Rendering Fake Soft Shadows with Smoothies

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SIGGRAPH2004

CSAIL

Clarification

Clarification

Real-Time Soft Shadows

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Goals:

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

NVIDIA

Challenge:

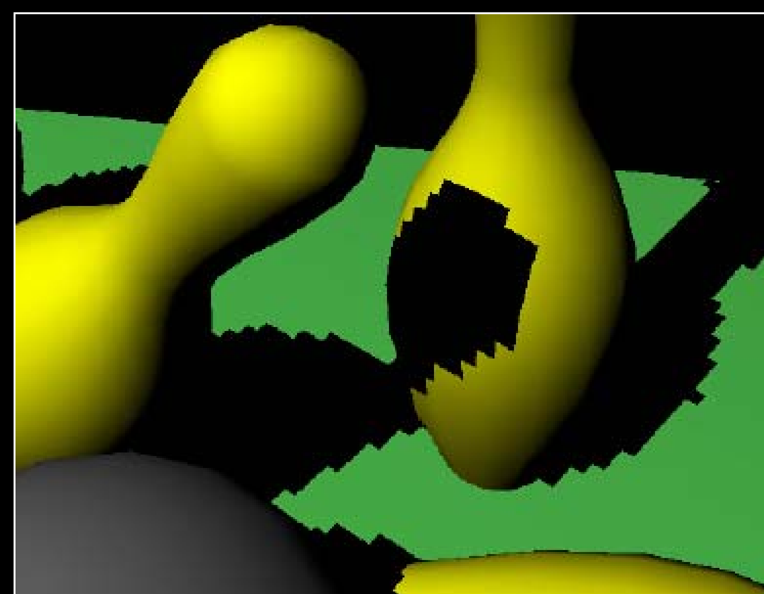
- How to balance quality and performance?

Ordinary Shadow Maps

Image-space algorithm:

- Fast and simple
- Supported in hardware
- Aliasing artifacts

NVIDIA



Sen et al. [SIGGRAPH 2003]

Soft Shadow Maps

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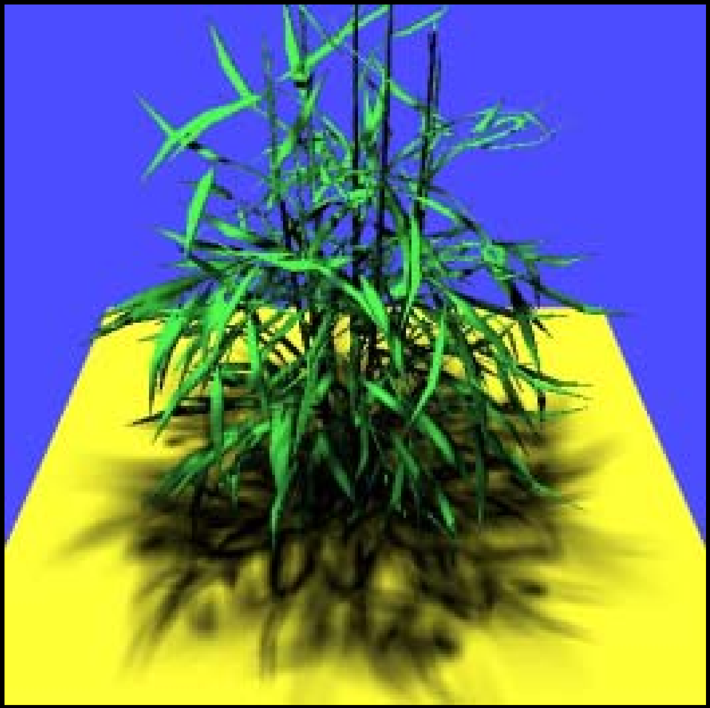
Techniques:

- 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.)

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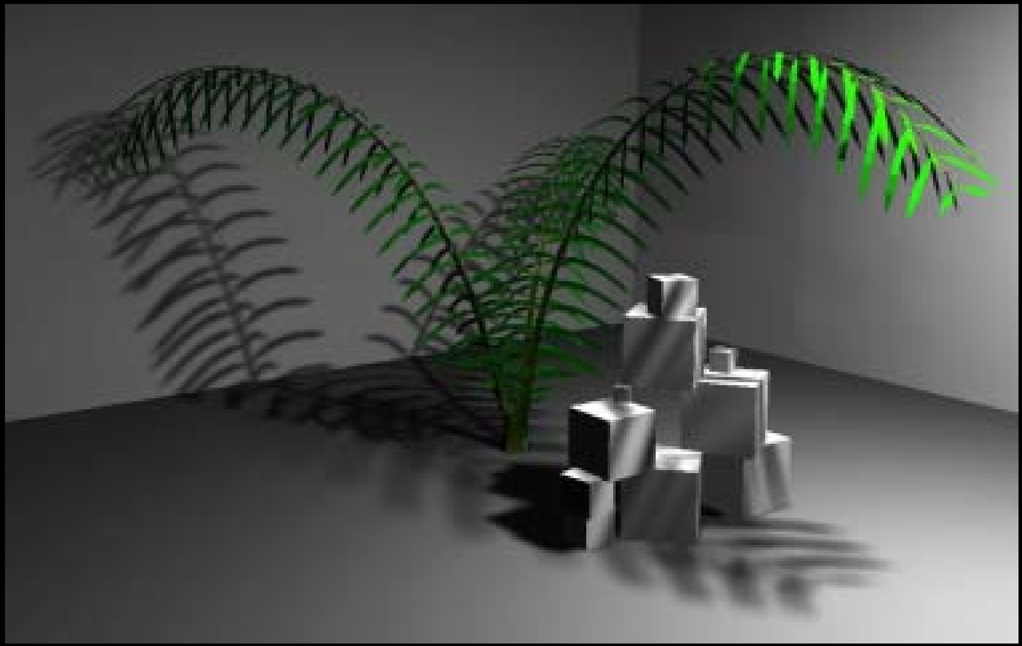
Approximations



Soler and Sillion

Examples:

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

Idea

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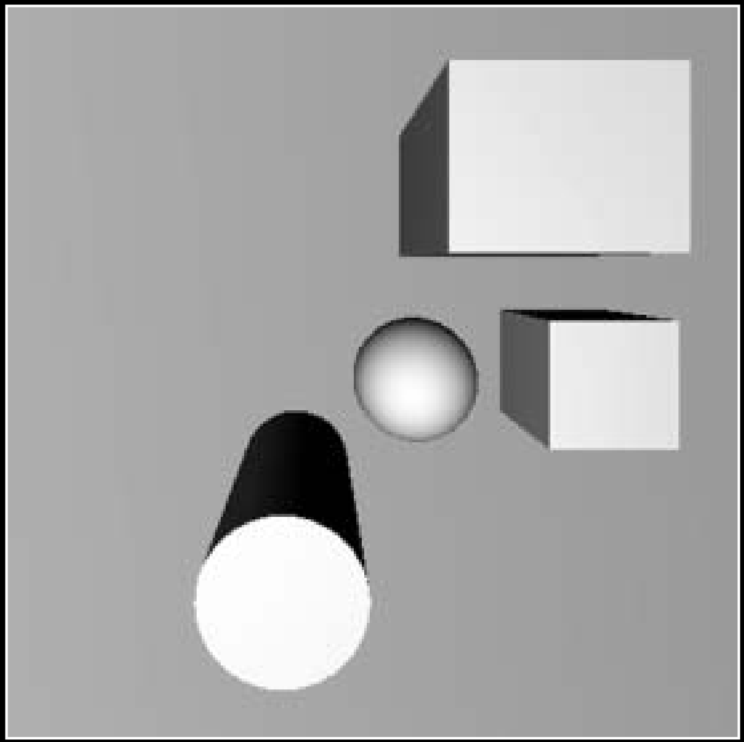
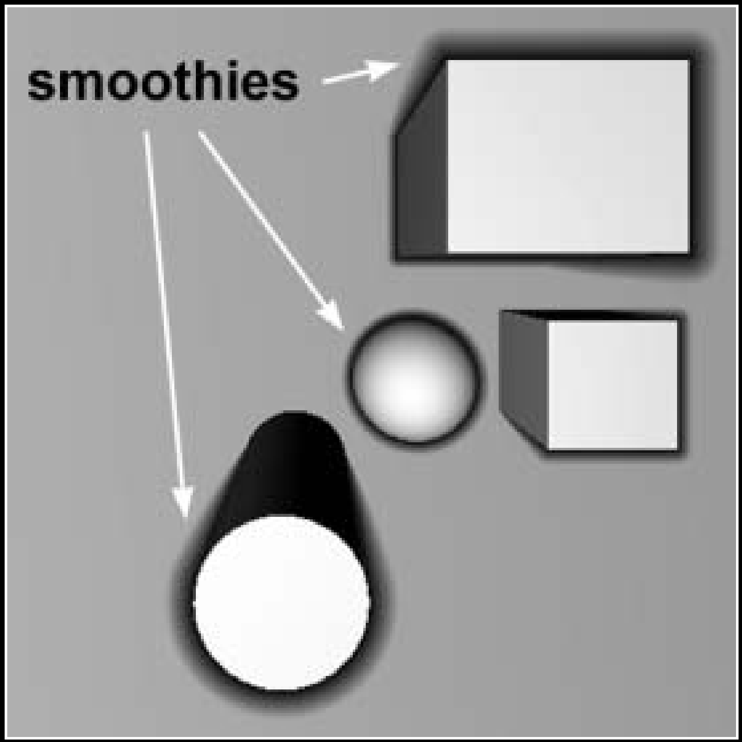
Extend basic shadow map approach

Extra primitives (smoothies) soften shadows



light's view (blockers only)



light's view (blockers + smoothies)

Fake Soft Shadows

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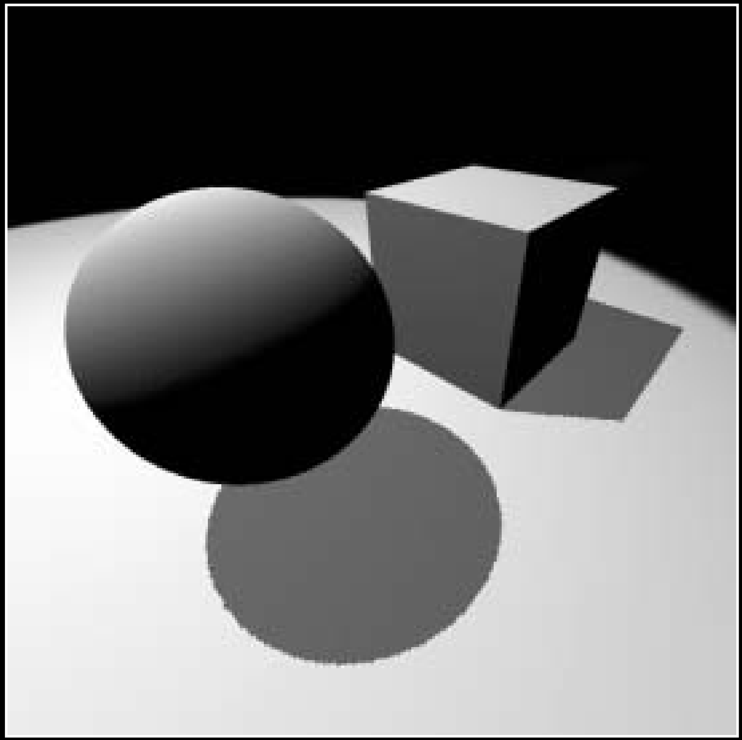
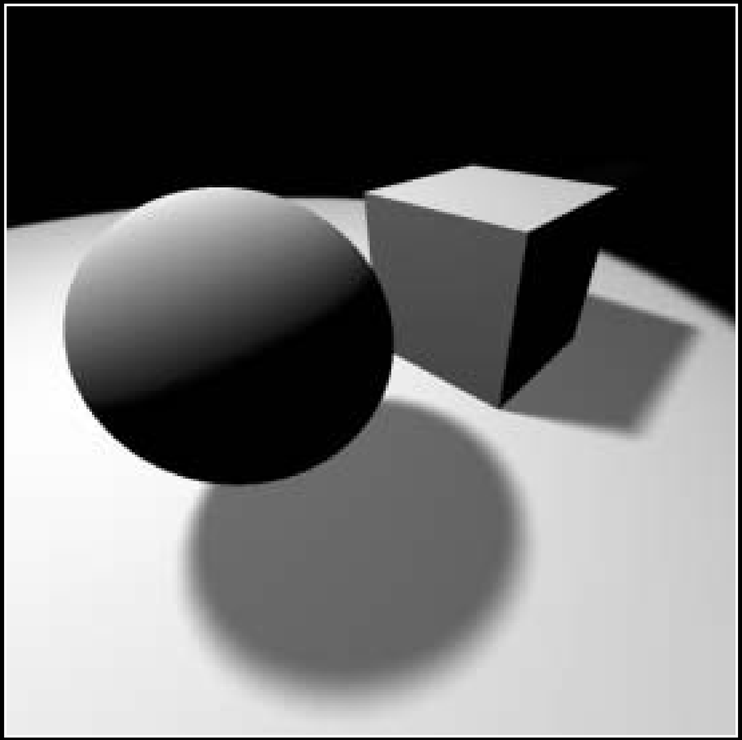
Shadows not geometrically correct

Shadows appear qualitatively like soft shadows



Hard shadows



Fake soft shadows

Smoothie Algorithm

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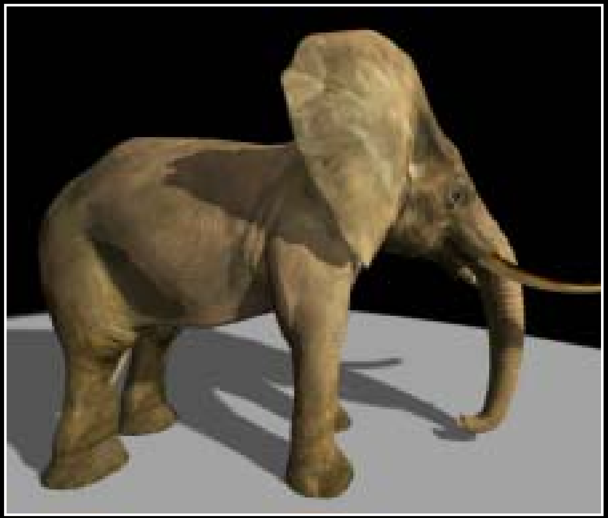
Properties:

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



References

Rendering Fake Soft Shadows with Smoothies

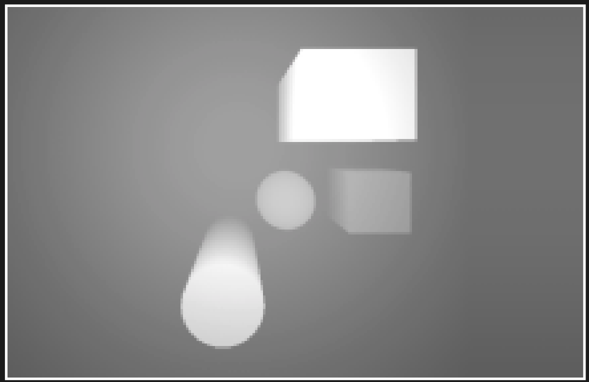
- E. Chan and F. Durand [EGSR 2003]

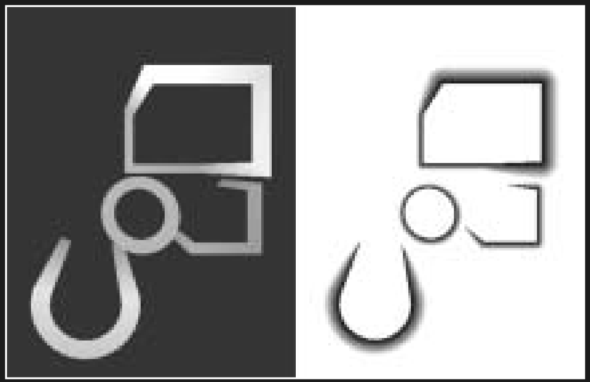
Penumbra Maps

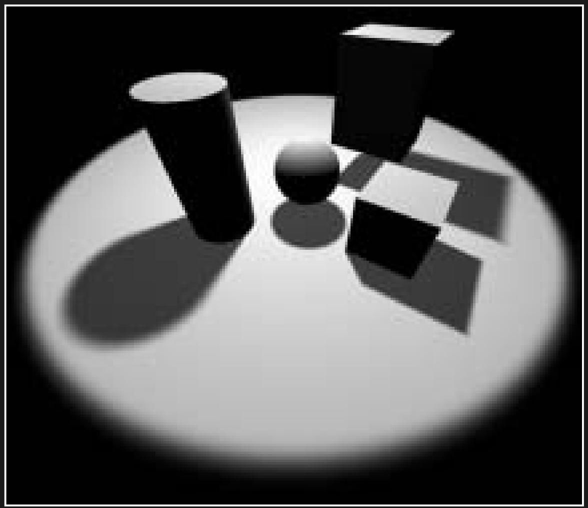
- C. Wyman and C. Hansen [EGSR 2003]

Algorithm

Algorithm Overview





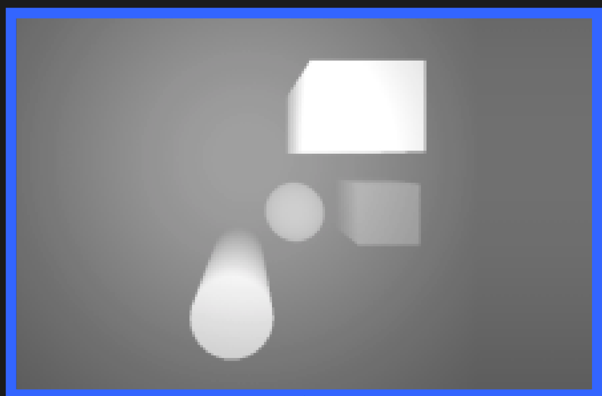


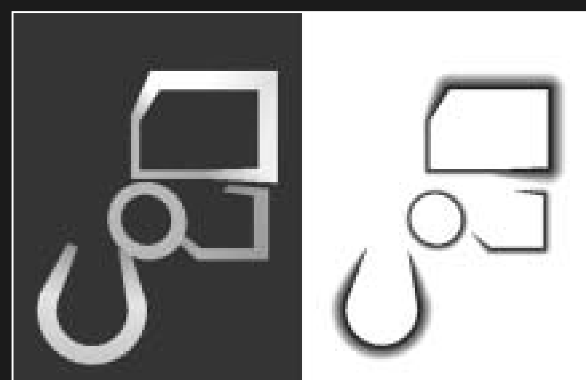
Focus on concepts

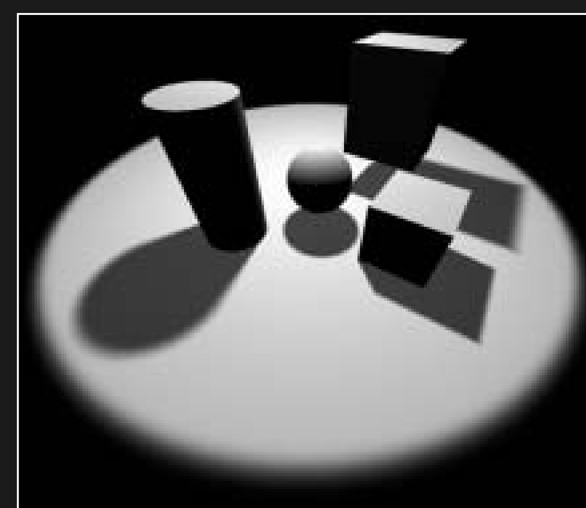
Implementation details later

Algorithm Overview

Step 1



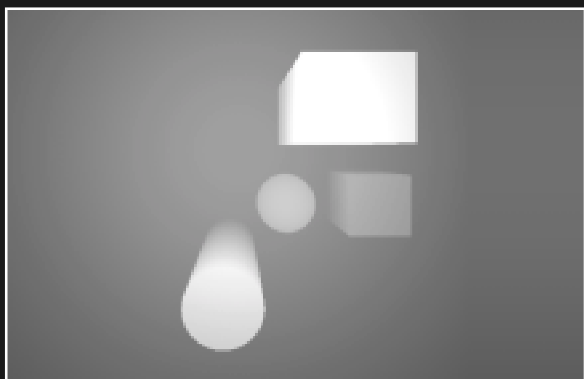


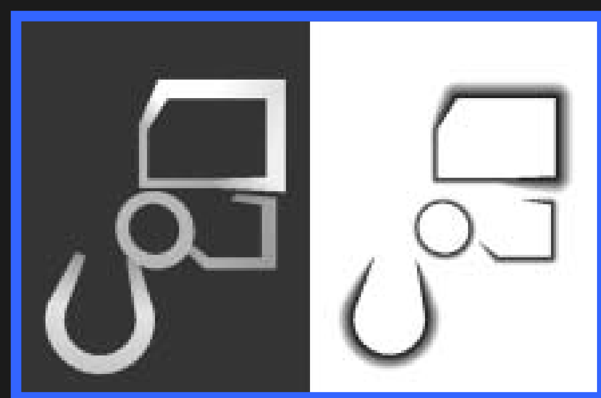


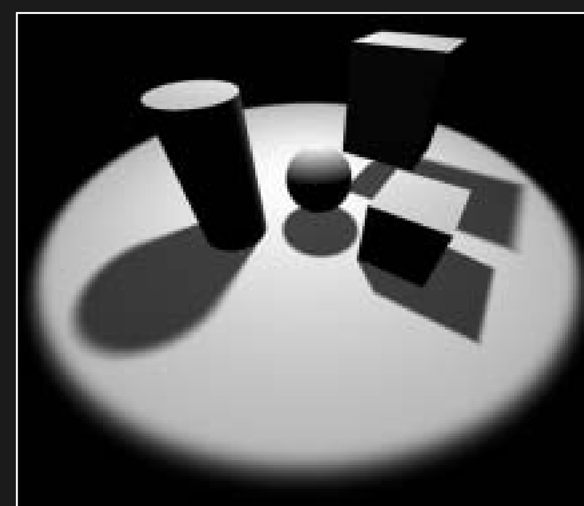
Create depth map

Algorithm Overview

Step 2







Create smoothie buffer

Algorithm Overview

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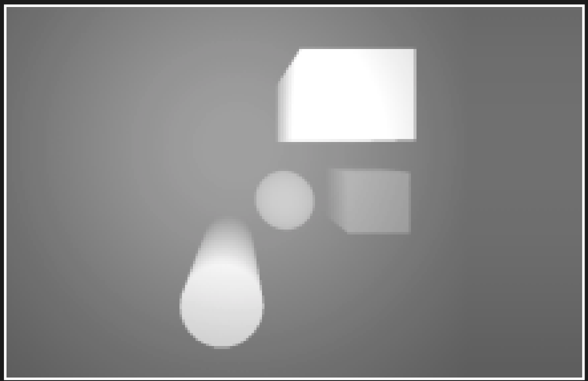
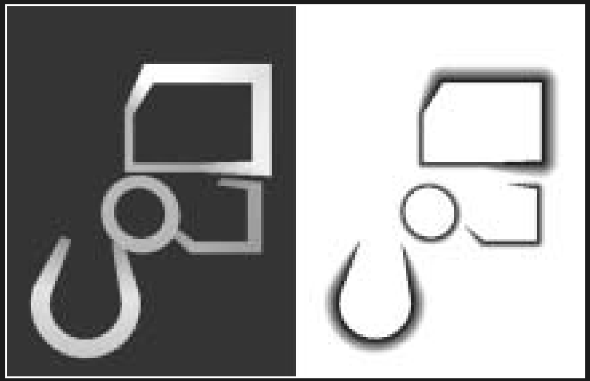
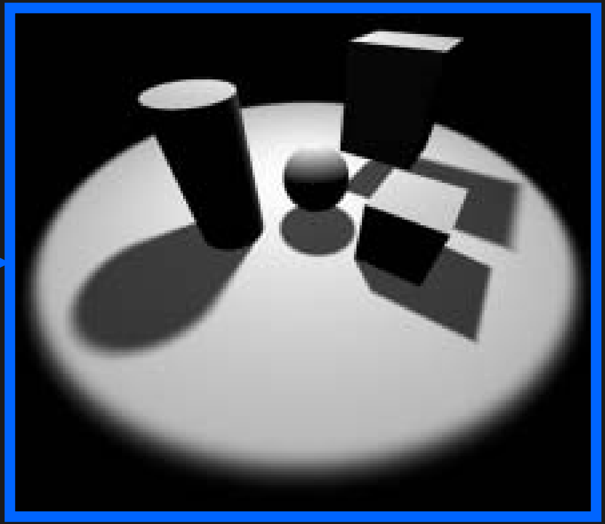
Step 3



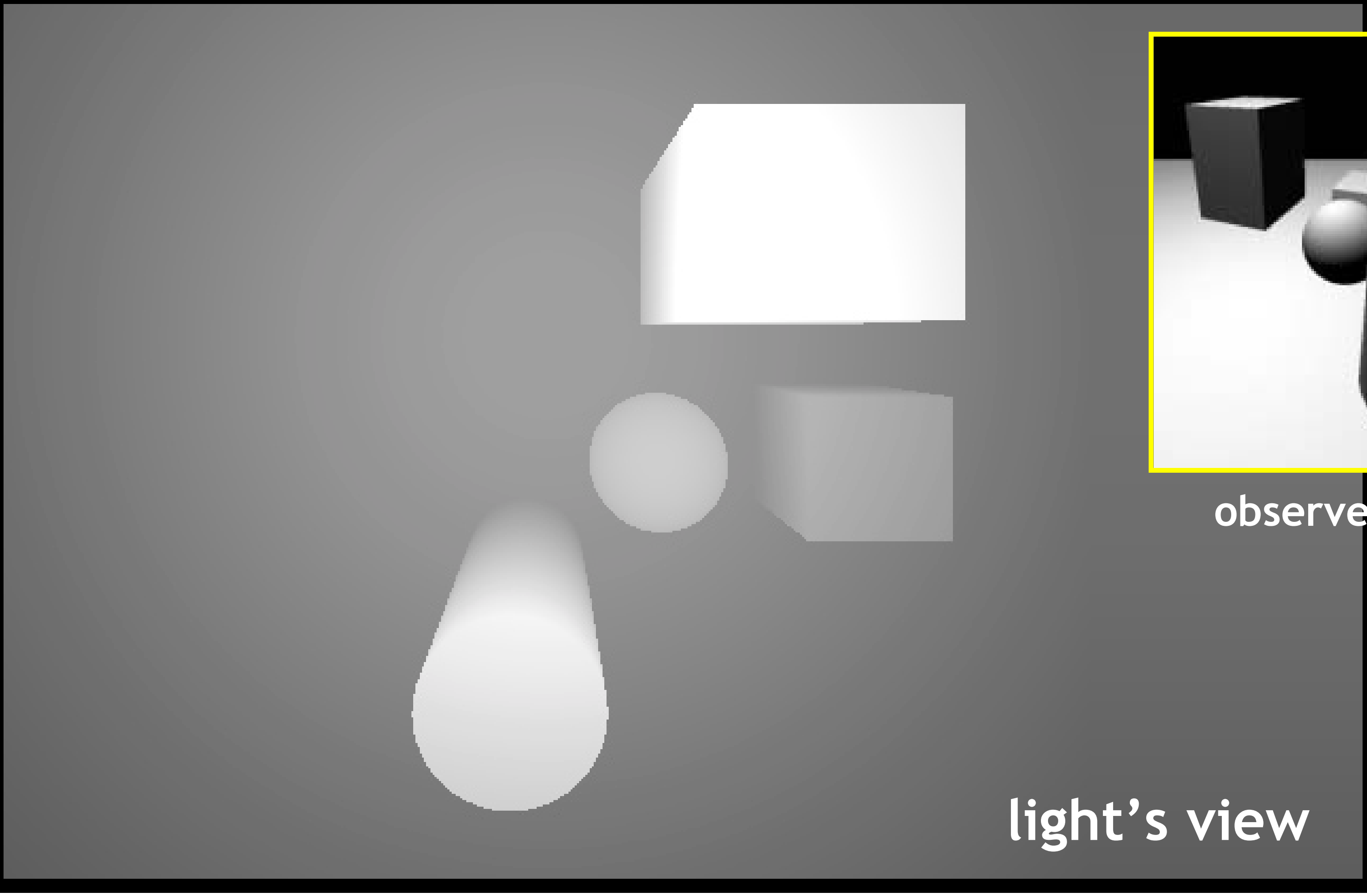


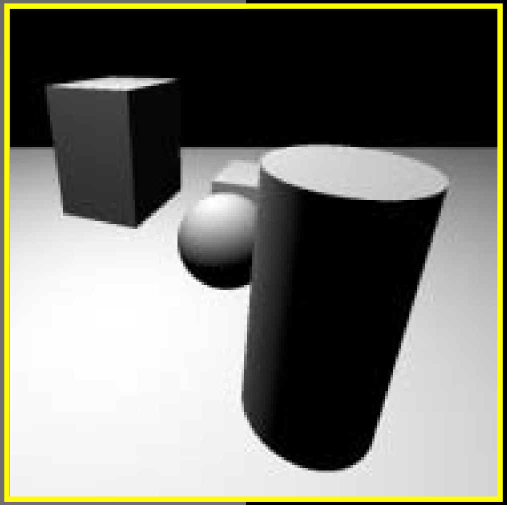


Render scene + shadows

Create Shadow Map

Render blockers into depth map

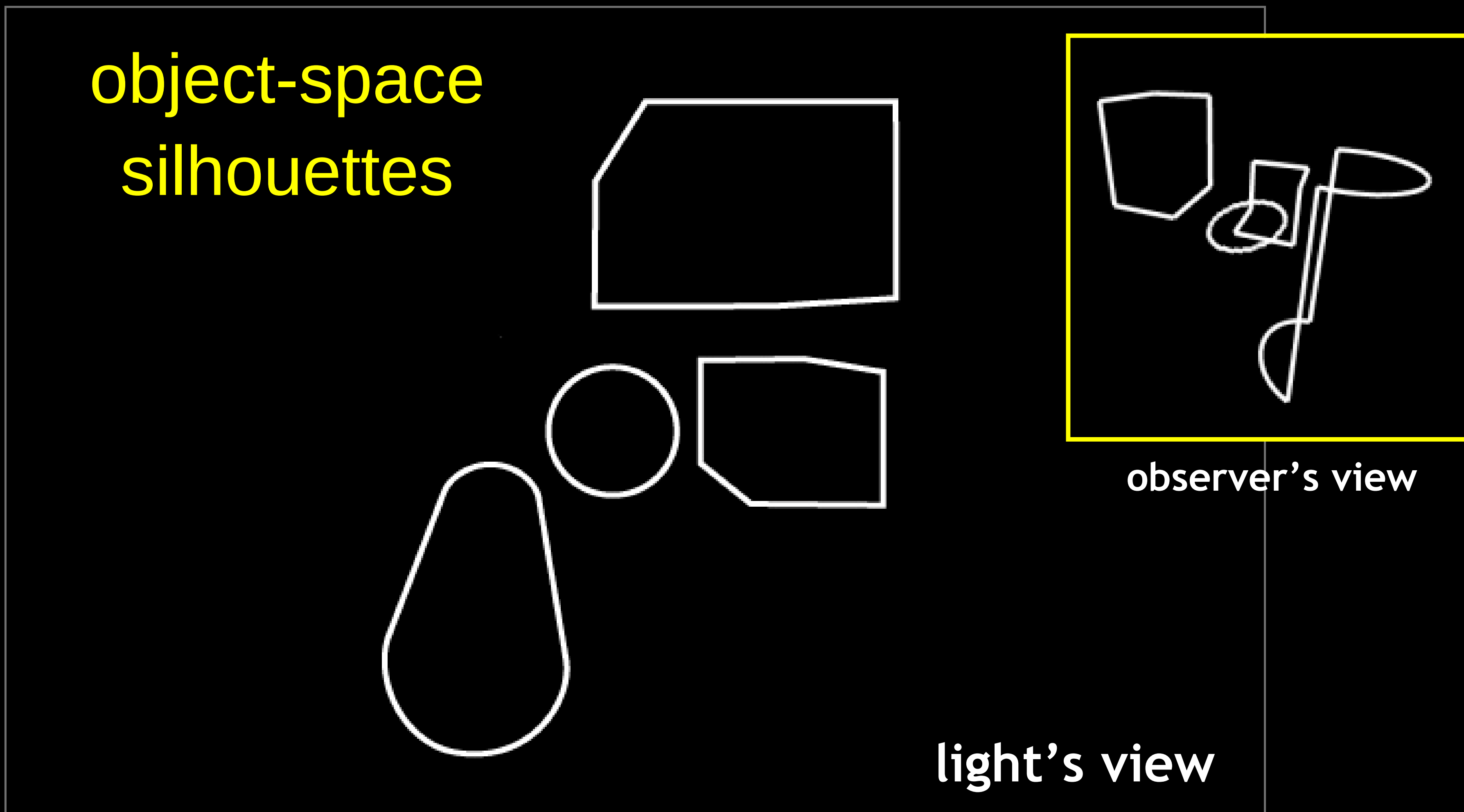




observer's view

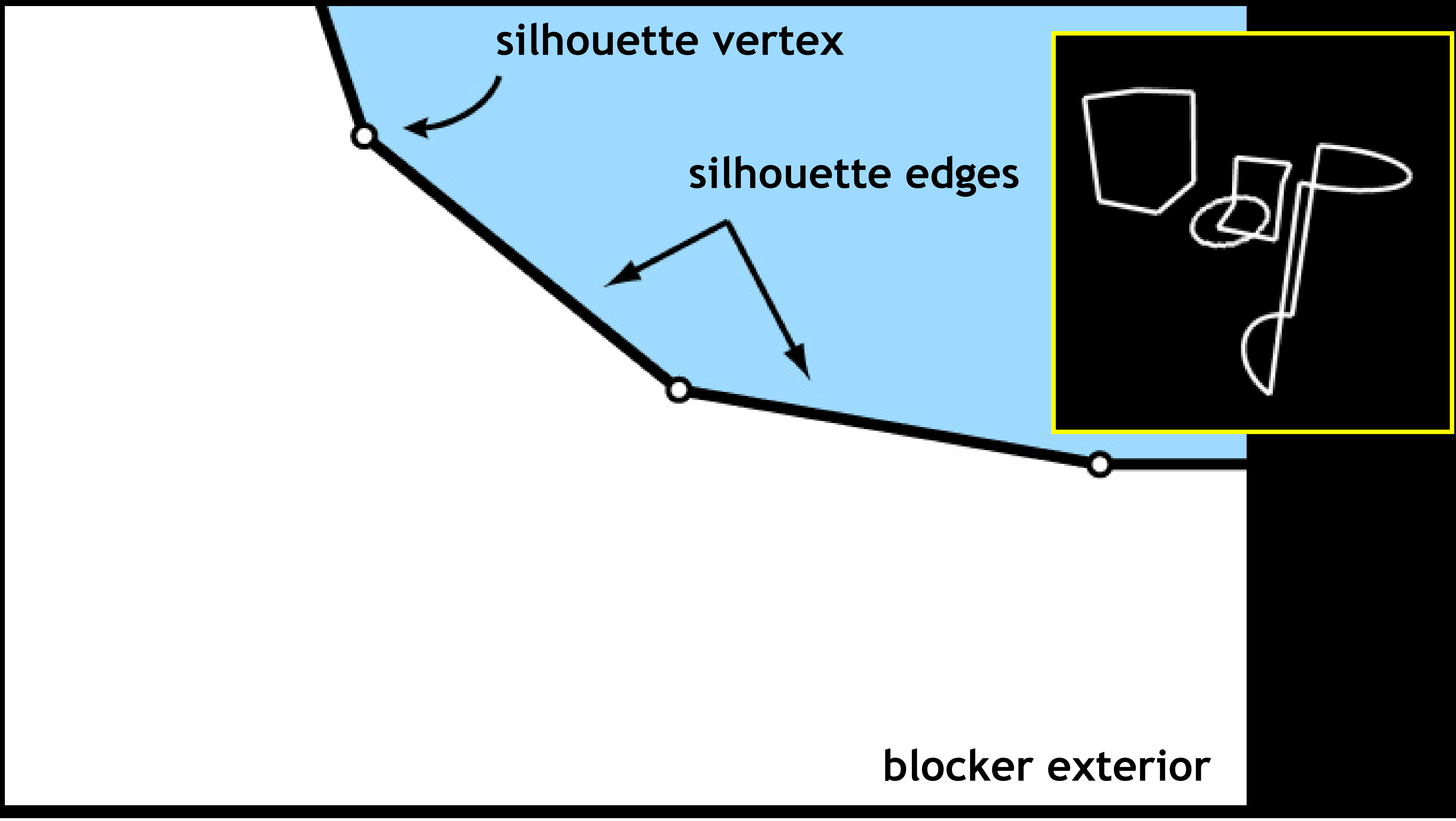
Find Silhouette Edges

Find blockers' silhouette edges in object space



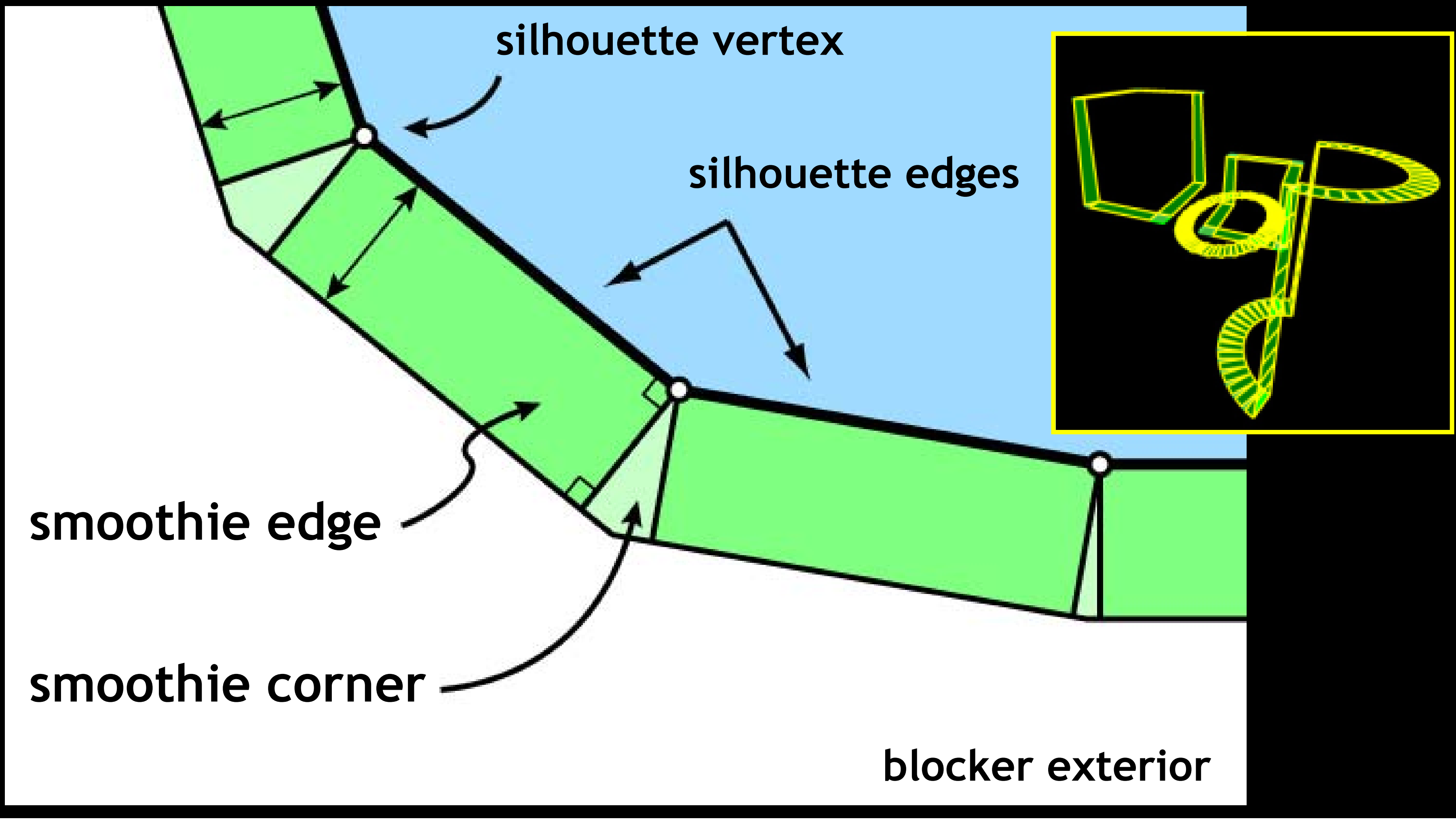
Construct Smoothies

Blocker only:



Construct Smoothies

Blocker + smoothies:



Construct Smoothies

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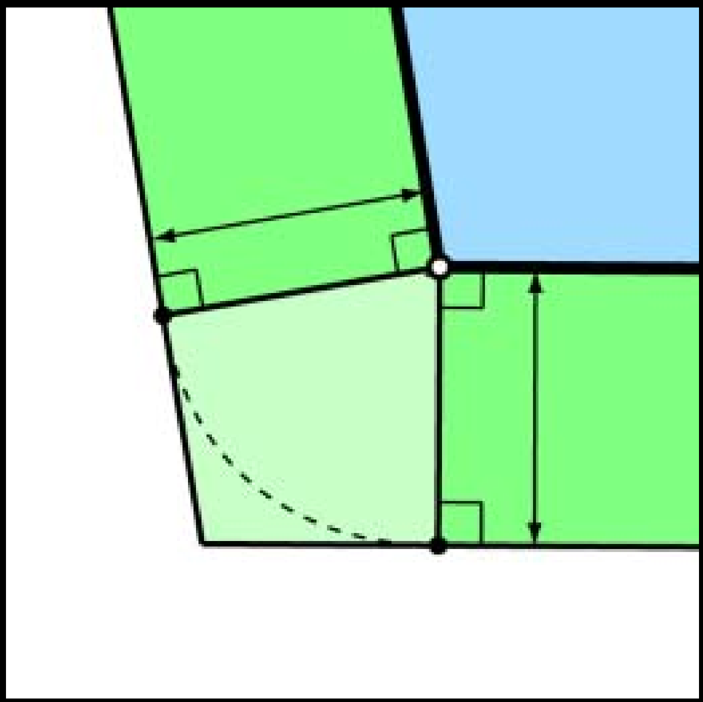
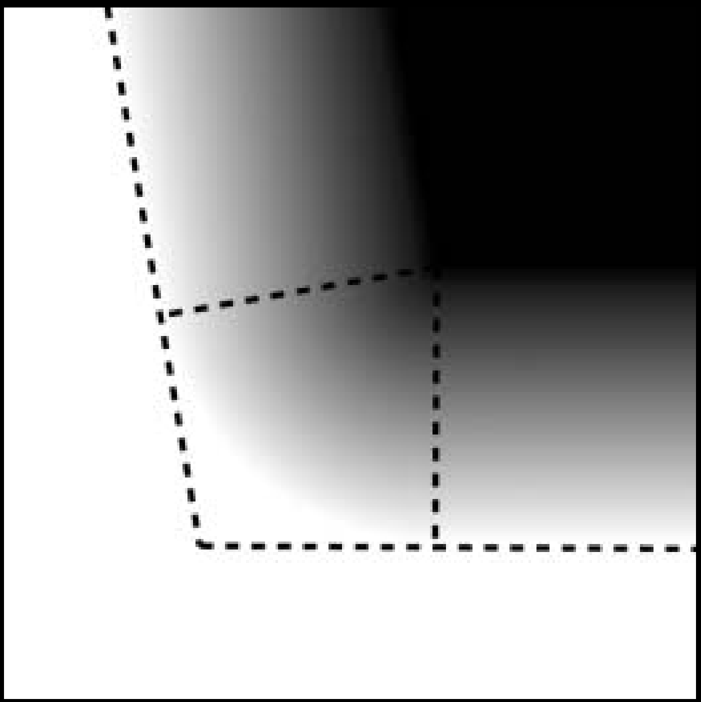
Smoothie edges are fixed-width rectangles in screen space

Smoothie corners connect adjacent smoothie edges



geometry



shading

Render Smoothies

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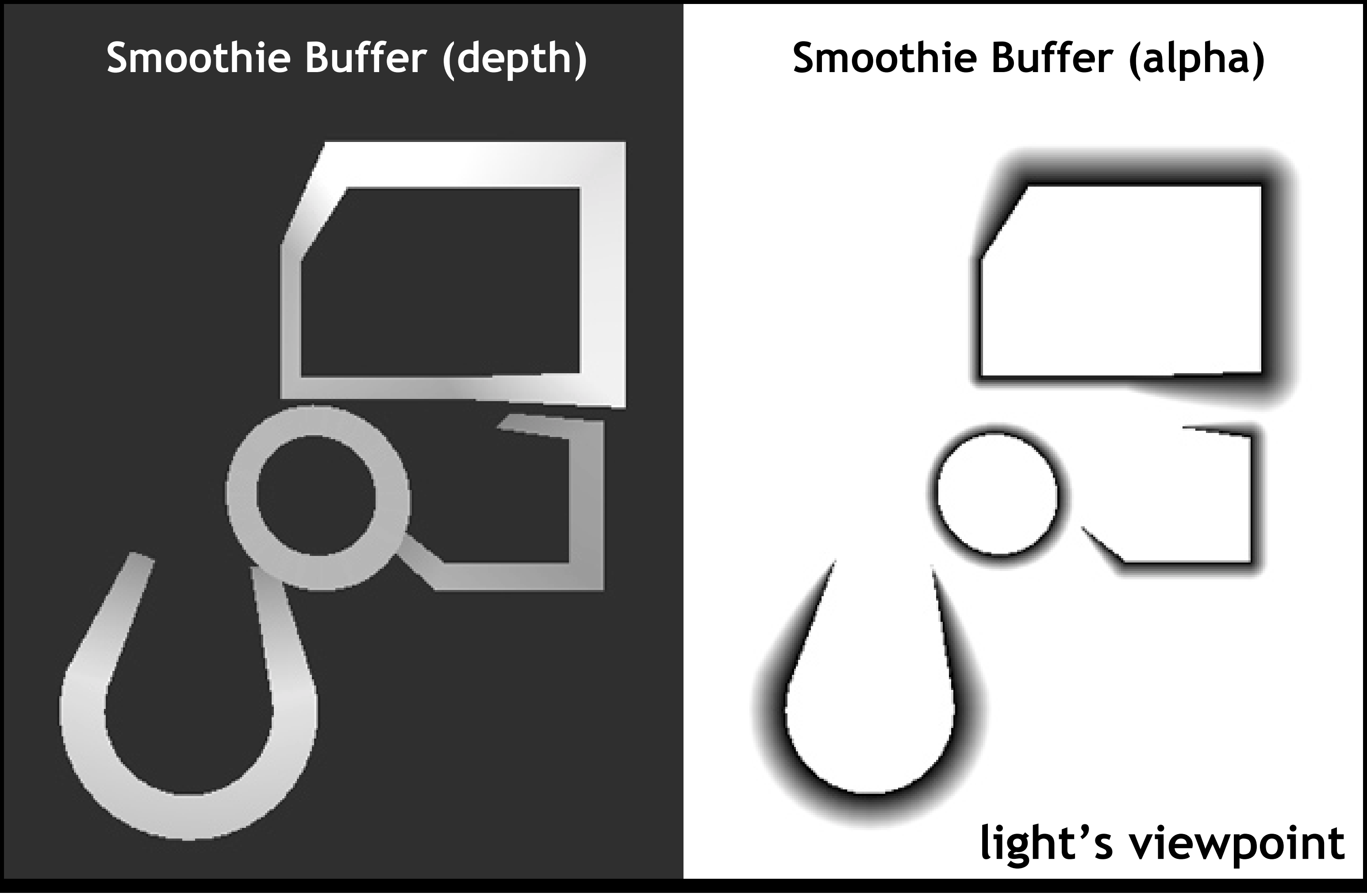
Store depth and alpha values into smoothie buffer



Compute Shadows

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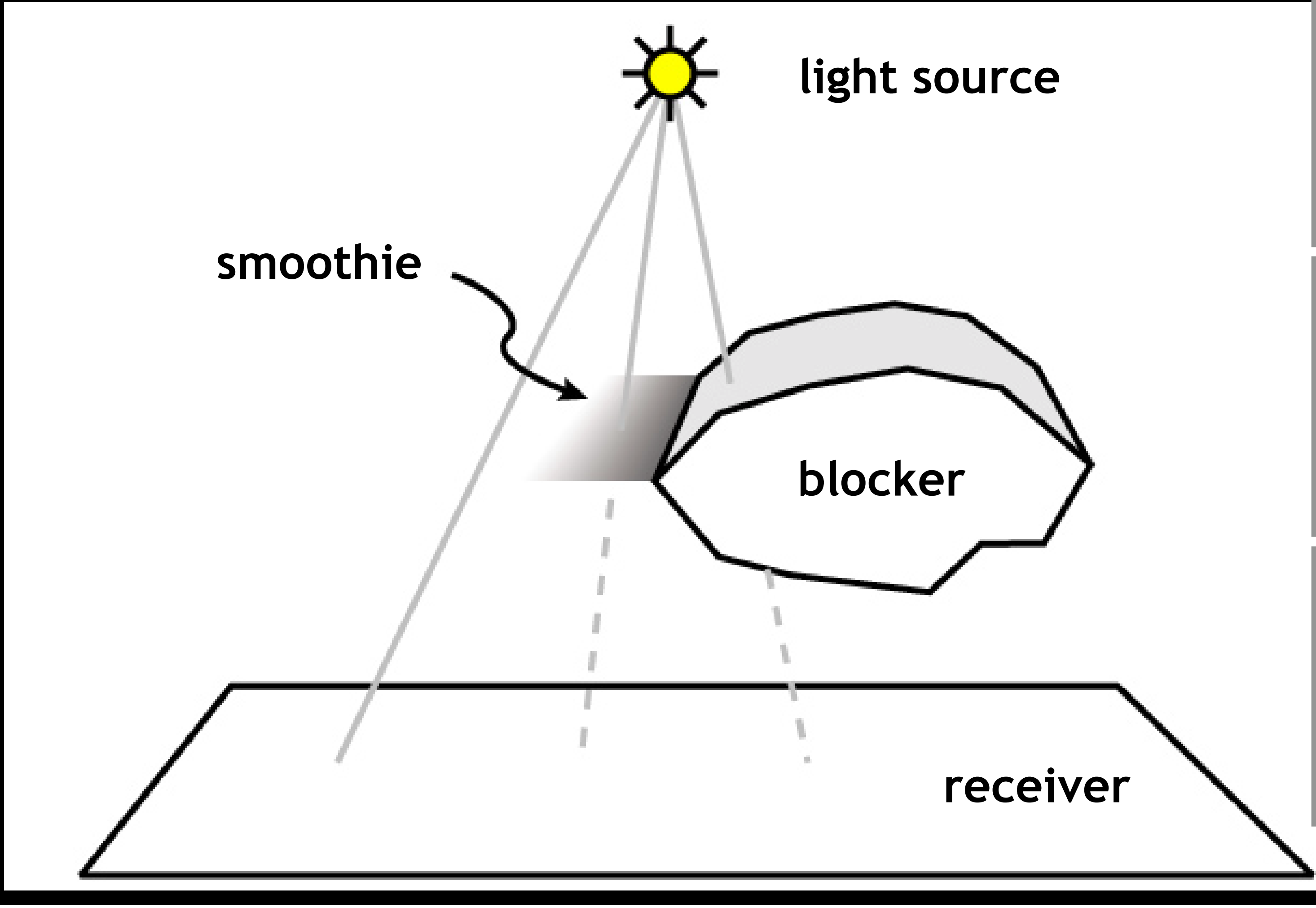
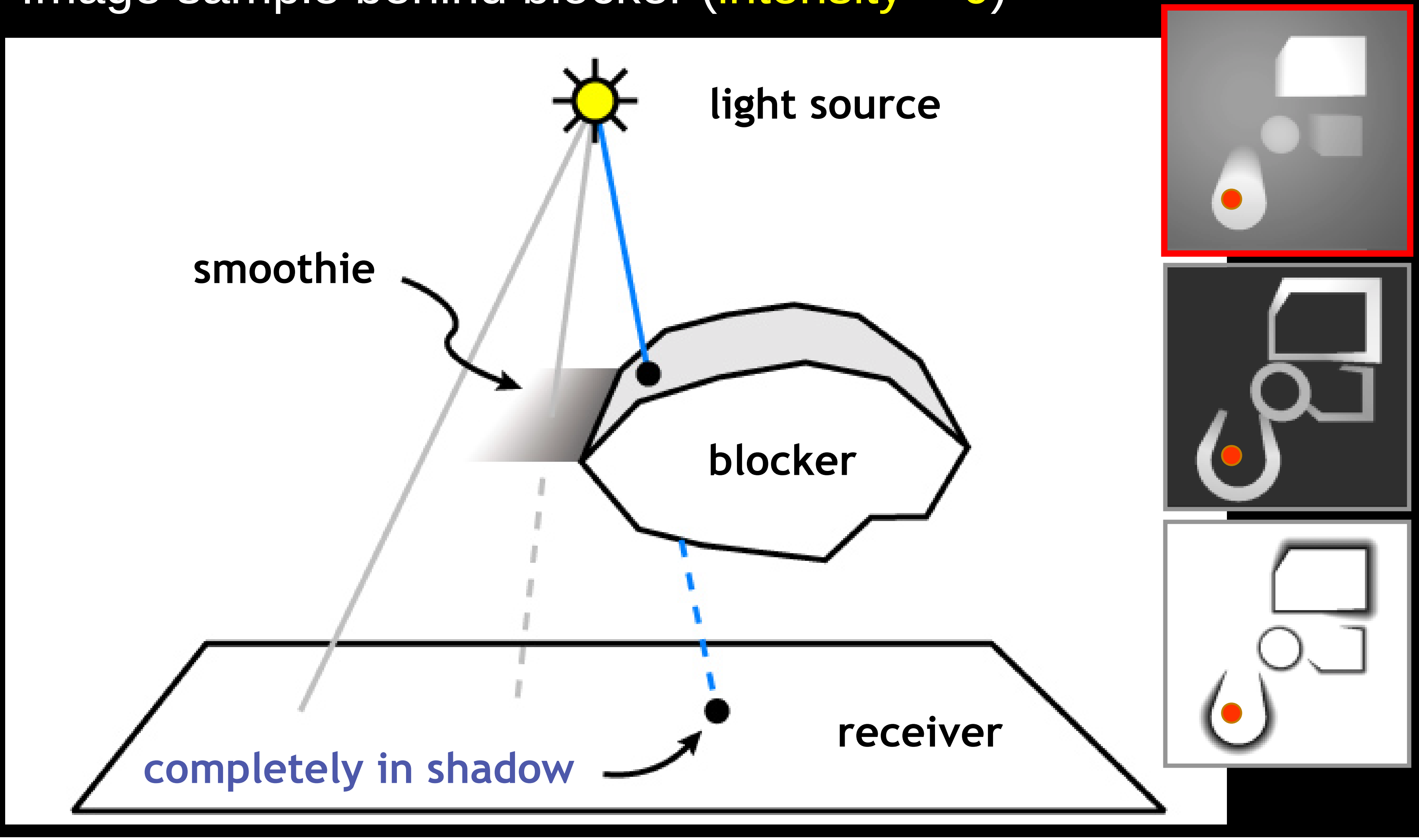
Compute intensity using depth comparisons



Compute Shadows (1 of 3)

Image sample behind blocker (intensity = 0)



Compute Shadows (2 of 3)

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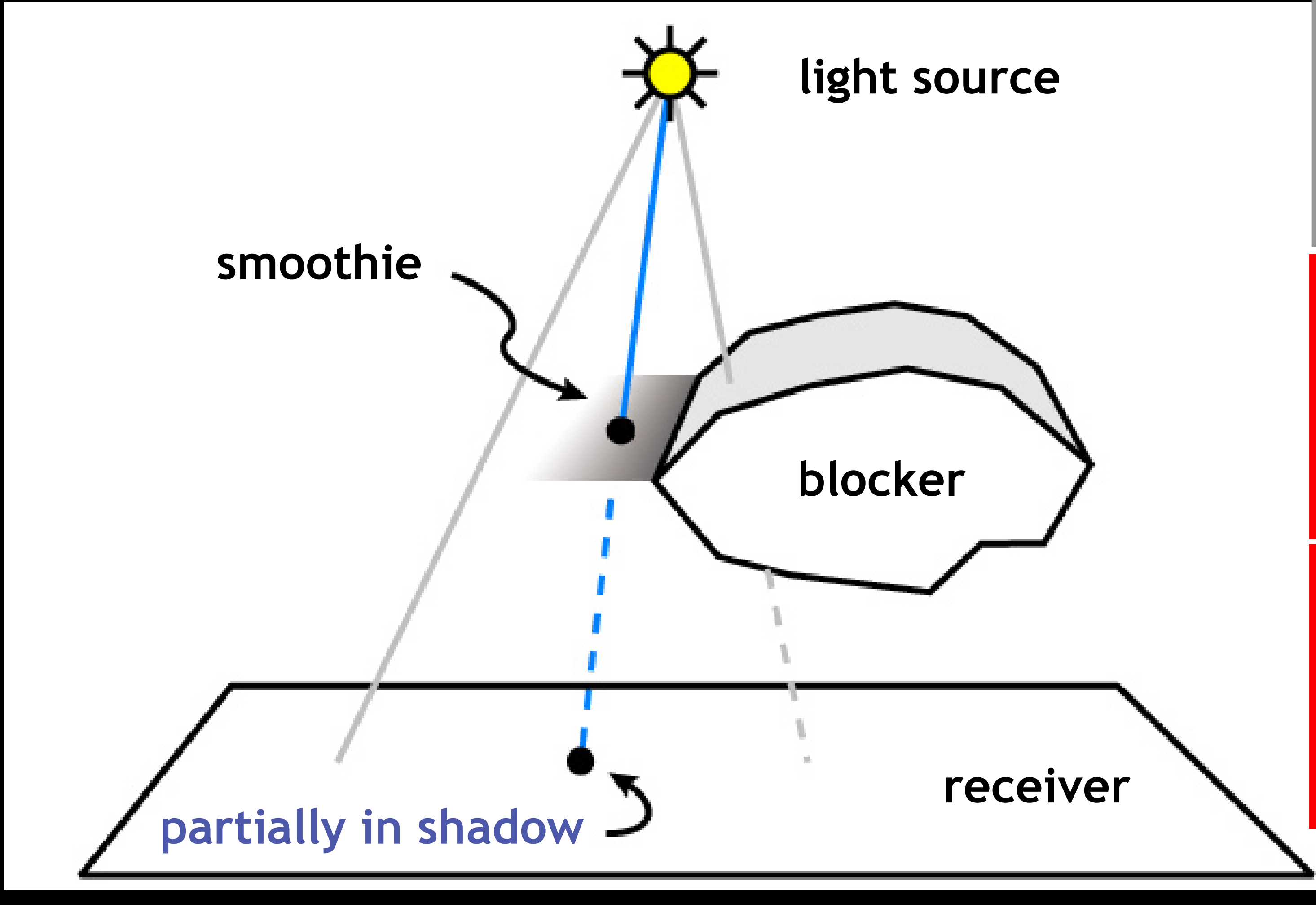
Image sample behind smoothie (intensity = α)



Compute Shadows (3 of 3)

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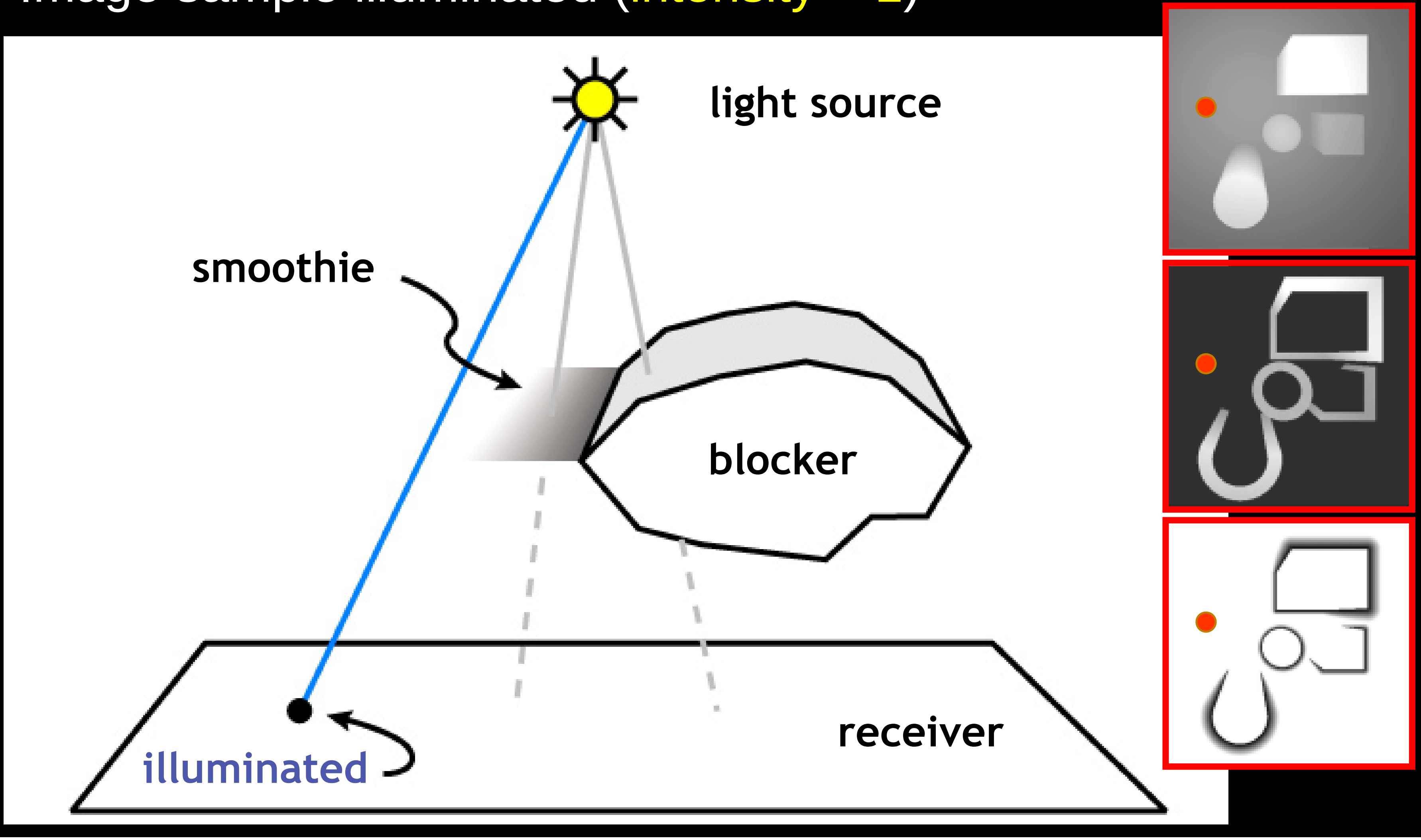
Image sample illuminated (intensity = 1)



Computing Alpha Values

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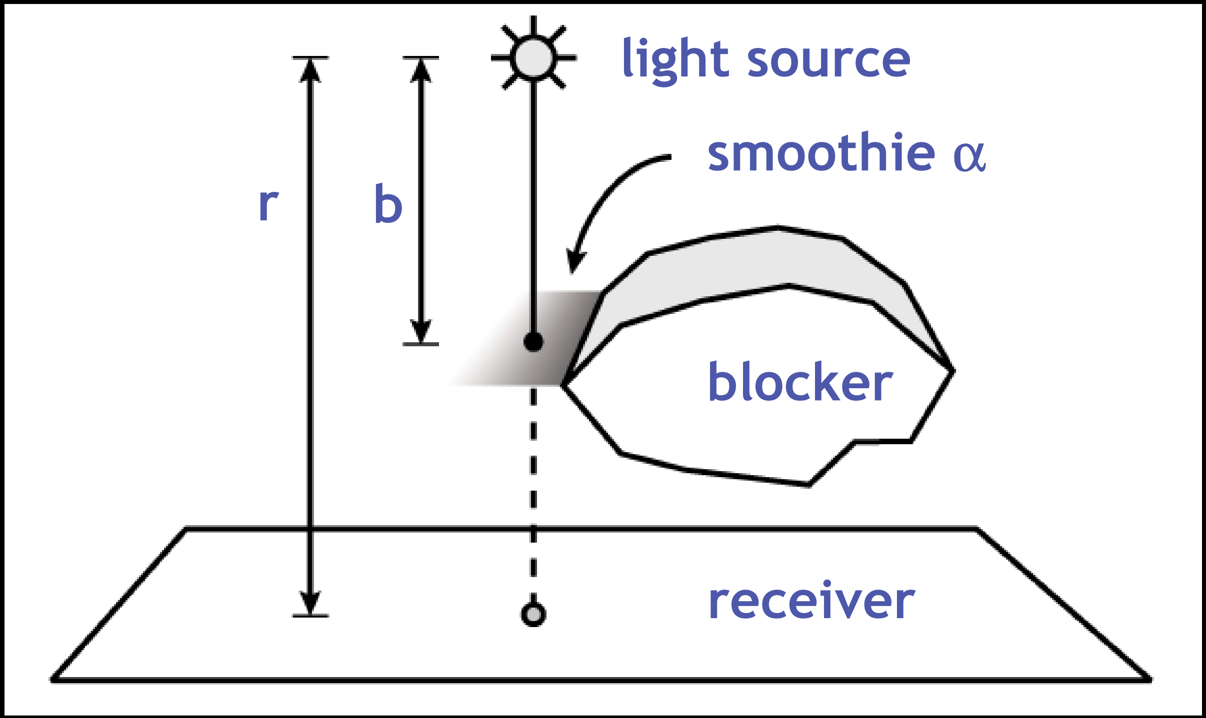
Intuition:

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



Without Alpha Remapping

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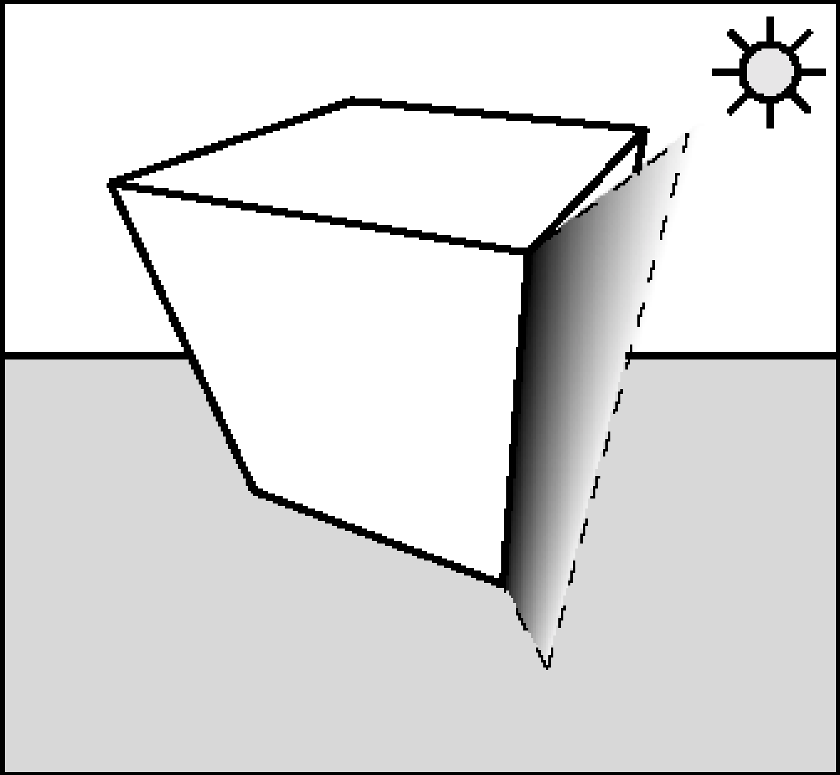
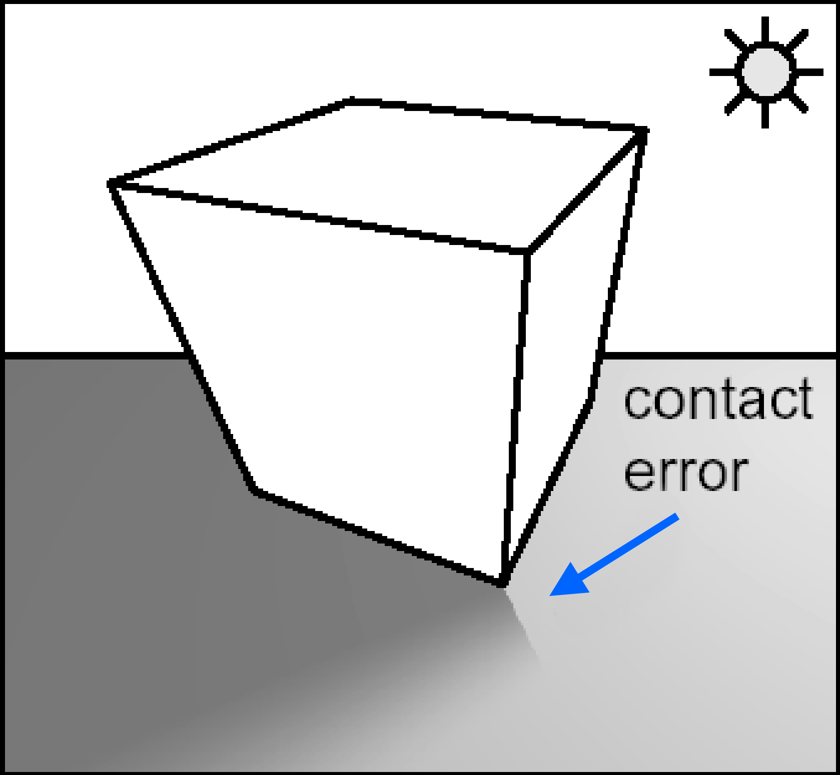
Linearly interpolated alpha → undesired results!



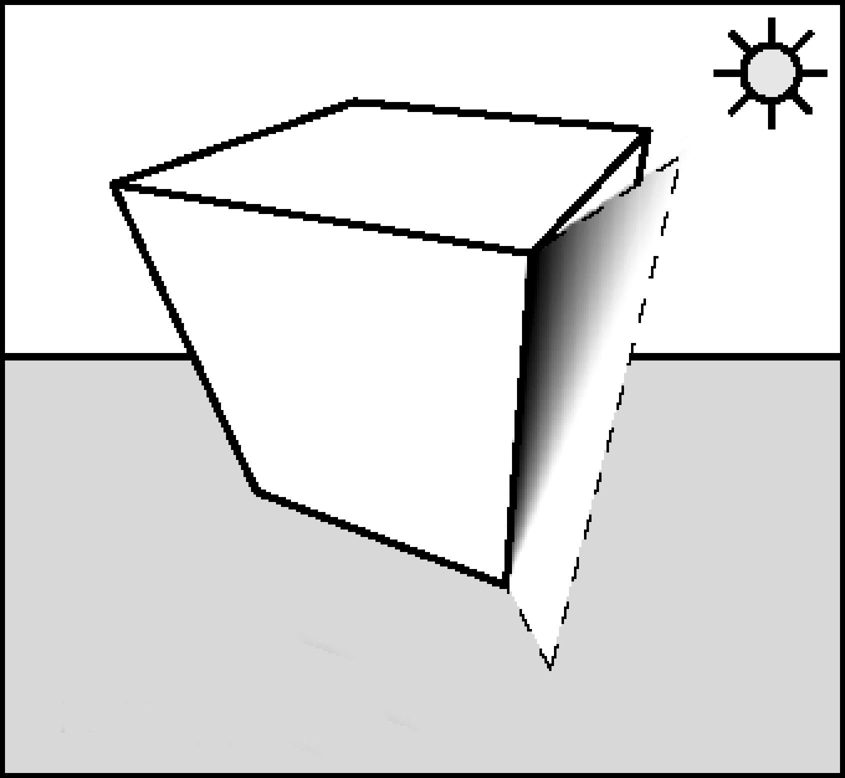
smoothie



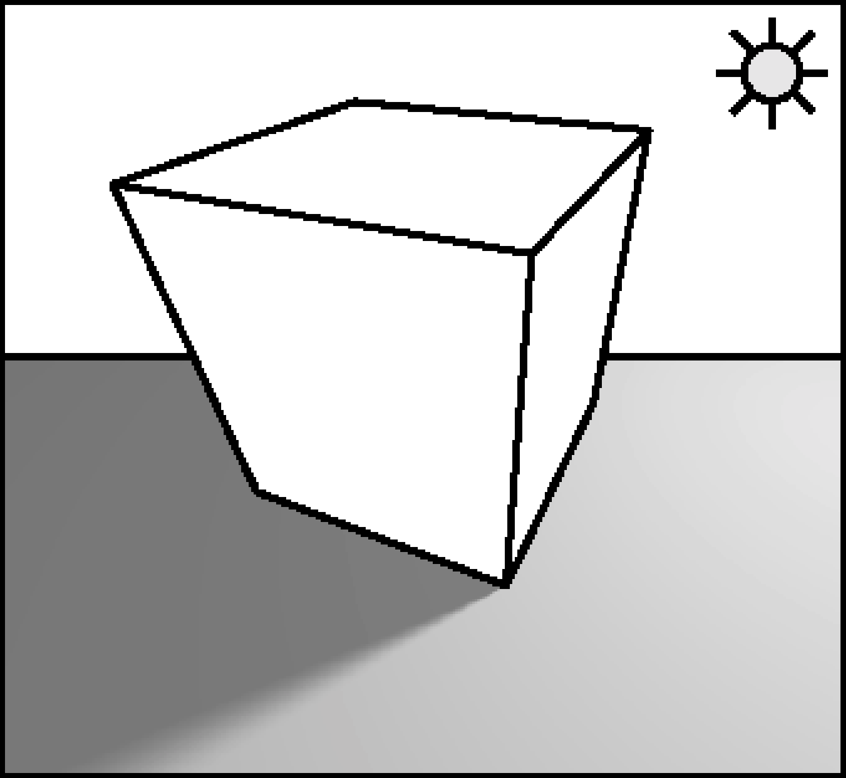
contact problem

With Alpha Remapping

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



smoothie



fixed contact problem

Computing Alpha Values

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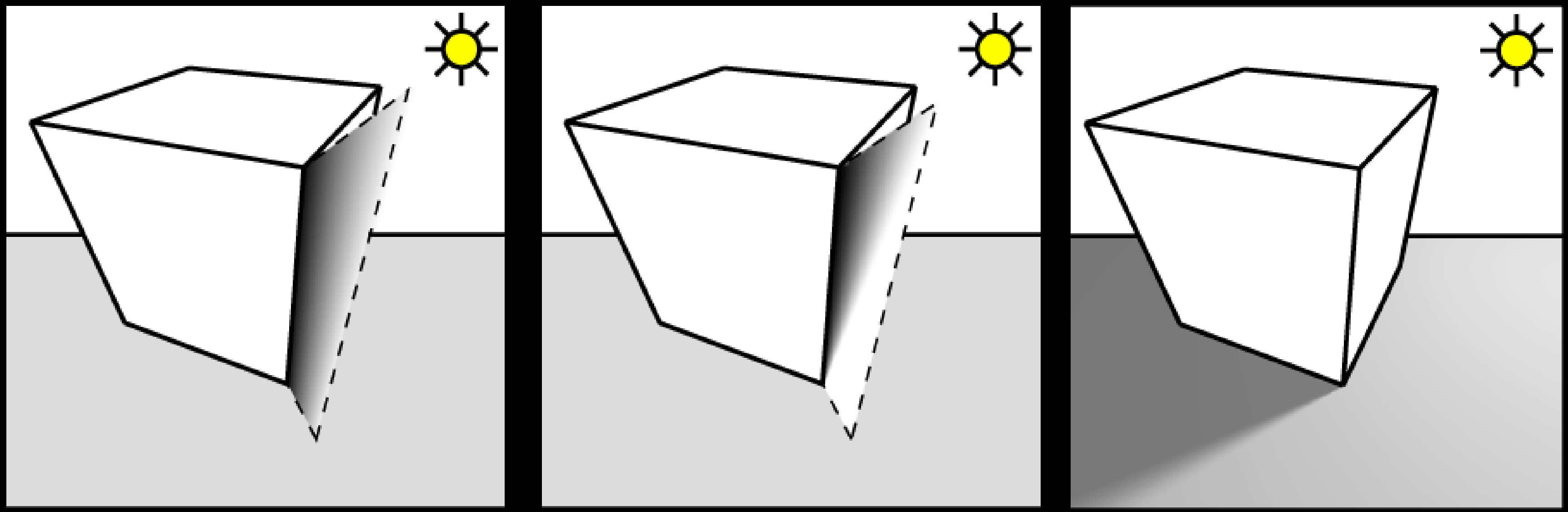
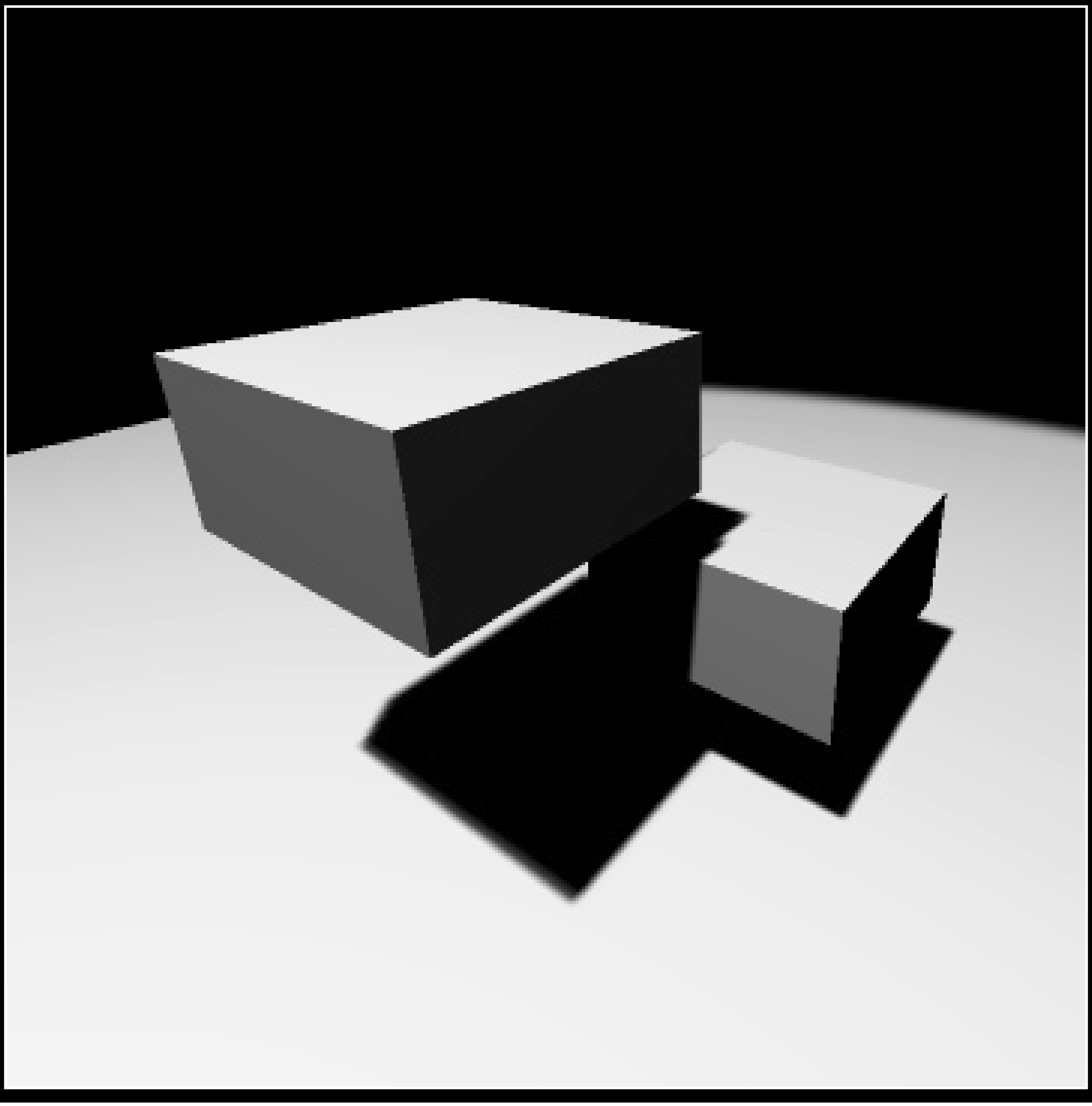
1. Linearly interpolate alpha
2. Remap alpha at each pixel using ratio b/r:

$$\boxed{\alpha' = \alpha / (1 - b/r)}$$

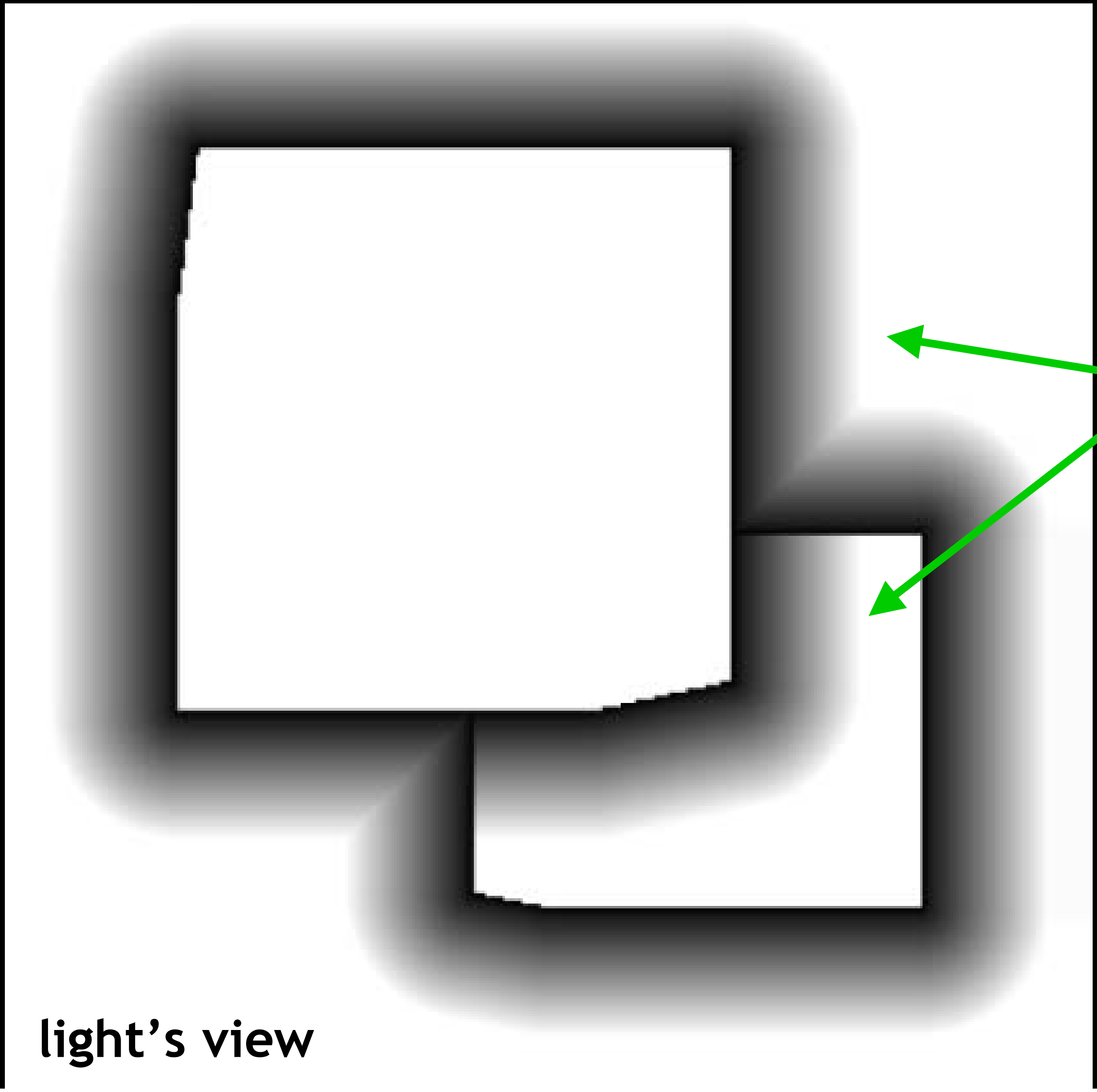


original α | remapped α | result

Multiple Objects



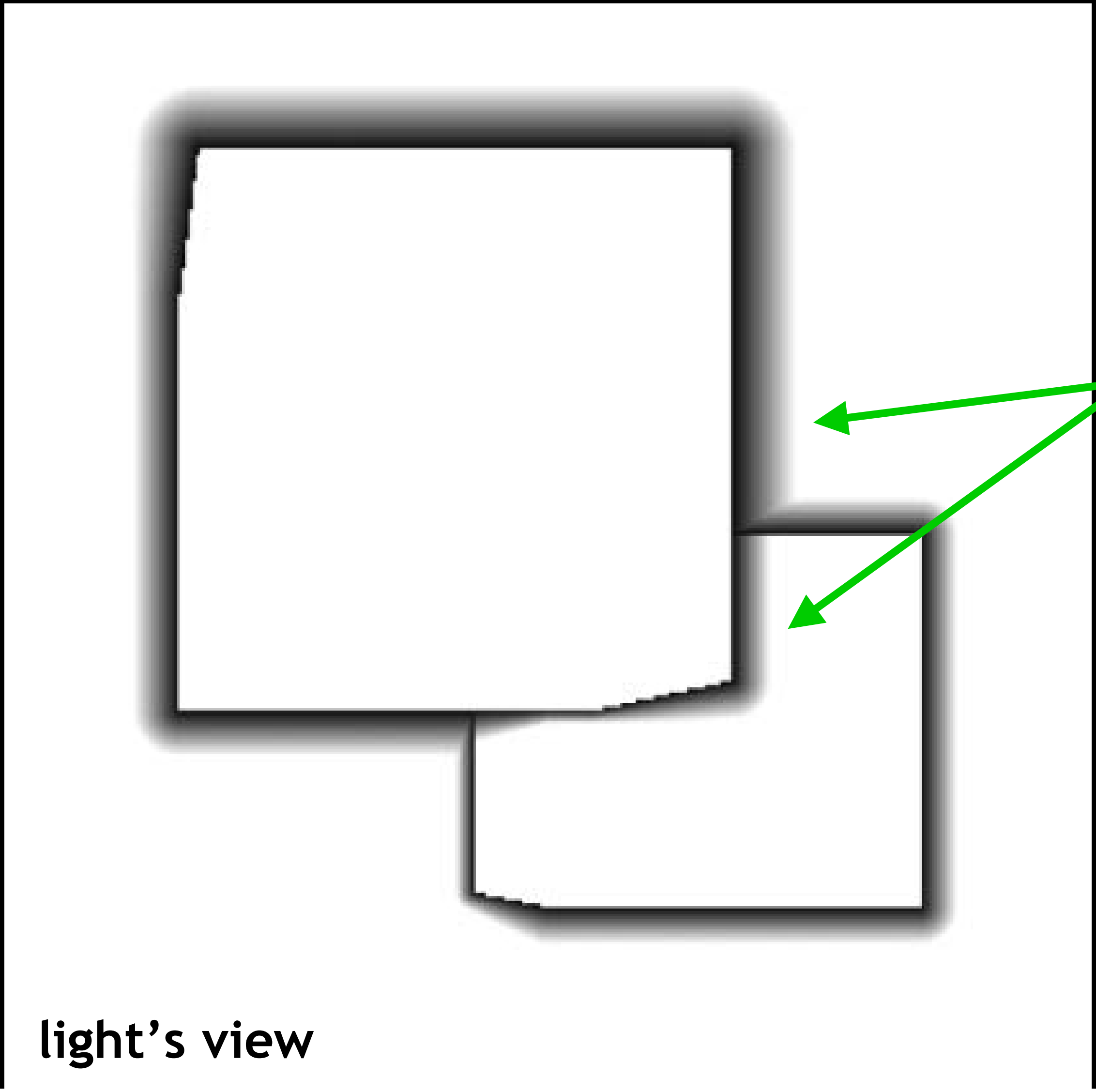
Multiple Receivers



Smoothie buffer
(linearly-interpolated α)

same thickness

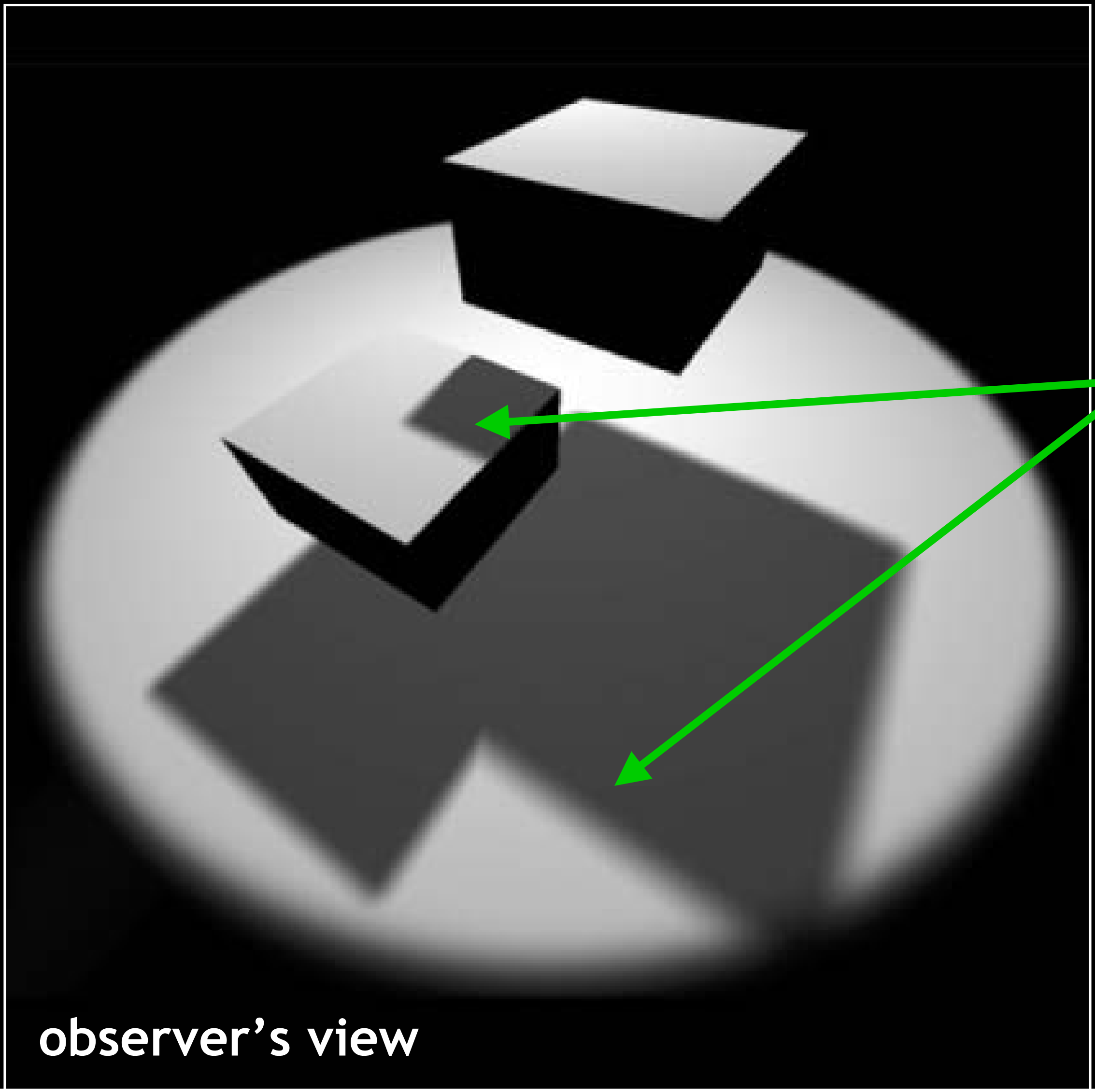
Multiple Receivers



Smoothie buffer
(remapped α)

different thickness

Multiple Receivers



Final image

different thickness

Multiple Blockers

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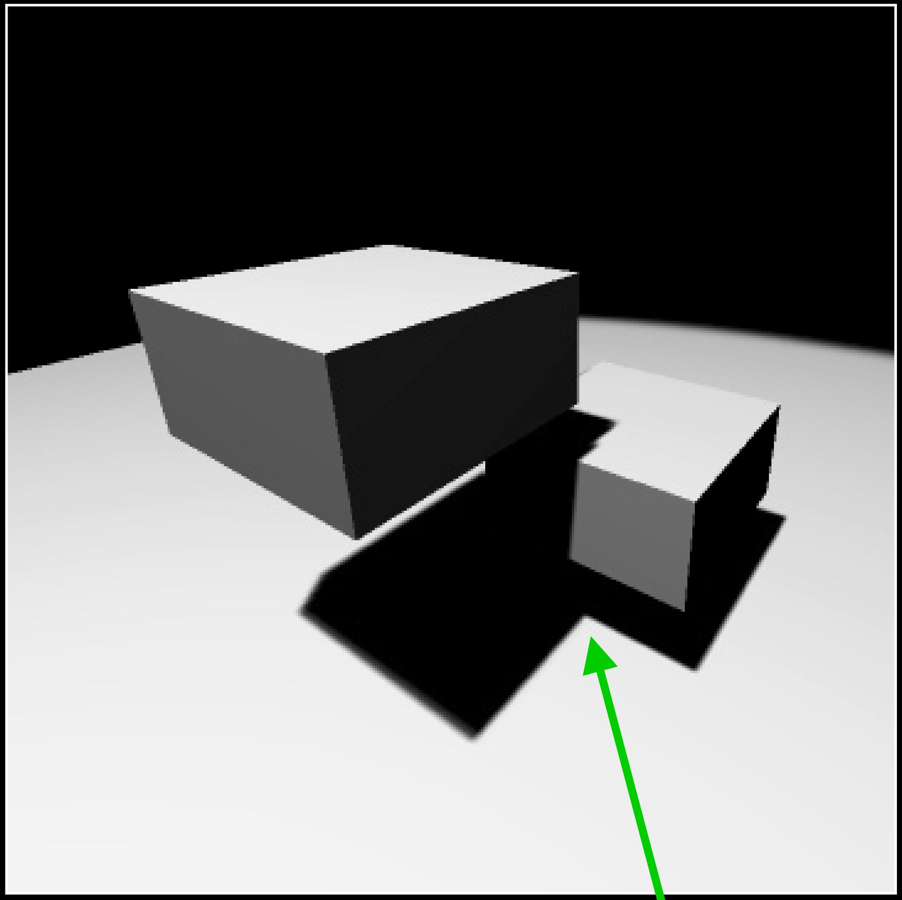
What happens when smoothies overlap?



smoothie overlap

Multiple Blockers

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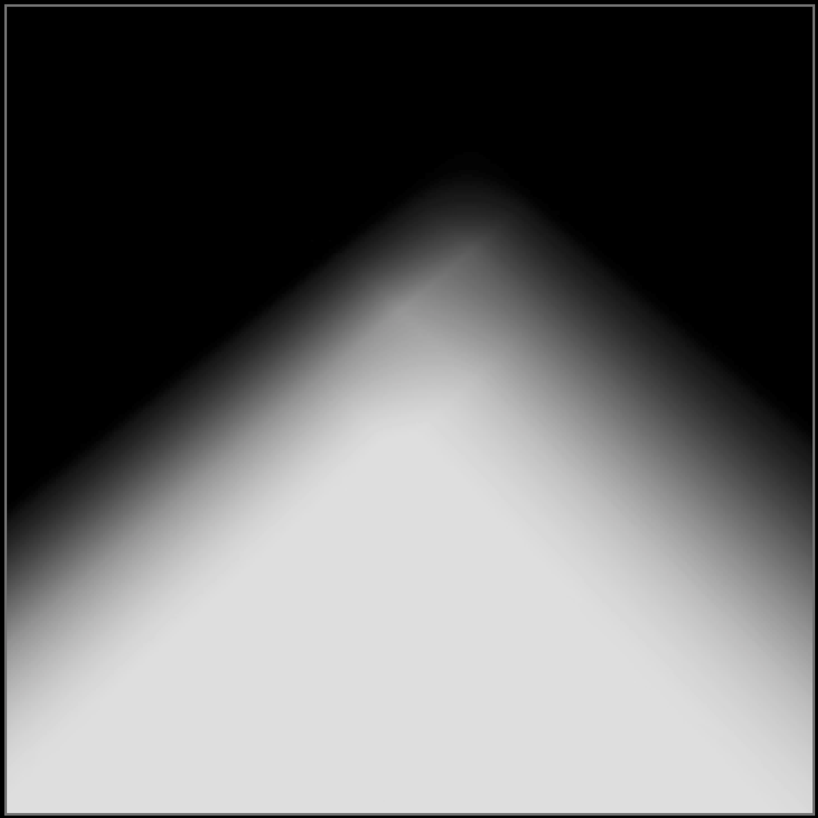
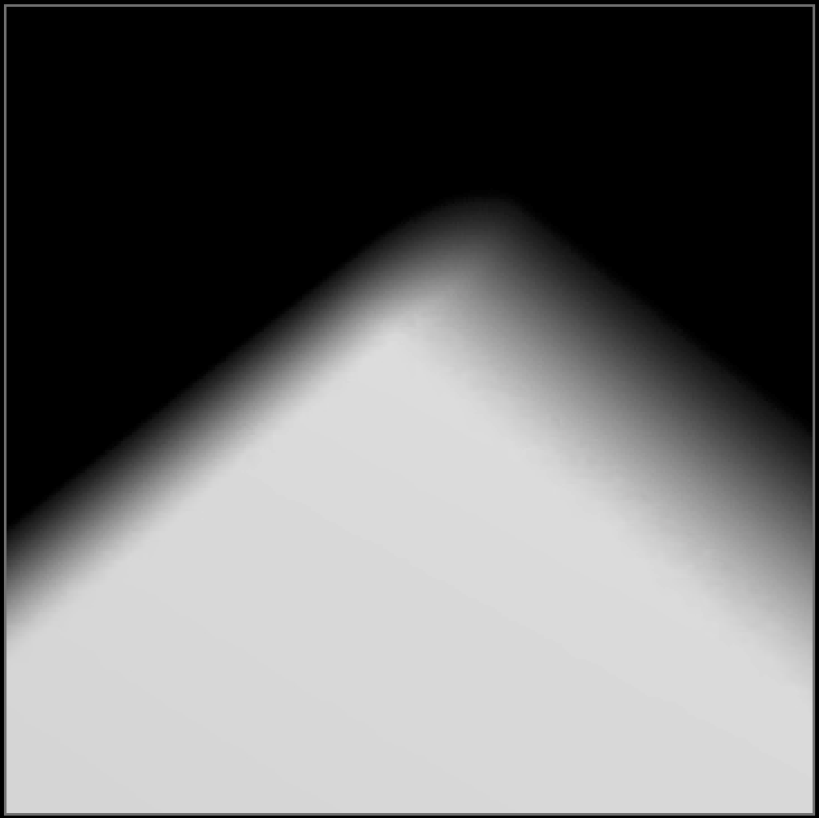
Minimum blending: just keep minimum of alpha values



smoothie



ray tracer

Implementation

Implementation

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- 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)

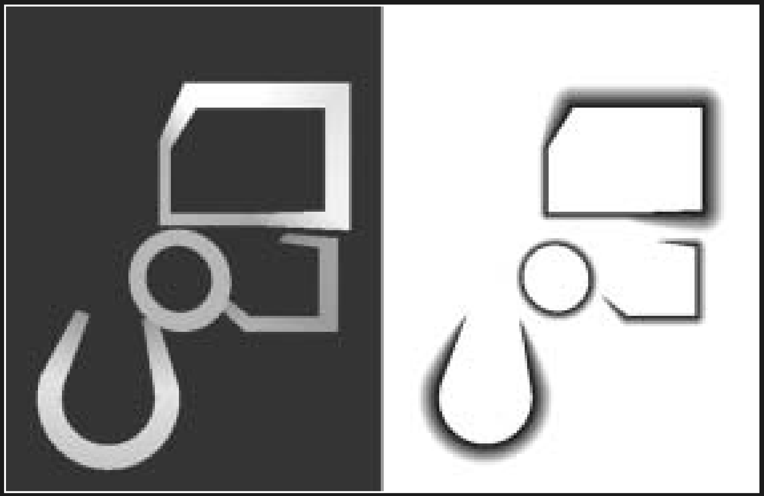
- Floating-point, eye space
- Pre-perspective, linear distribution of z
- Unlike regular shadow maps

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:

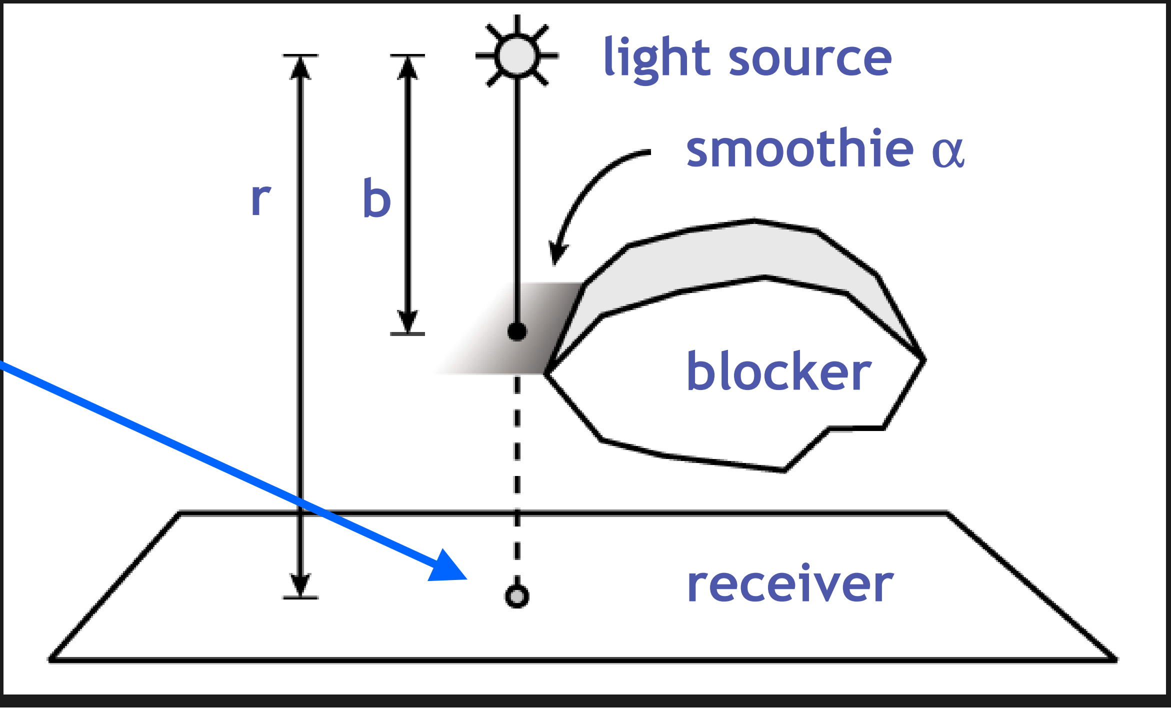
1. store nearest depth value into depth buffer
2. blend alpha values into color buffer

Computing Alpha

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

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

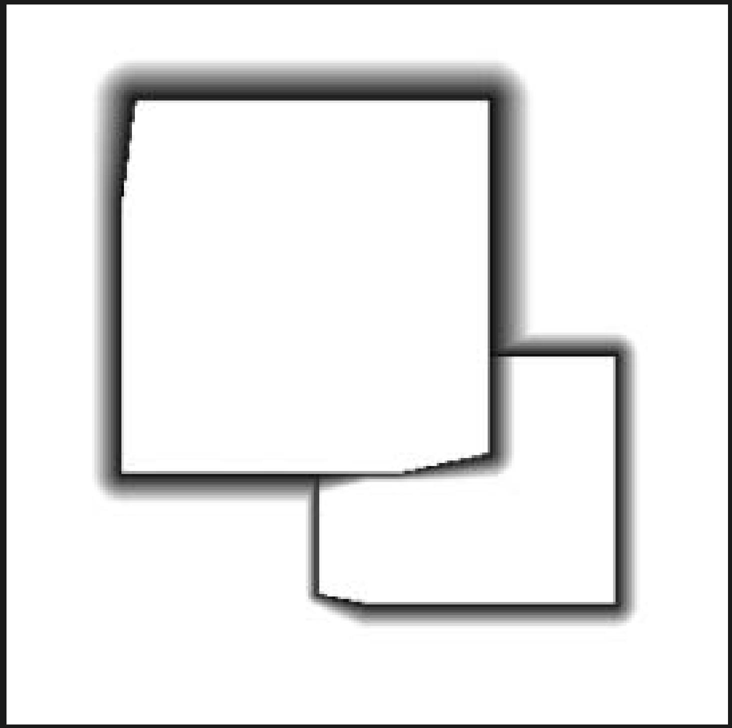
current sample



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

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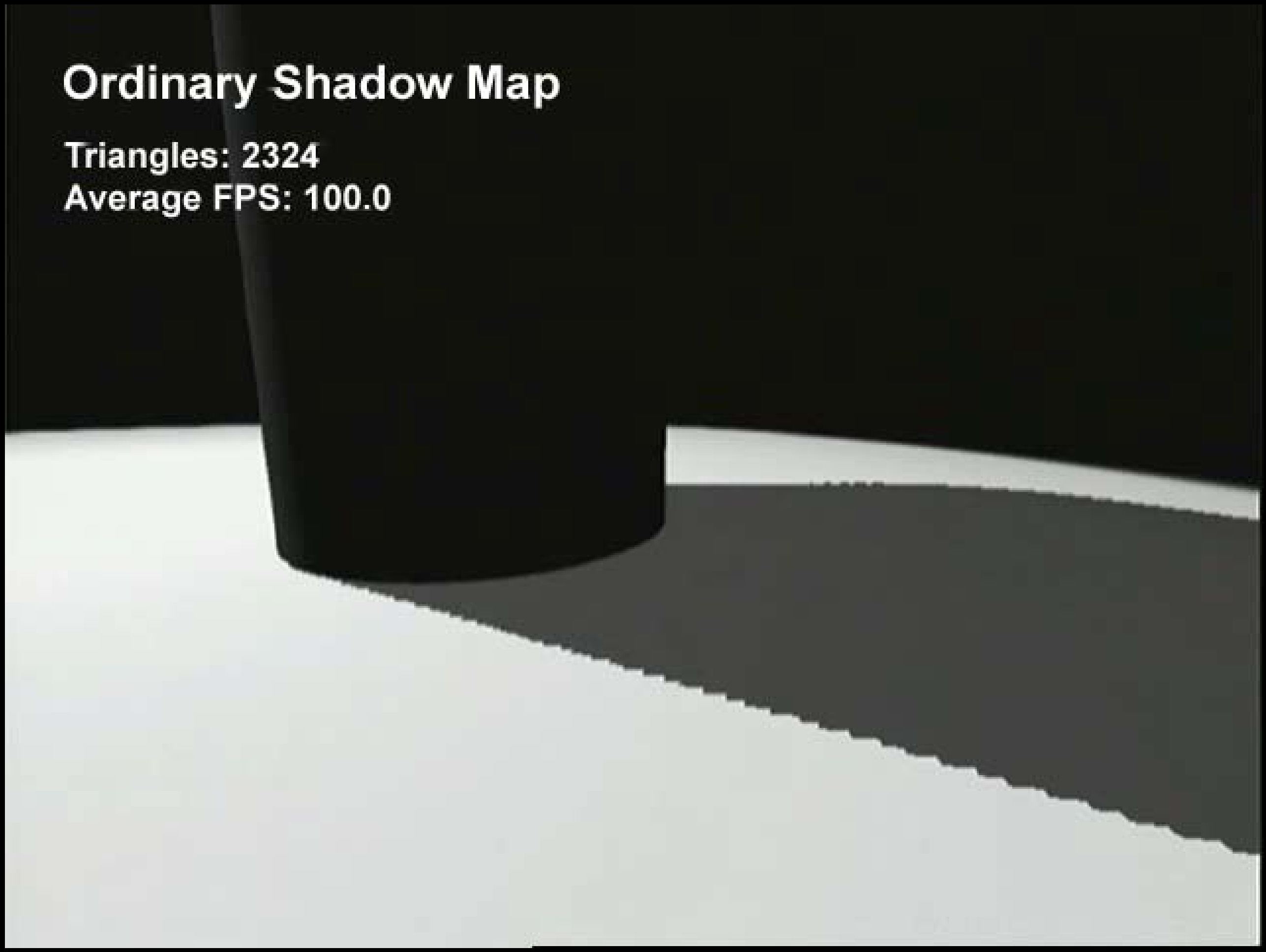
Combination of methods:

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

See paper (course notes) for Cg shader code

Examples

Video



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Hiding Aliasing (256 x 256)

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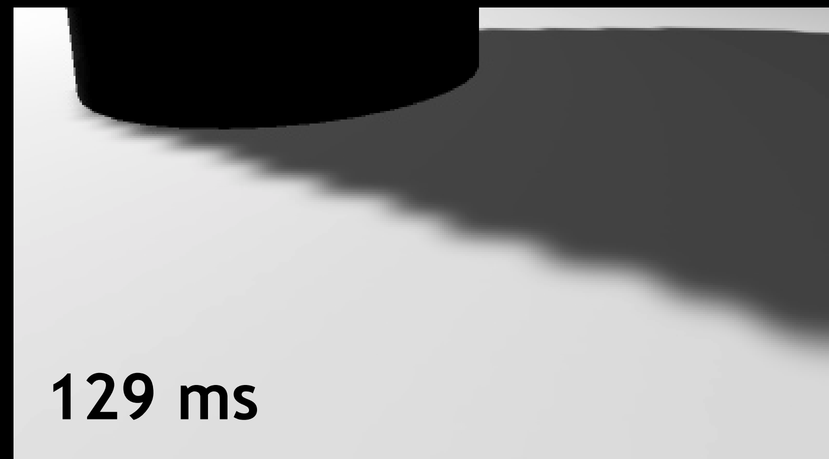
shadow map



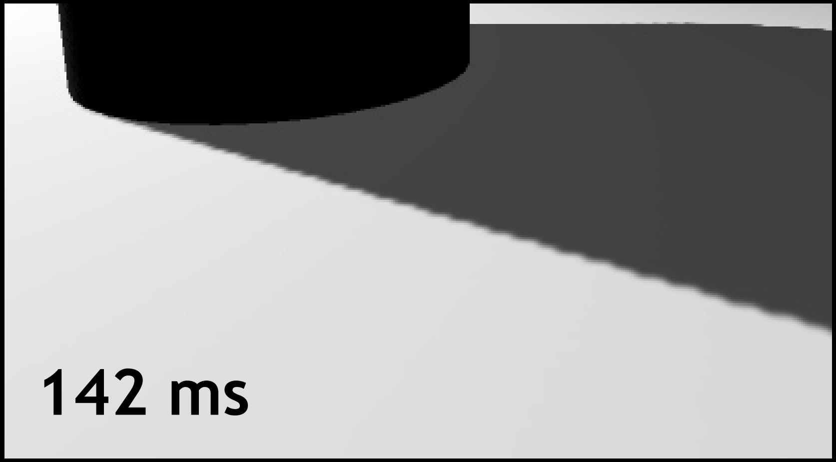
bicubic filter

smoothie (t = 0.02)

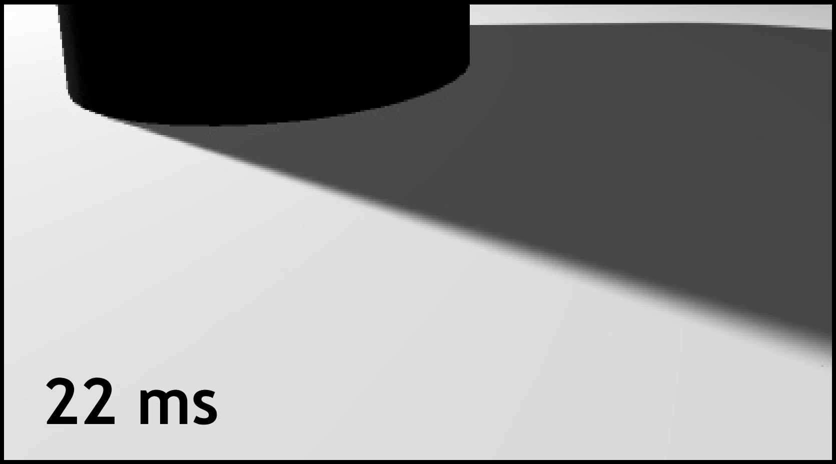
smoothie (t = 0.08)

Hiding Aliasing (1k x 1k)

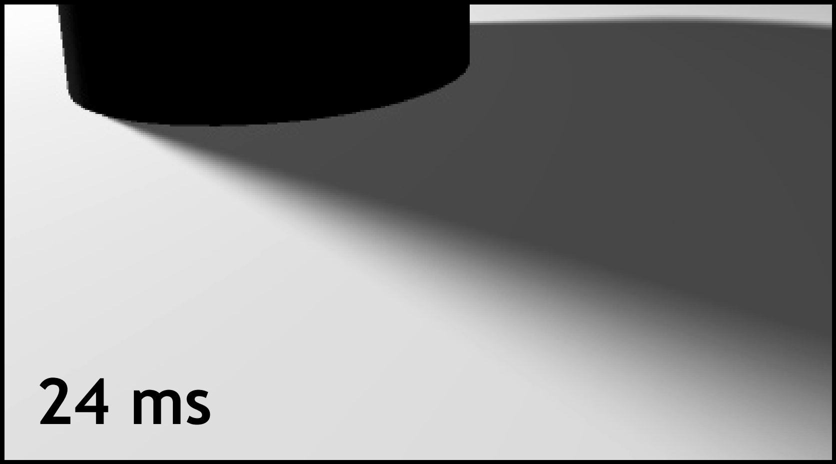
shadow map



bicubic filter



smoothie (t = 0.02)



smoothie (t = 0.08)

Antialiasing Example #1

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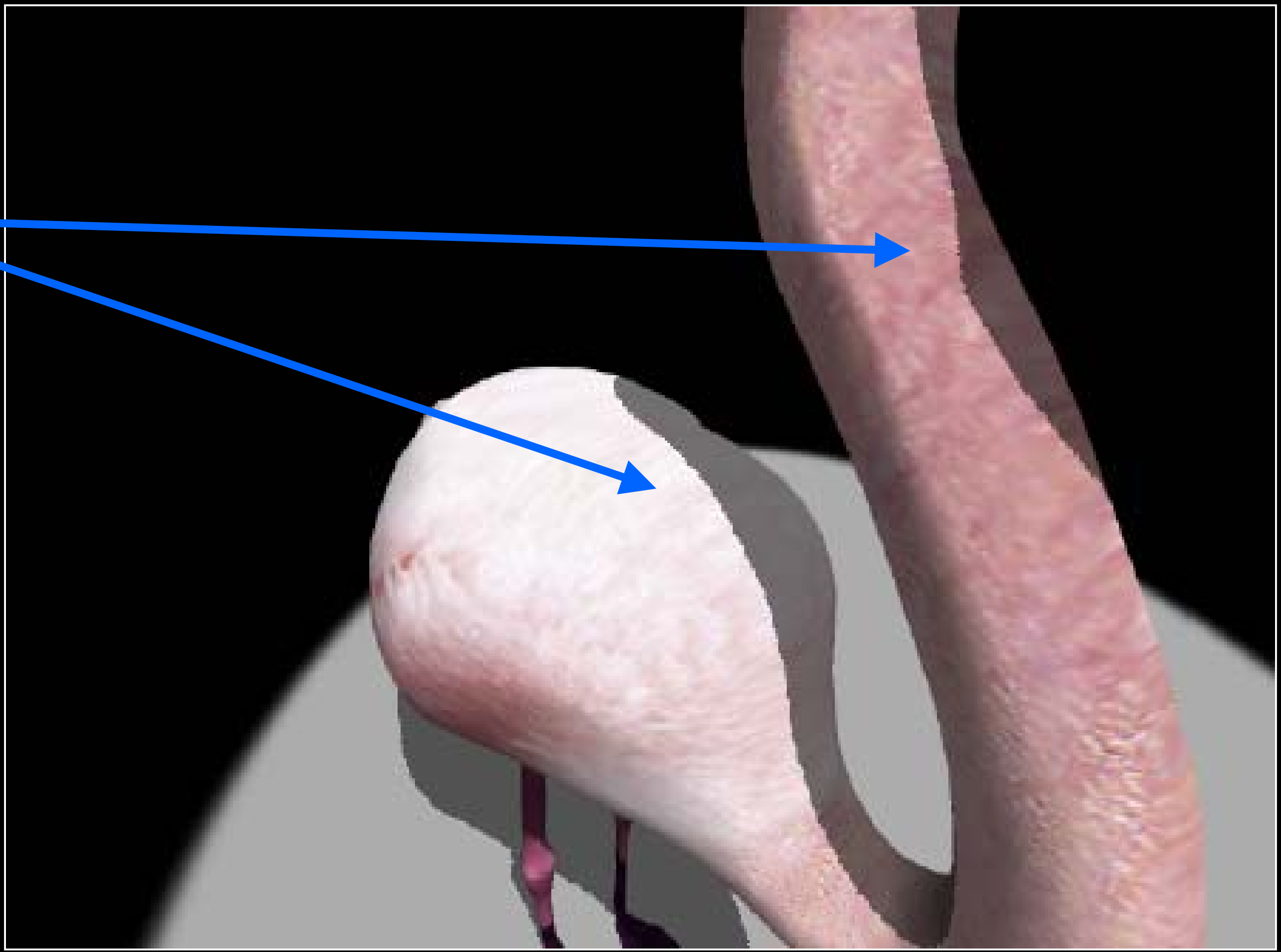
hard shadows
(aliased)



shadow map

Antialiasing Example #1

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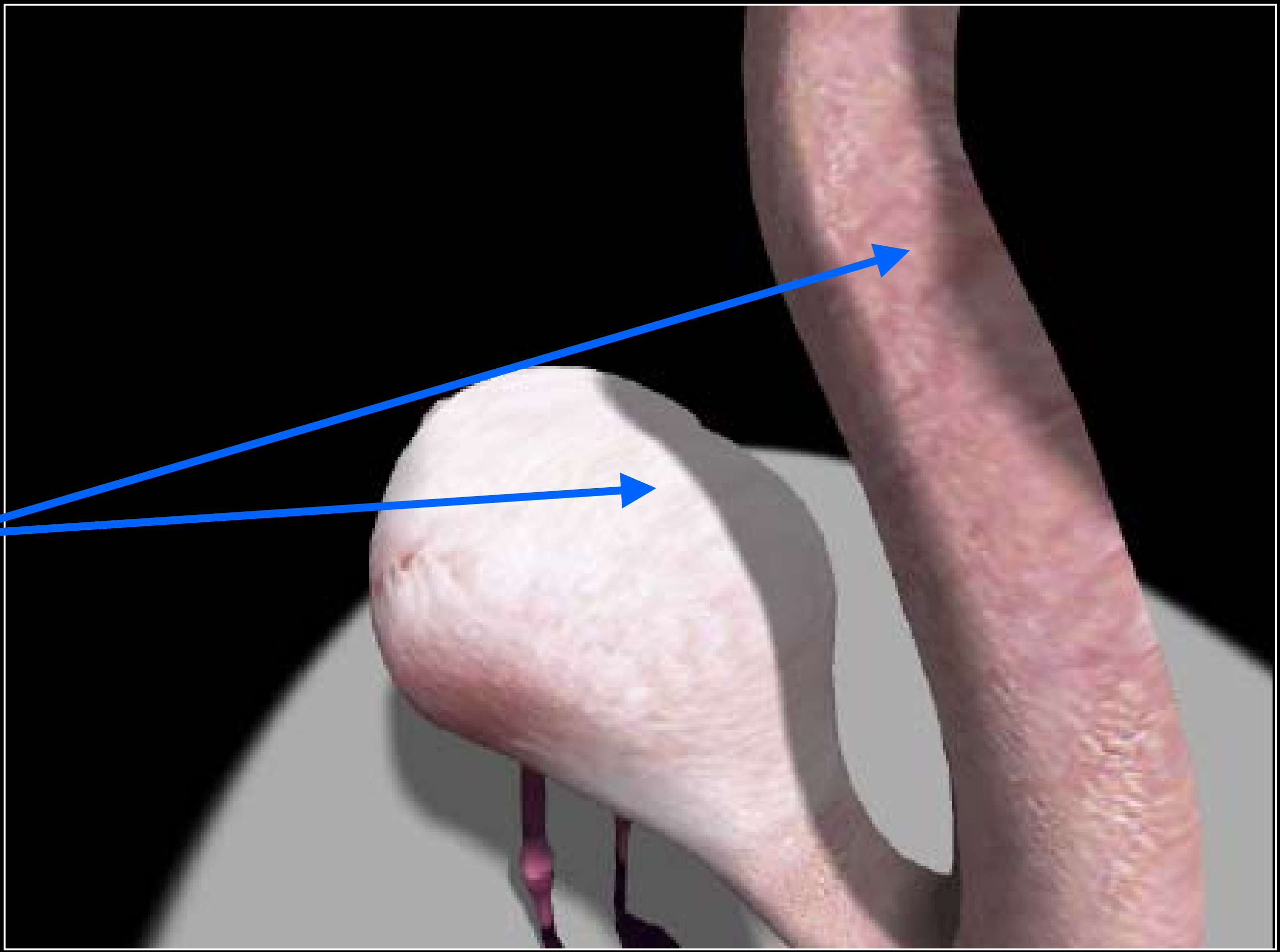
soft shadows
(antialiased)



smoothies

Antialiasing Example #2

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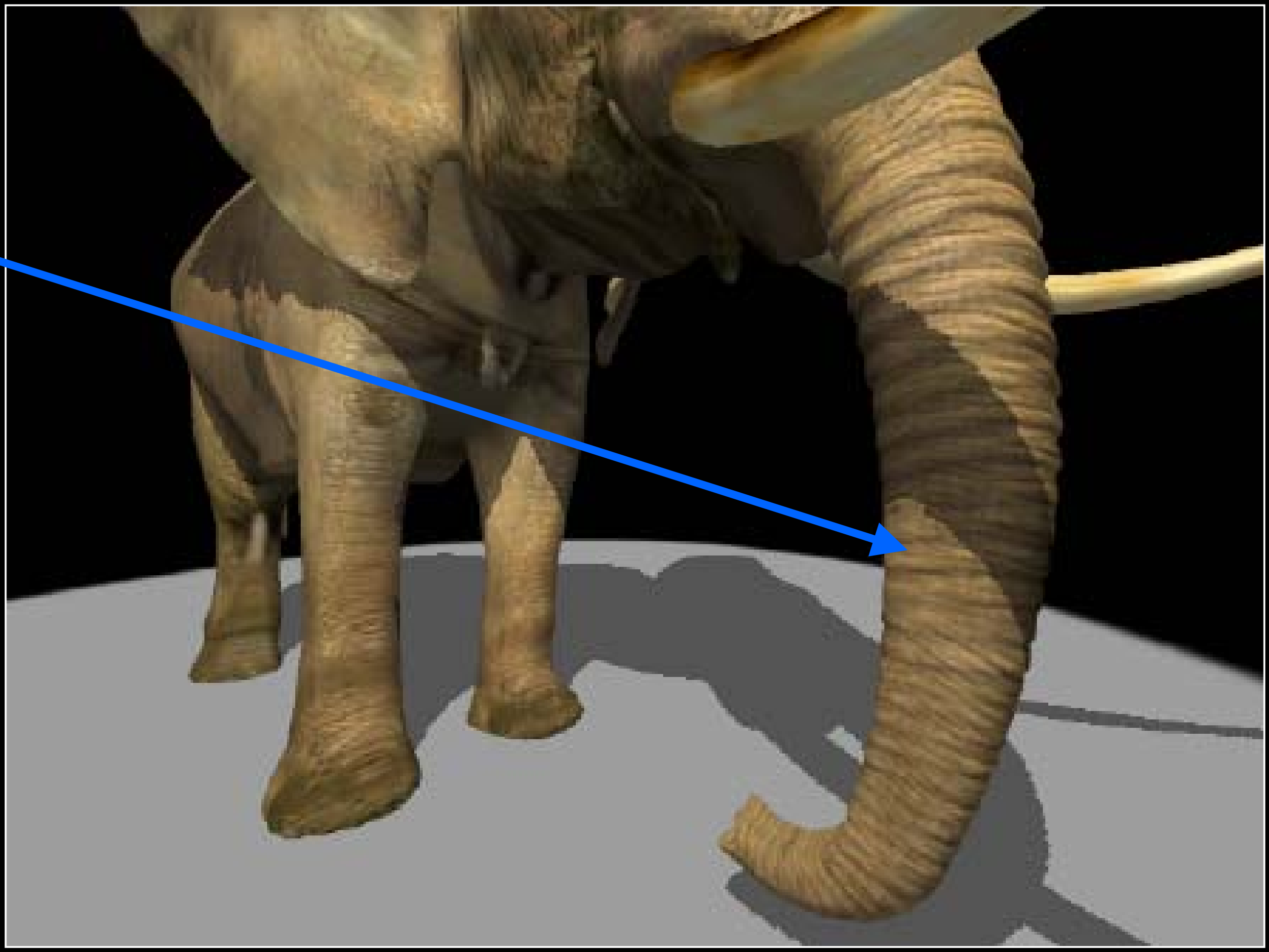
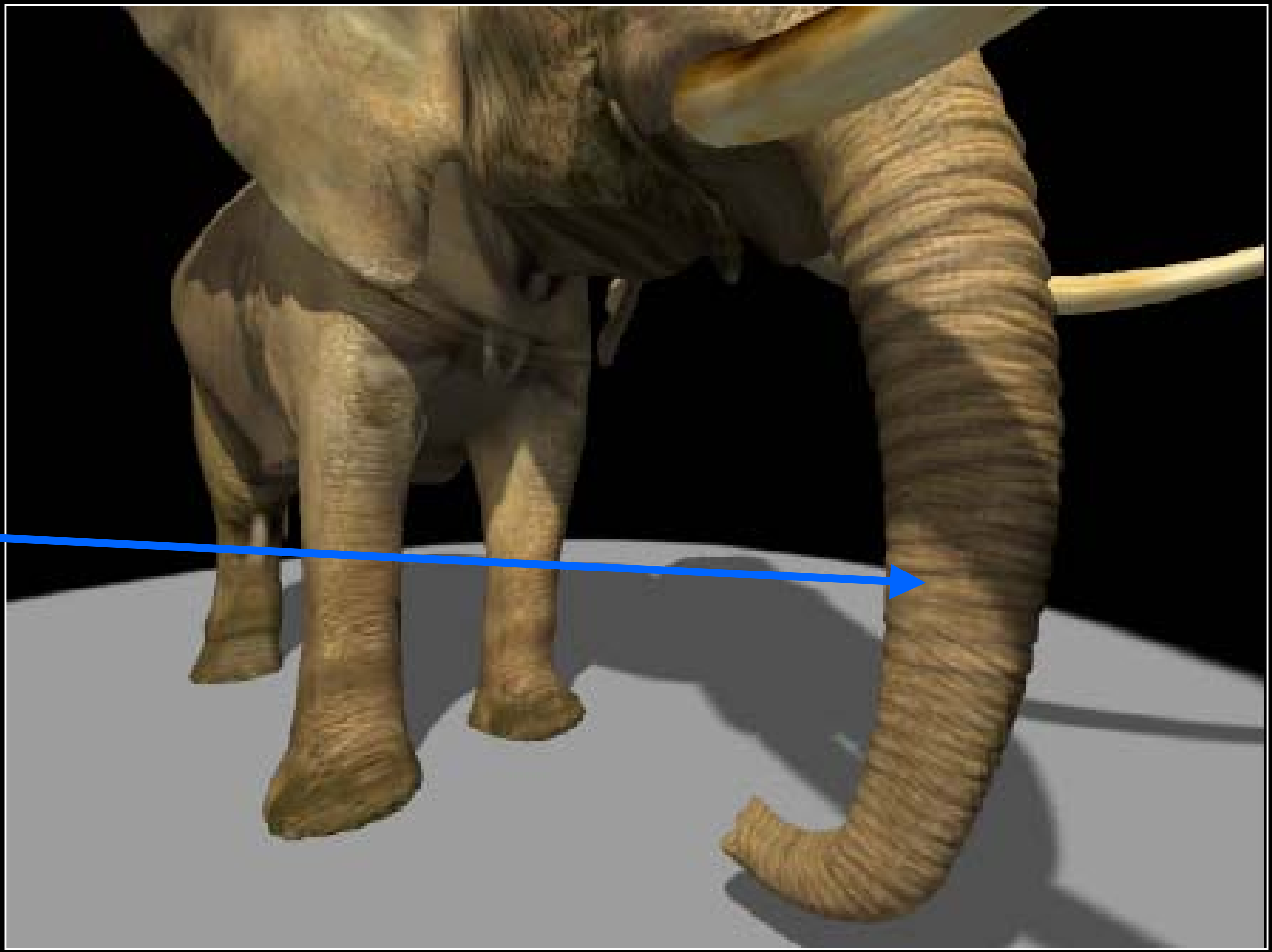
hard shadows
(aliased)



shadow map

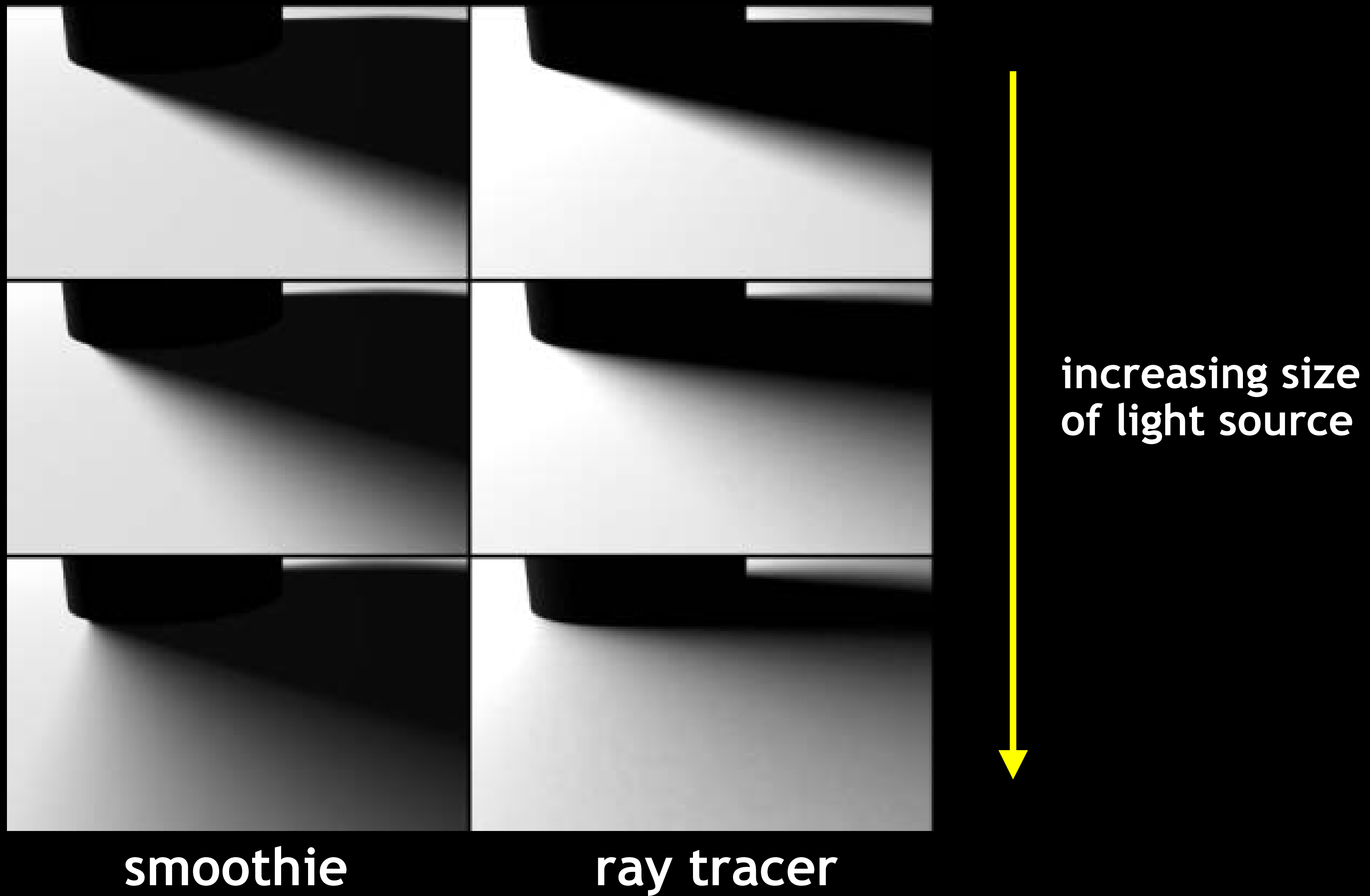
Antialiasing Example #2

soft shadows
(antialiased)



smoothies

Limitations



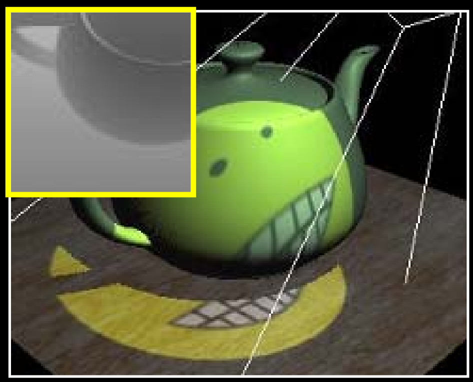
Video

original md2shader demo courtesy of Mark Kilgard

Tradeoffs

Shadow maps:

- Assumes directional light or spotlight
- Discrete buffer samples



Tradeoffs

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Shadow maps:

- Assumes directional light or spotlight
- Discrete buffer samples

Shadow volumes:

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

Tradeoffs

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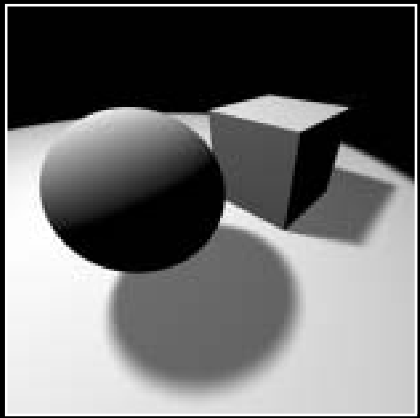

Shadow maps:

- 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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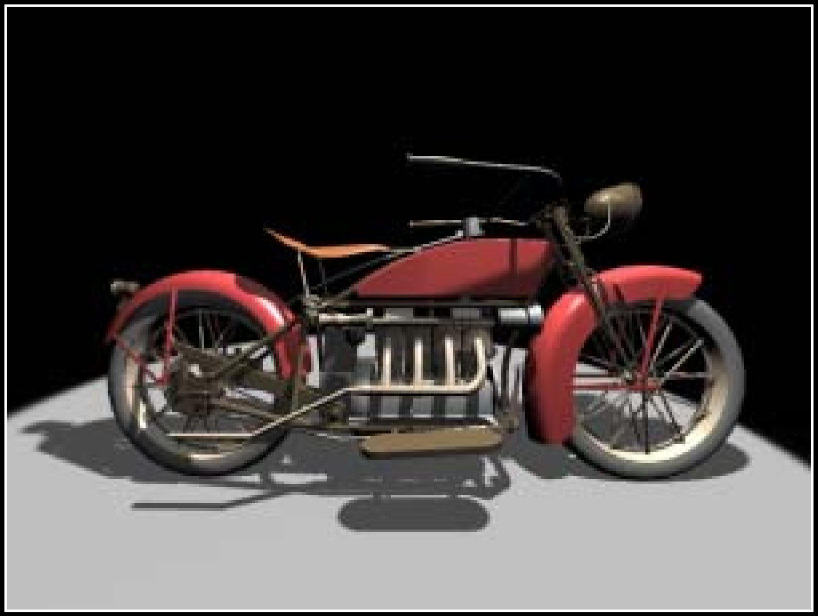
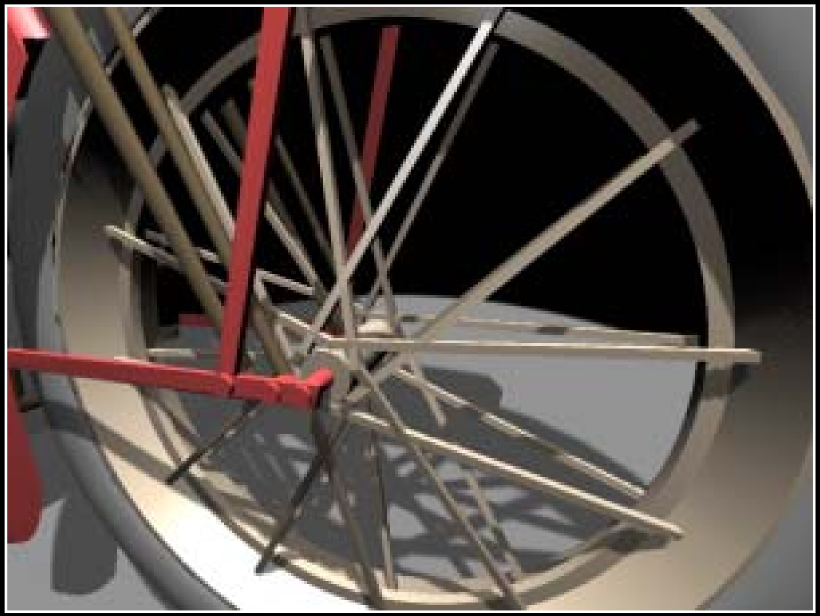
Main points:

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





Acknowledgments

SIGGRAPH2004

Hardware, drivers, and bug fixes

- Mark Kilgard, Cass Everitt, David Kirk, Matt Papakipos (NVIDIA)
- Michael Doggett, Evan Hart, James Percy (ATI)

Writing and code

- Sylvain Lefebvre, George Drettakis, Janet Chen, Bill Mark
- Xavier Décoret, Henrik Wann Jensen

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