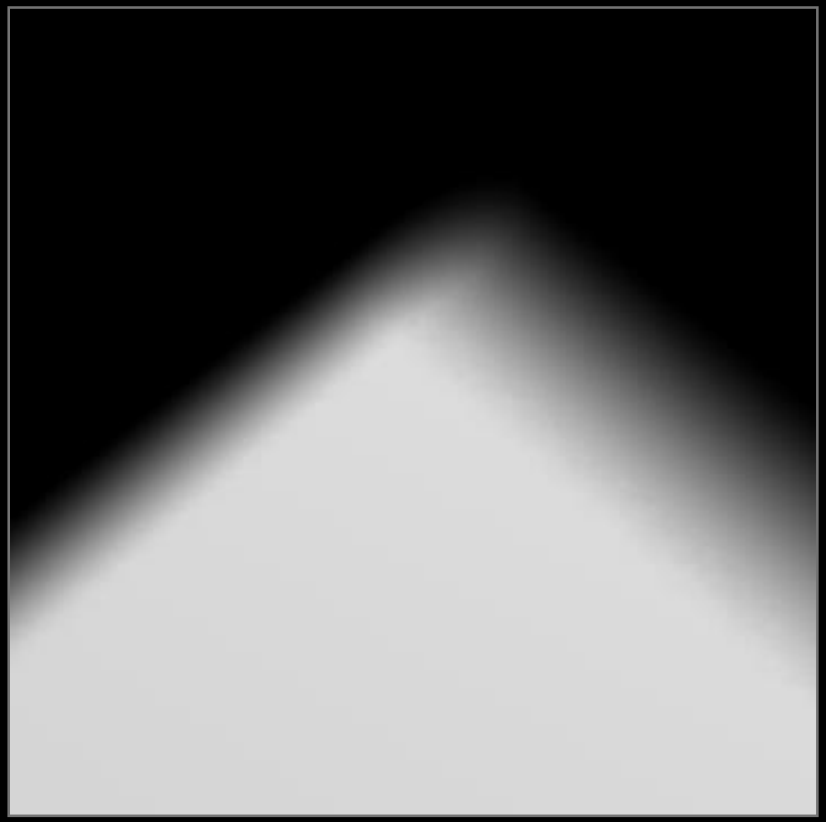


Multiple Blockers

Minimum blending: just keep minimum of alpha values



smoothie



ray tracer

Implementation

Implementation

- Details (OpenGL)
- Hardware acceleration
- Optimizations

Create Shadow Map

Render to standard OpenGL depth buffer

- 24-bit, window space
- Post-perspective, non-linear distribution of z

Also write to color buffer (using fragment program)

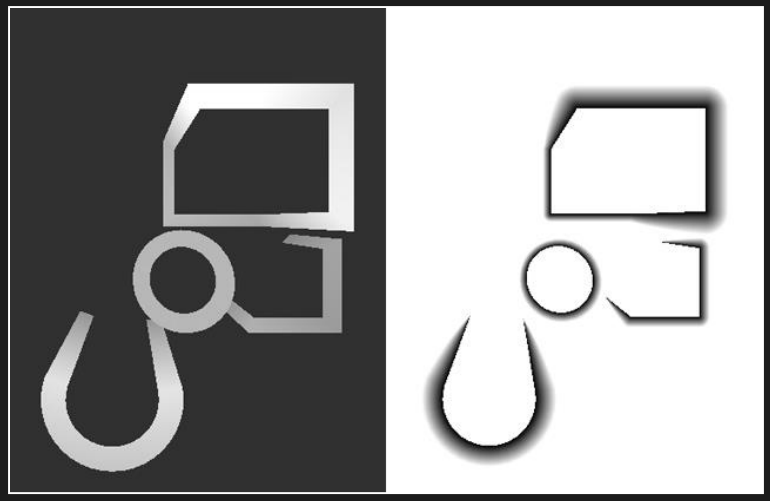
- Floating-point, eye space
- Pre-perspective, linear distribution of z
- Unlike regular shadow maps

Why? Need linear depth for next rendering pass

Create Smoothie Buffer

Conceptually, draw the smoothies once:

- store depth and alpha into a buffer



In practice, draw smoothies twice:

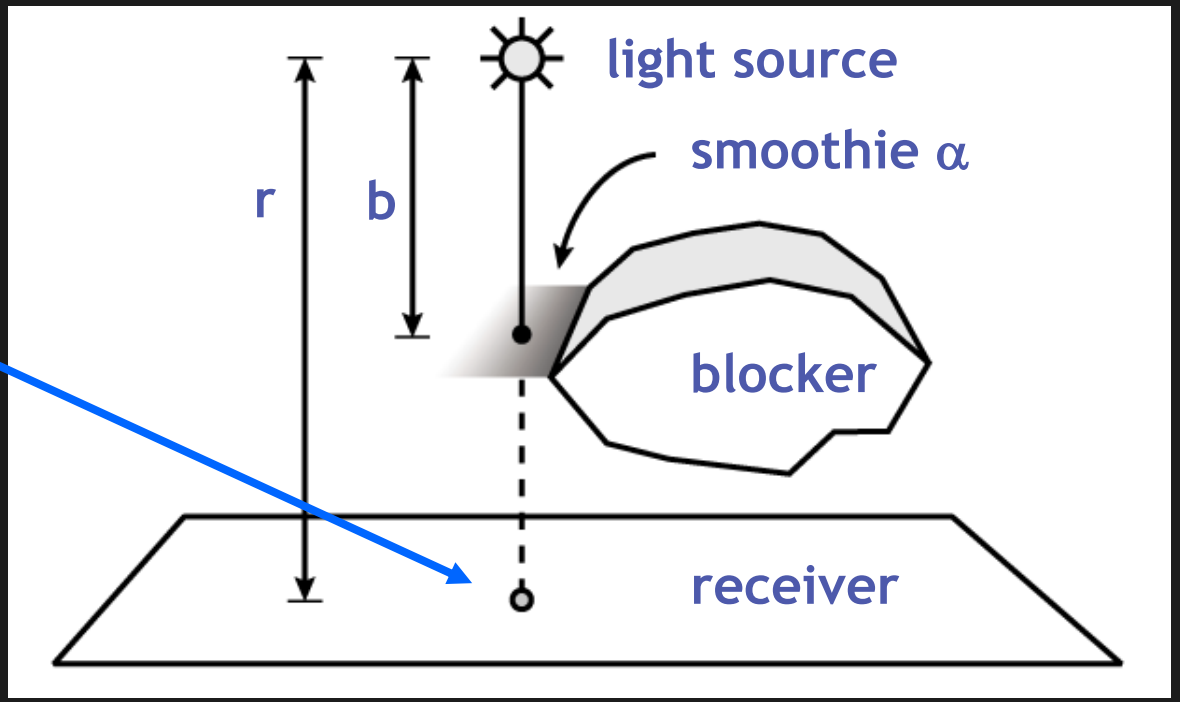
1. store nearest depth value into depth buffer
2. blend alpha values into color buffer

Computing Alpha

How to compute alpha? Recall $\alpha' = \alpha / (1 - b/r)$

- α is linearly interpolated from 0 to 1 across quad
- b is computed in fragment program
- r is obtained from shadow map (linear depth!)

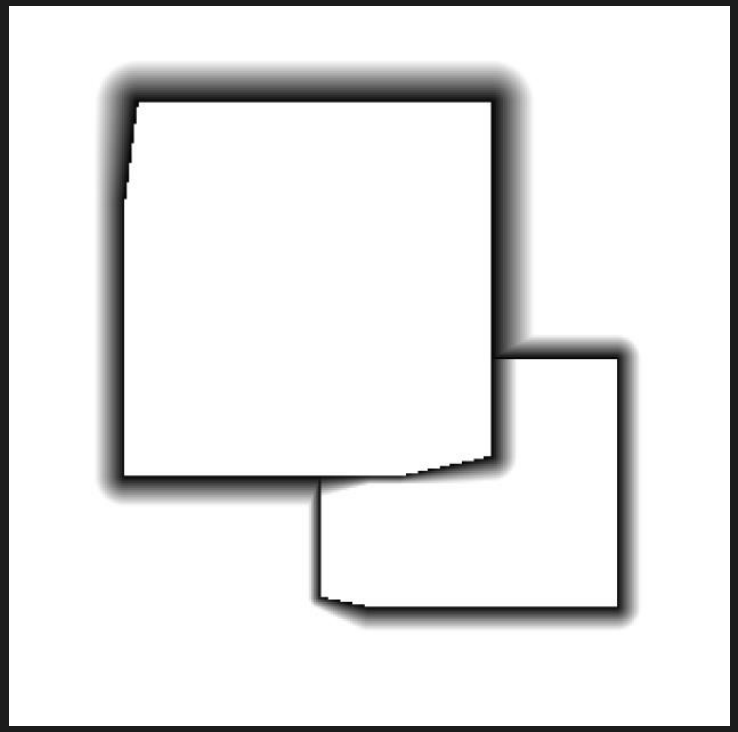
current sample

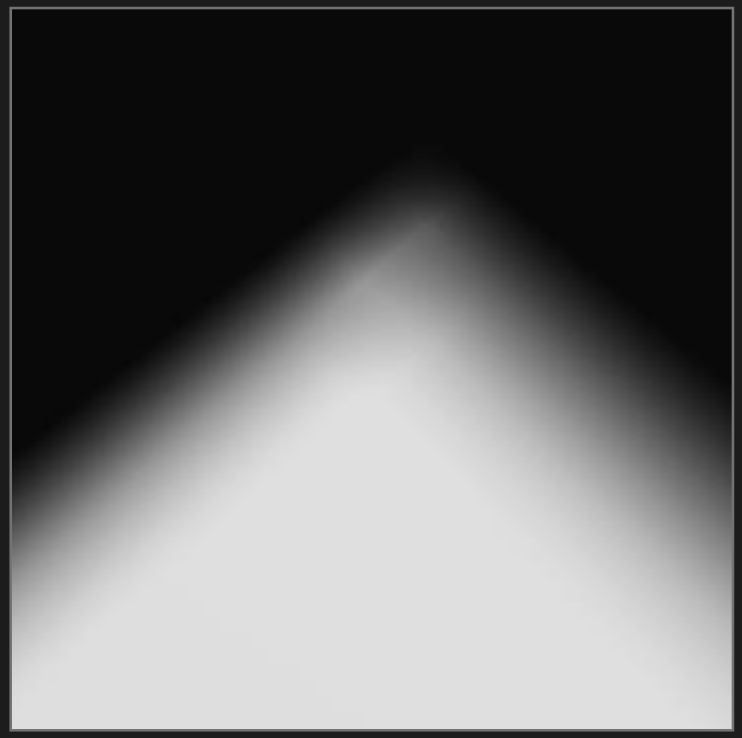


Minimum Blending

Implementation in OpenGL:

- Supported natively in hardware
- use glBlendEquationEXT(GL_MIN_EXT)

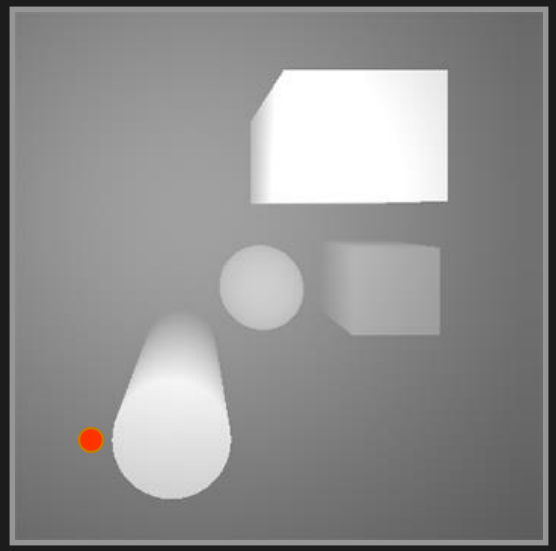




Final Rendering Pass

Implementation using fragment program:

- Project each sample into light space
- Multiple texture lookups



shadow map
(depth)

smoothie buffer
(depth)

smoothie buffer
(alpha)

Additional Details

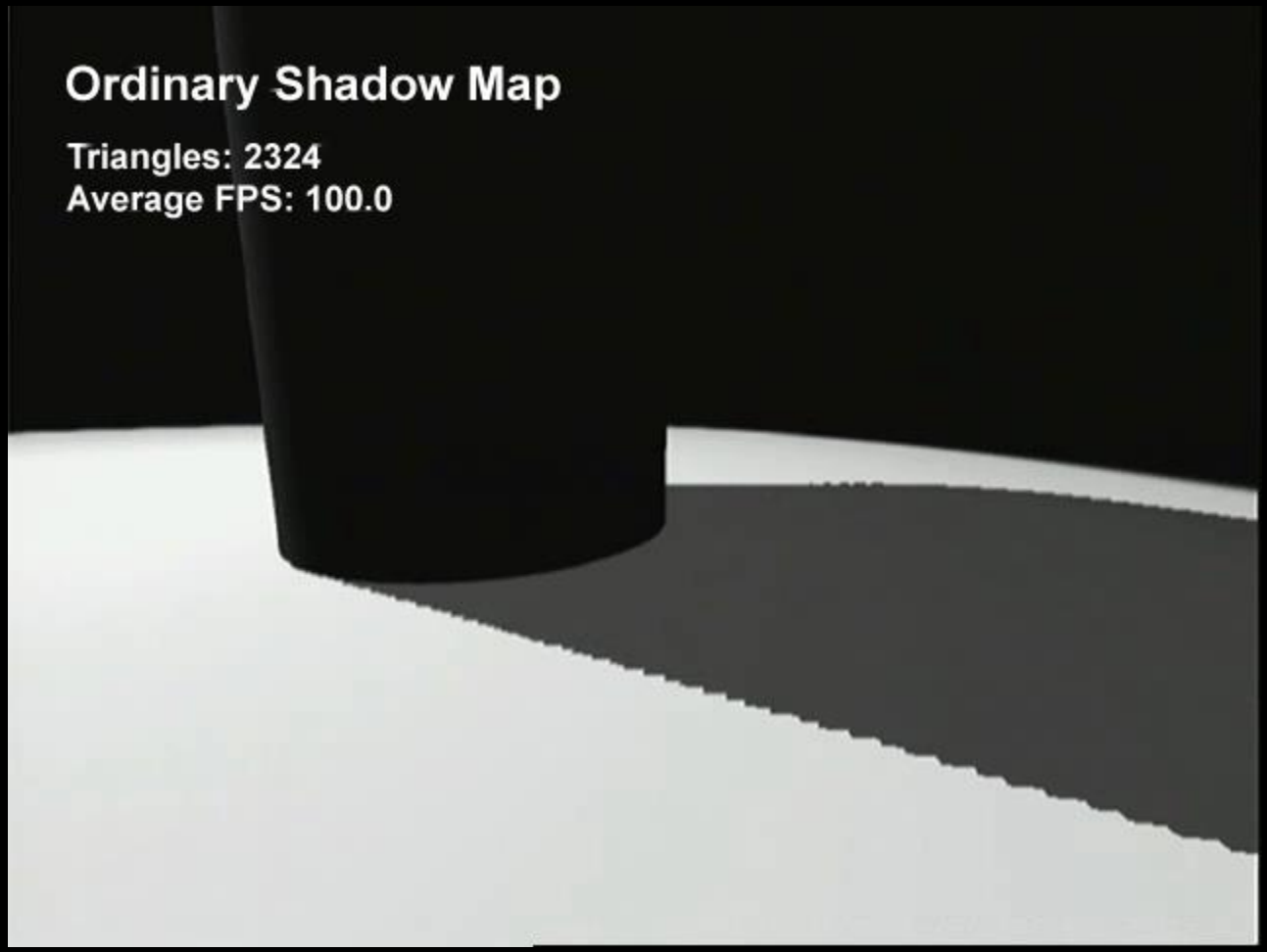
Combination of methods:

- percentage closer filtering (2 x 2 filtering in shader)
- perspective shadow maps

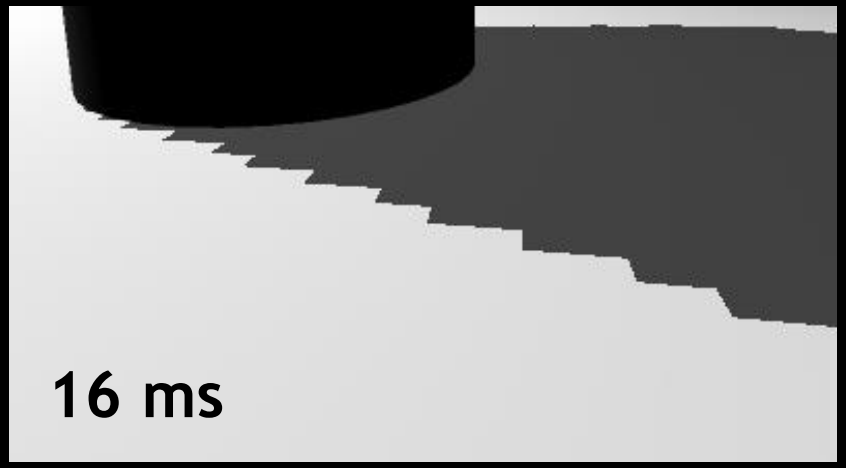
See paper (course notes) for Cg shader code

Examples

Video

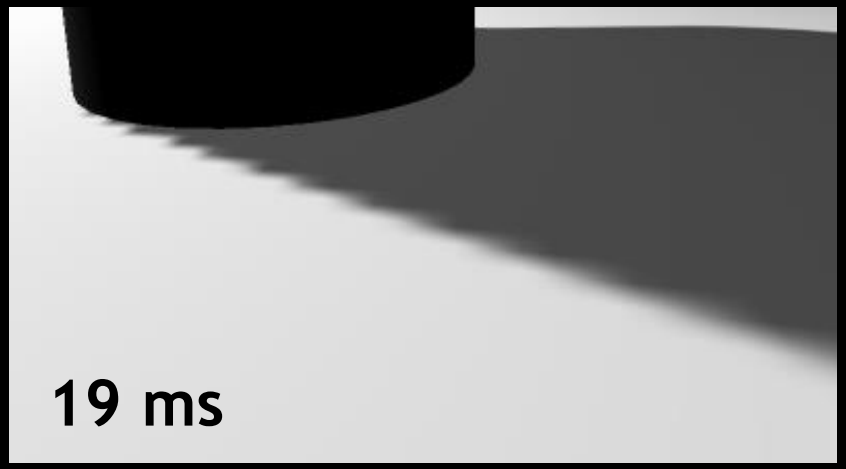


Hiding Aliasing (256 x 256)

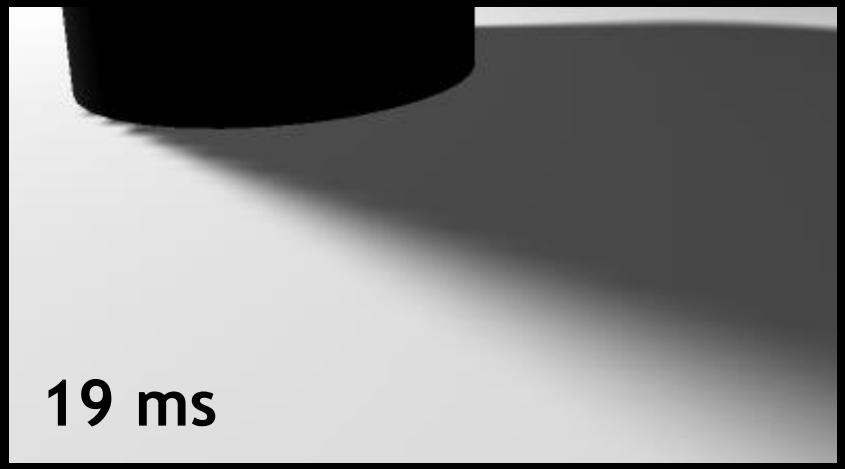


shadow map

bicubic filter

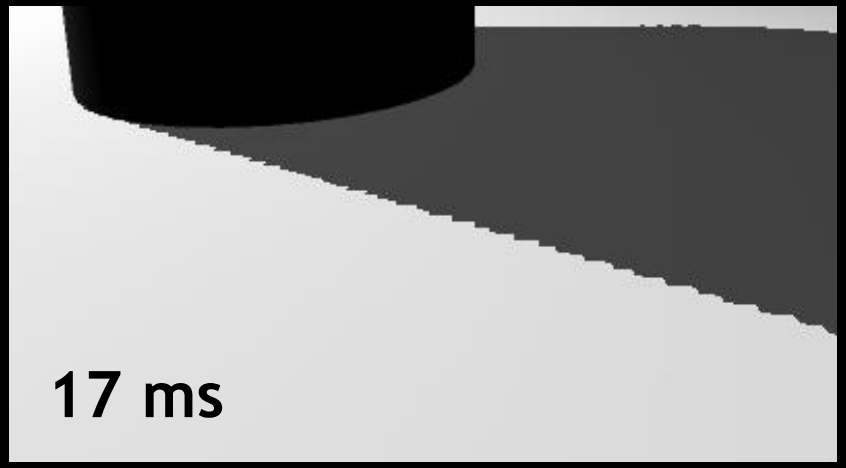


smoothie (t = 0.02)

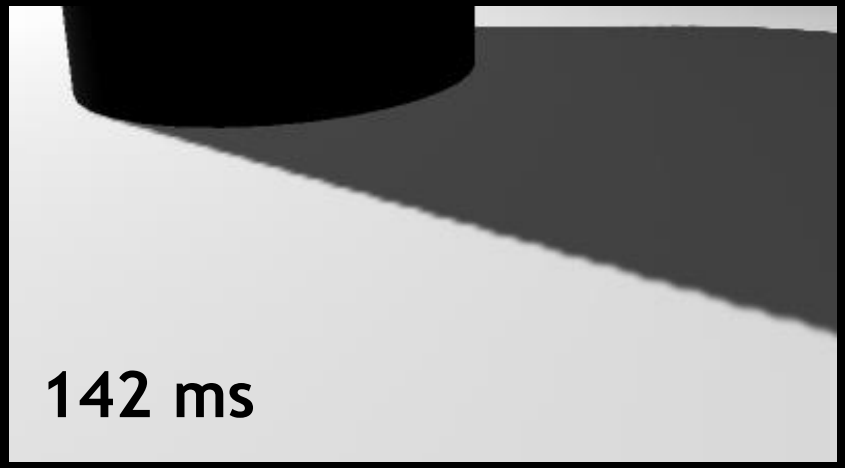


smoothie (t = 0.08)

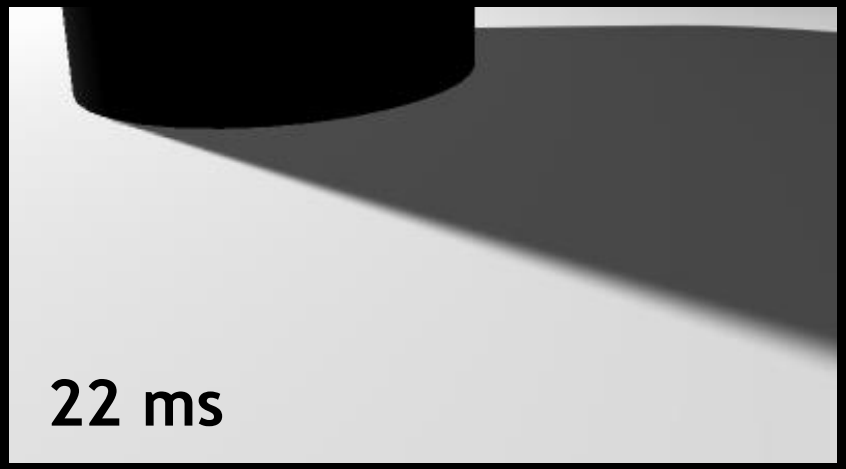
Hiding Aliasing (1k x 1k)



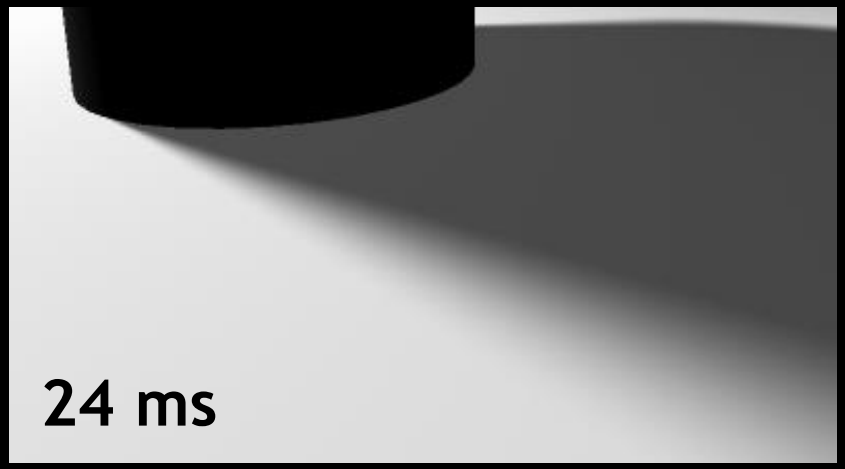
shadow map



bicubic filter



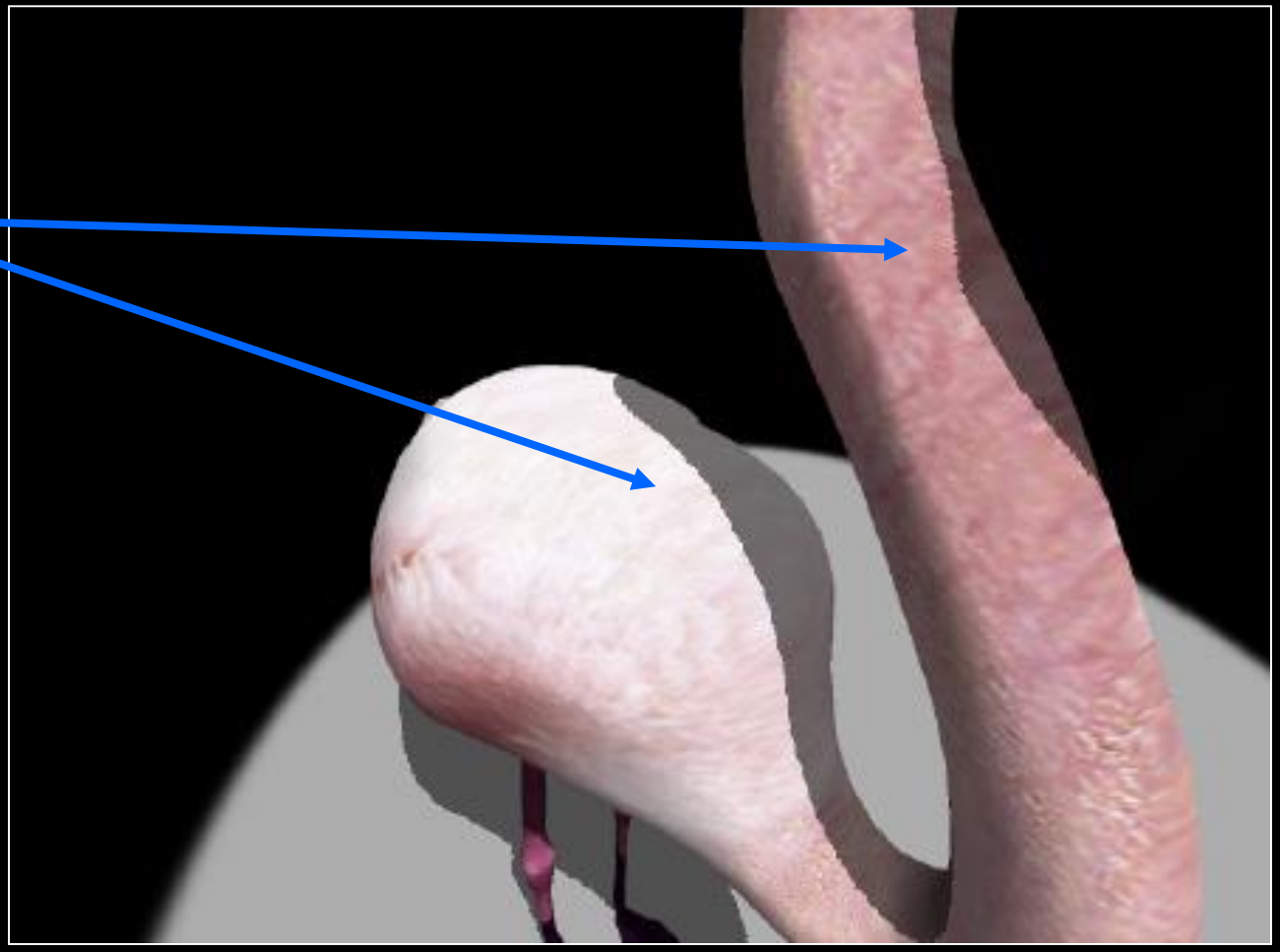
smoothie (t = 0.02)



smoothie (t = 0.08)

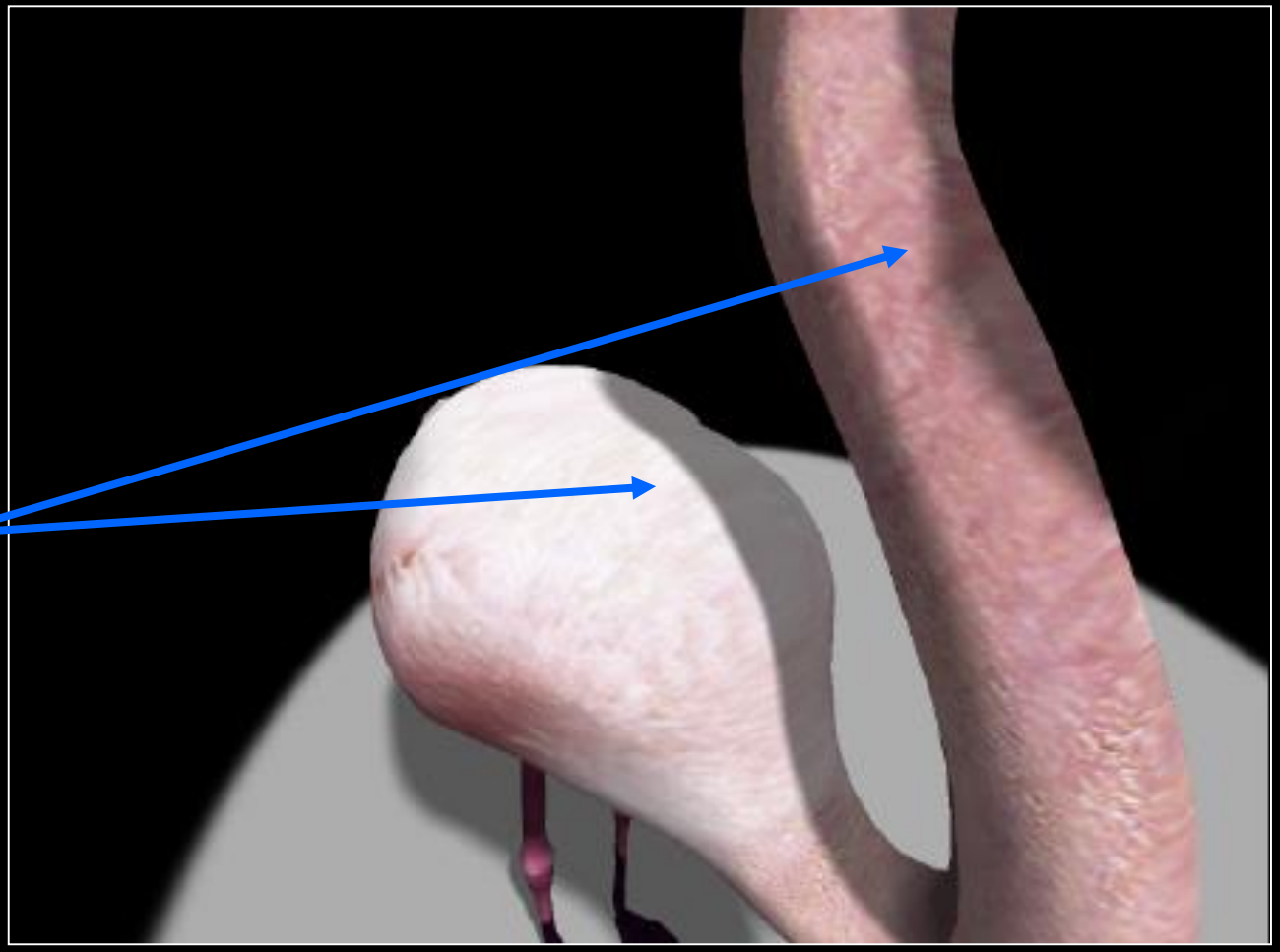
Antialiasing Example #1

hard shadows
(aliased)



shadow map

Antialiasing Example #1

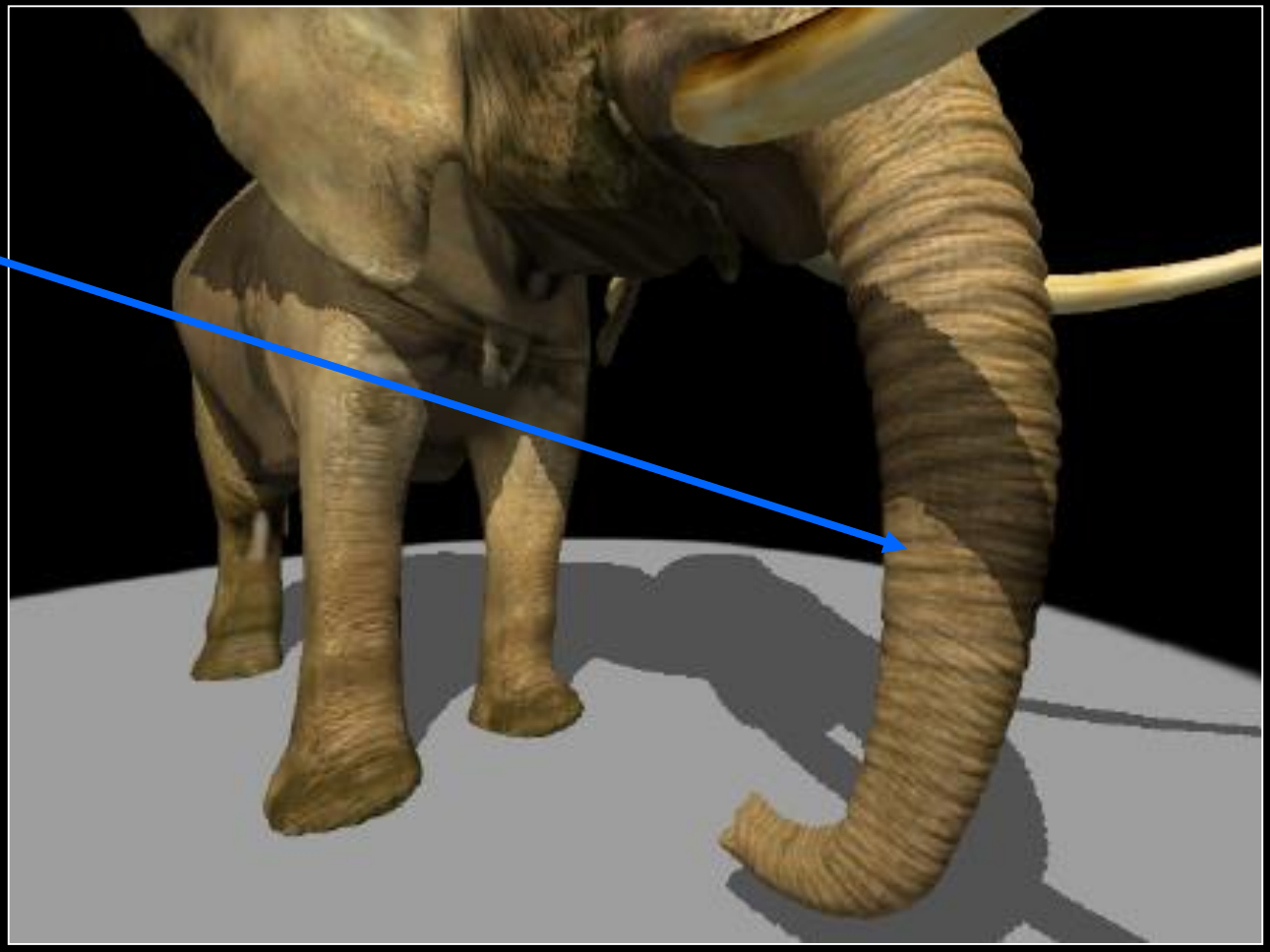


soft shadows
(antialiased)

smoothies

Antialiasing Example #2

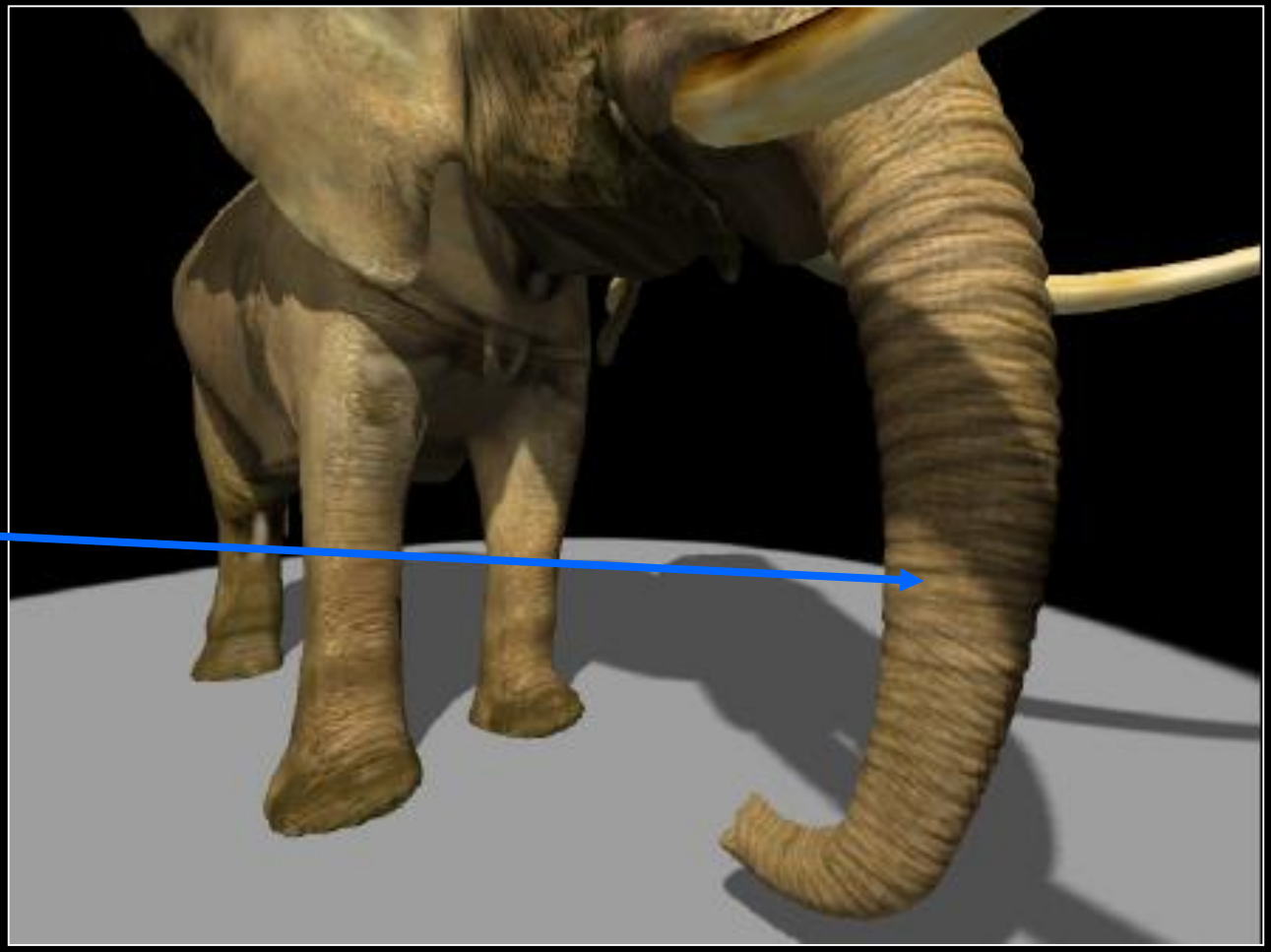
hard shadows
(aliased)



shadow map

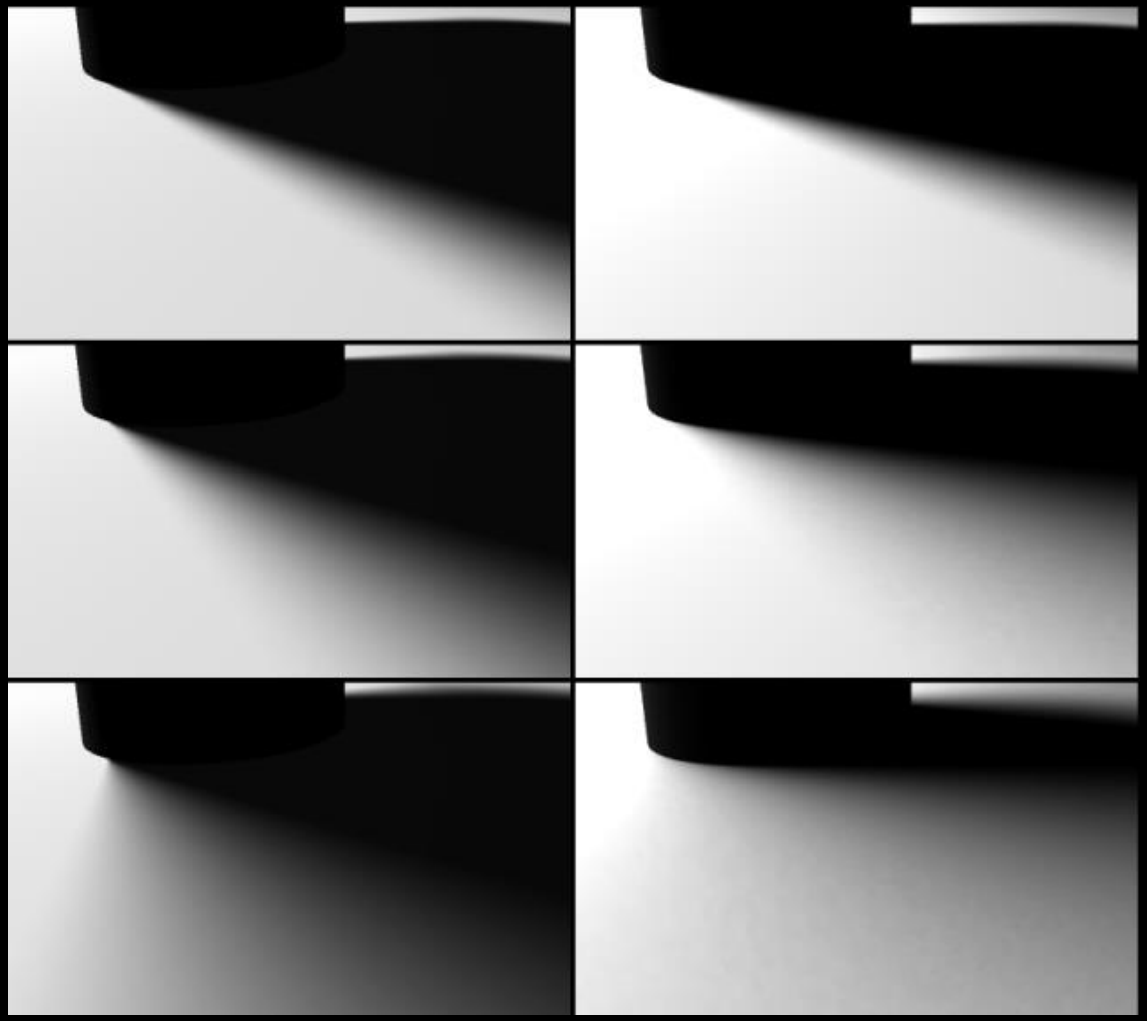
Antialiasing Example #2

soft shadows
(antialiased)



smoothies

Limitations



increasing size
of light source

smoothie

ray tracer

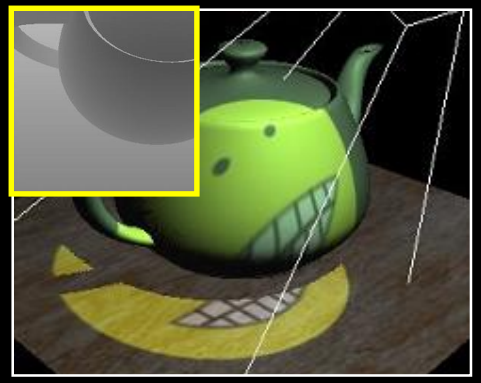
Video

original md2shader demo courtesy of Mark Kilgard

Tradeoffs

Shadow maps:

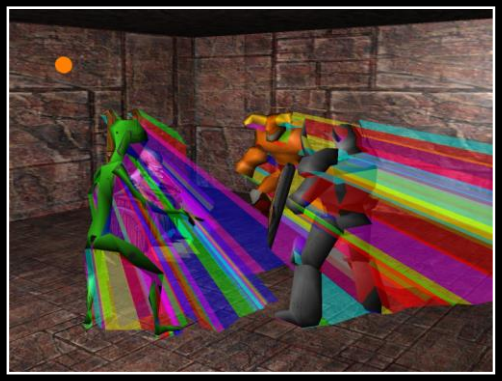
- Assumes directional light or spotlight
- Discrete buffer samples



Tradeoffs

Shadow maps:

- Assumes directional light or spotlight
- Discrete buffer samples



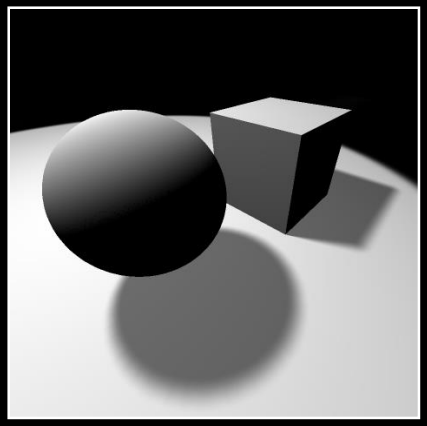
Shadow volumes:

- Assumes blockers are closed triangle meshes
- Silhouettes identified in object space

Tradeoffs

Shadow maps:

- Assumes directional light or spotlight
- Discrete buffer samples



Shadow volumes:

- Assumes blockers are closed triangle meshes
- Silhouettes identified in object space

Smoothies:

- Rendered from light's viewpoint
- Occupy small screen area → inexpensive

Summary

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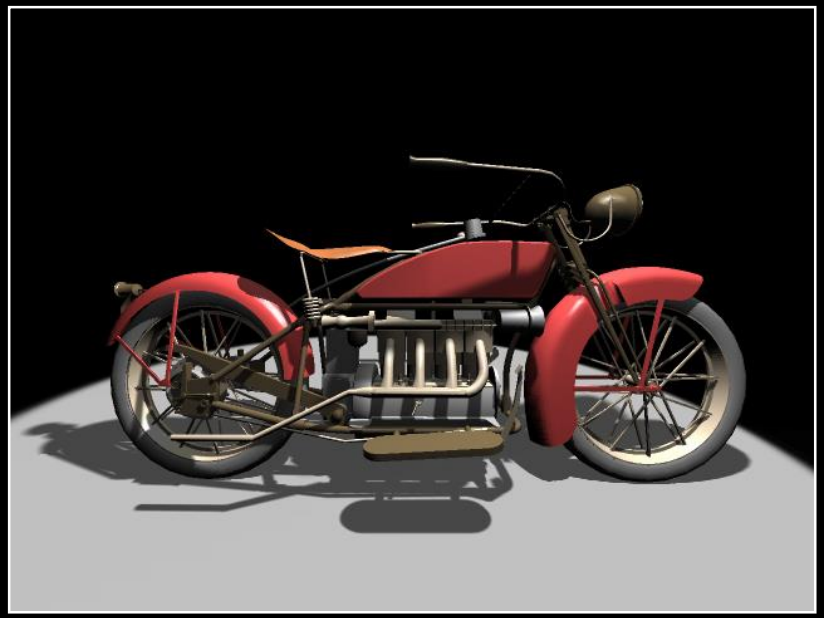
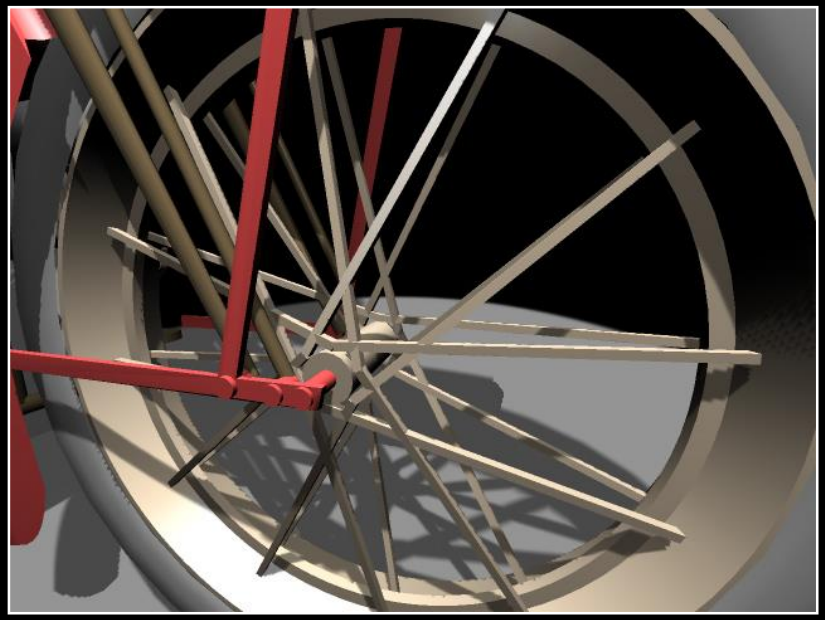
Main points:

- Simple extension to shadow maps
- Shadows edges are fake, but look like soft shadows
- Fast, maps well to graphics hardware





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- Xavier Décoret, Henrik Wann Jensen

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