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Percentage-Closer Soft Shadows

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Demo

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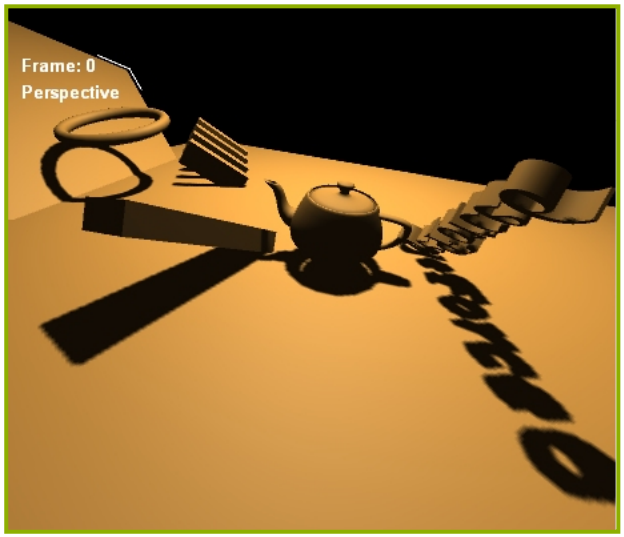
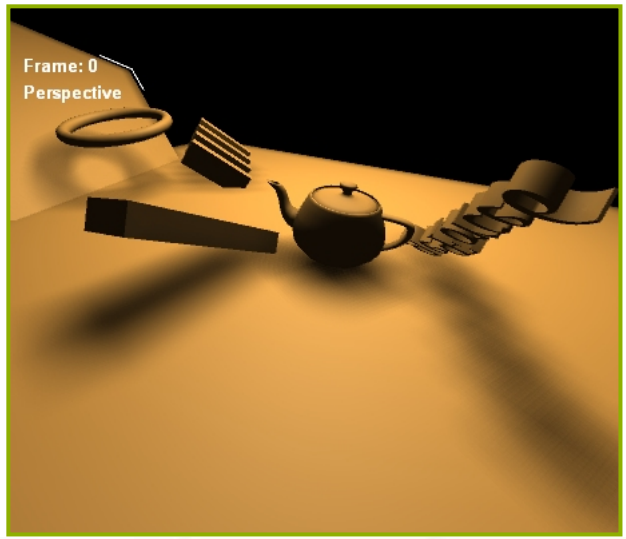
Algorithm Comparison



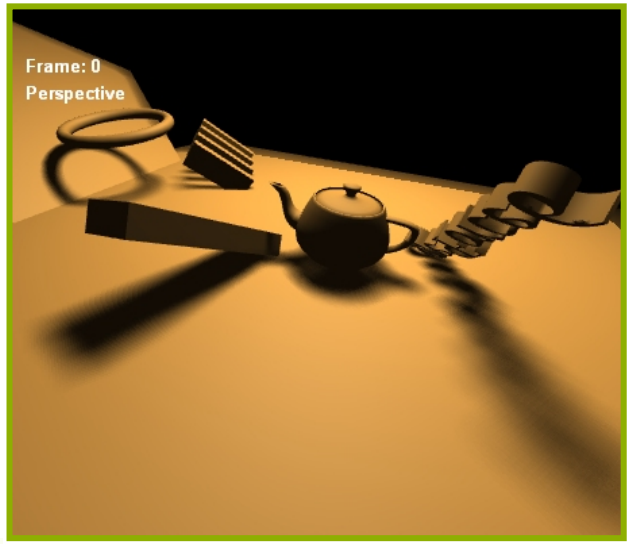
Regular Shadow Maps

- Always hard
- Noticeable Aliasing



Uniform Soft Shadows

- Always soft
- Aliasing is hidden



Perceptually-Correct Soft Shadows

- Shadows harden on contact
- Aliasing is hidden

Features

- Perceptually-correct soft shadows (good visual cues)
- Artifacts vary smoothly (no popping)
- Benefits from shadow mapping features
  - Independent of geometric complexity
  - Works with alpha testing, displacement mapping, etc…
- Integrates easily
  - Single floating-point shadow map and one shader
  - No special steps, preprocessing, etc…

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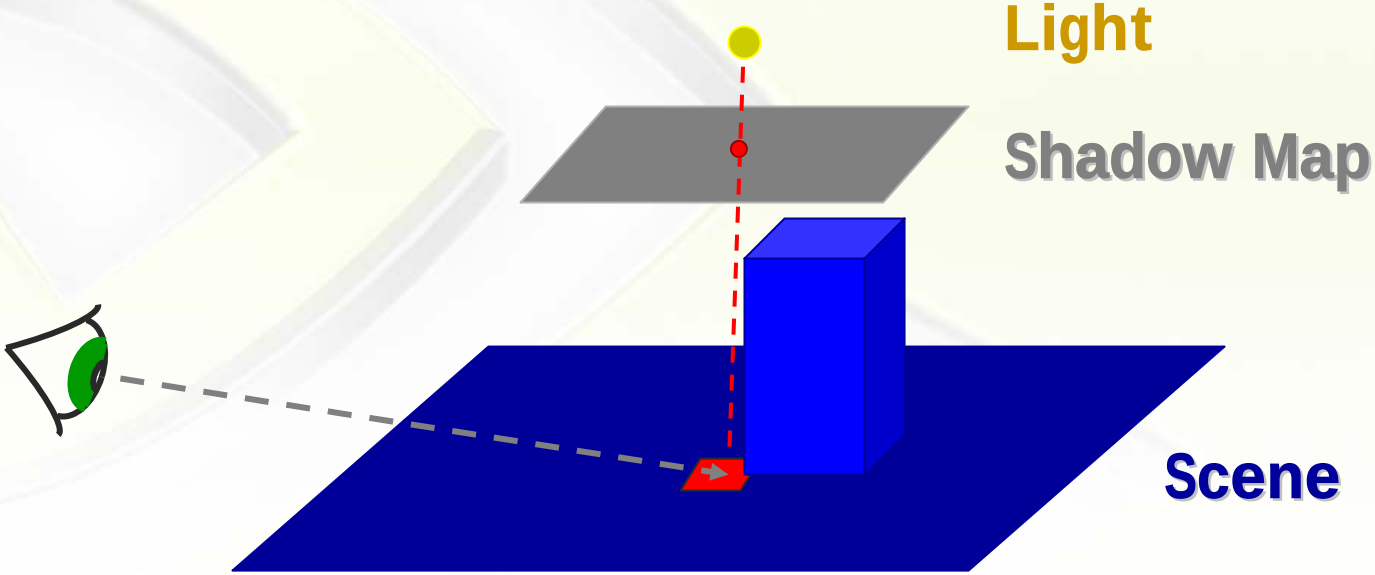
Ordinary Shadow Mapping



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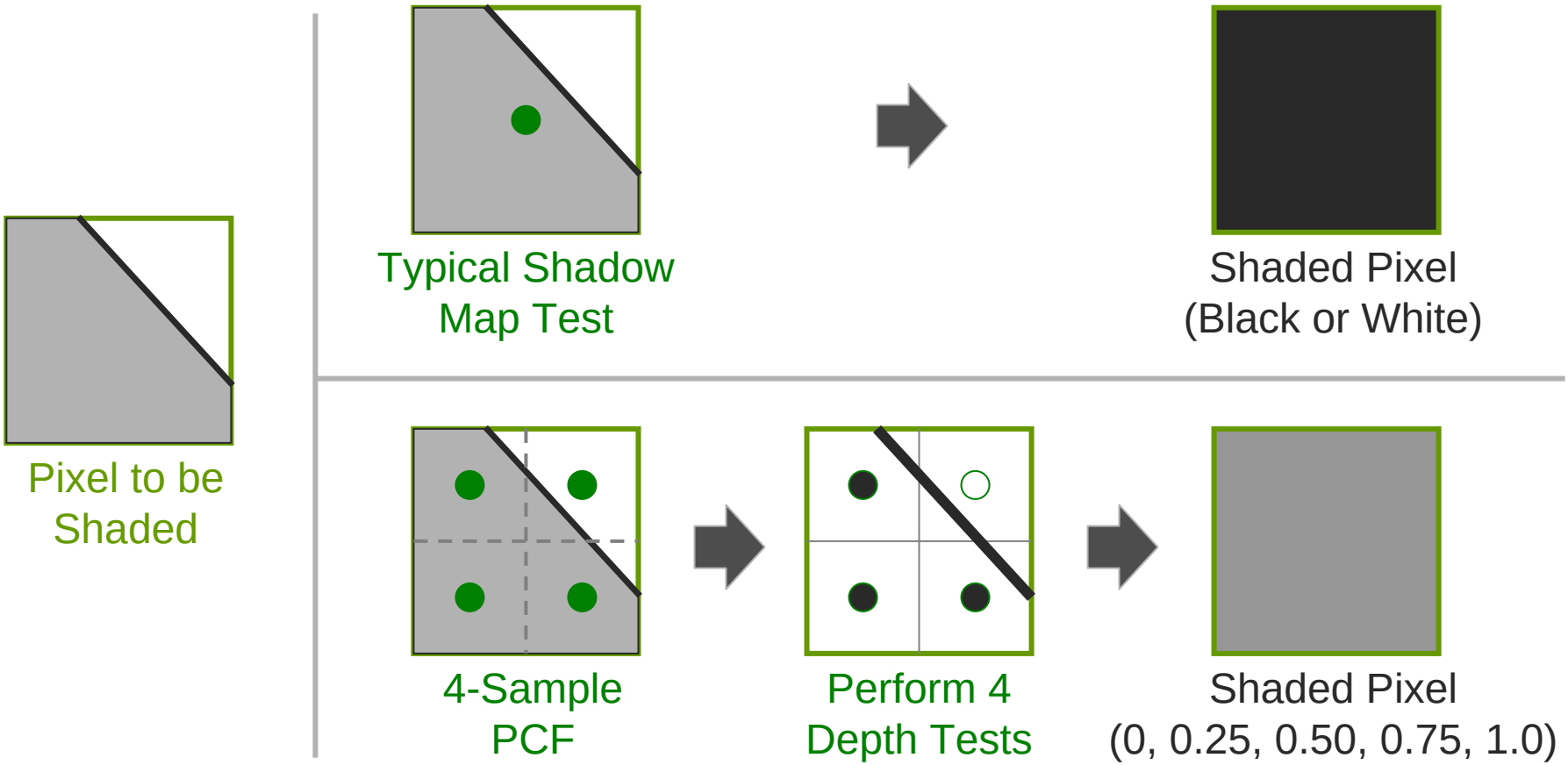
Percentage-Closer Filtering

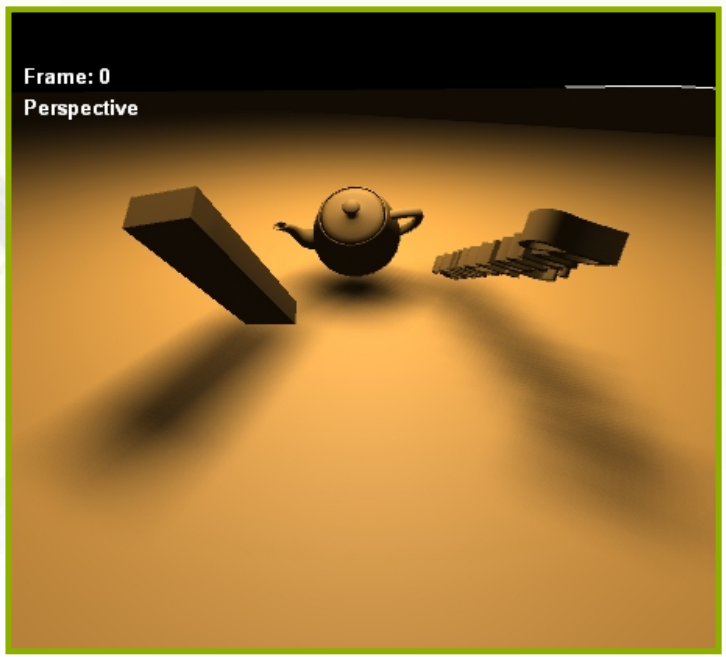
- Extension to shadow mapping
- How Percentage-Closer Filtering (PCF) works:



Basic Idea

- Soften shadows by varying PCF kernel width

Small Kernel
(Narrow Filter)



Large Kernel
(Wide Filter)

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Penumbra Estimation

- Vary amount of softening
  - Based on penumbra size
- Penumbra size estimate based on:
  - Blocker depth
  - Receiver depth
  - Light size

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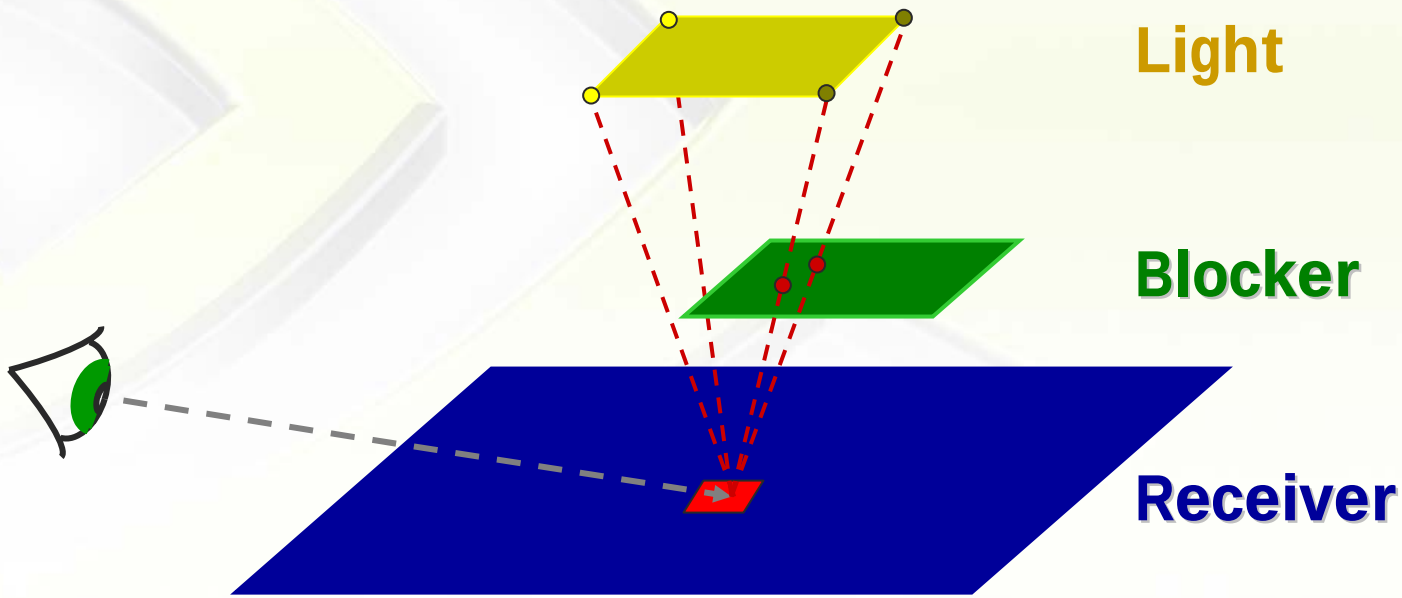
“Blockers” and “Receivers”



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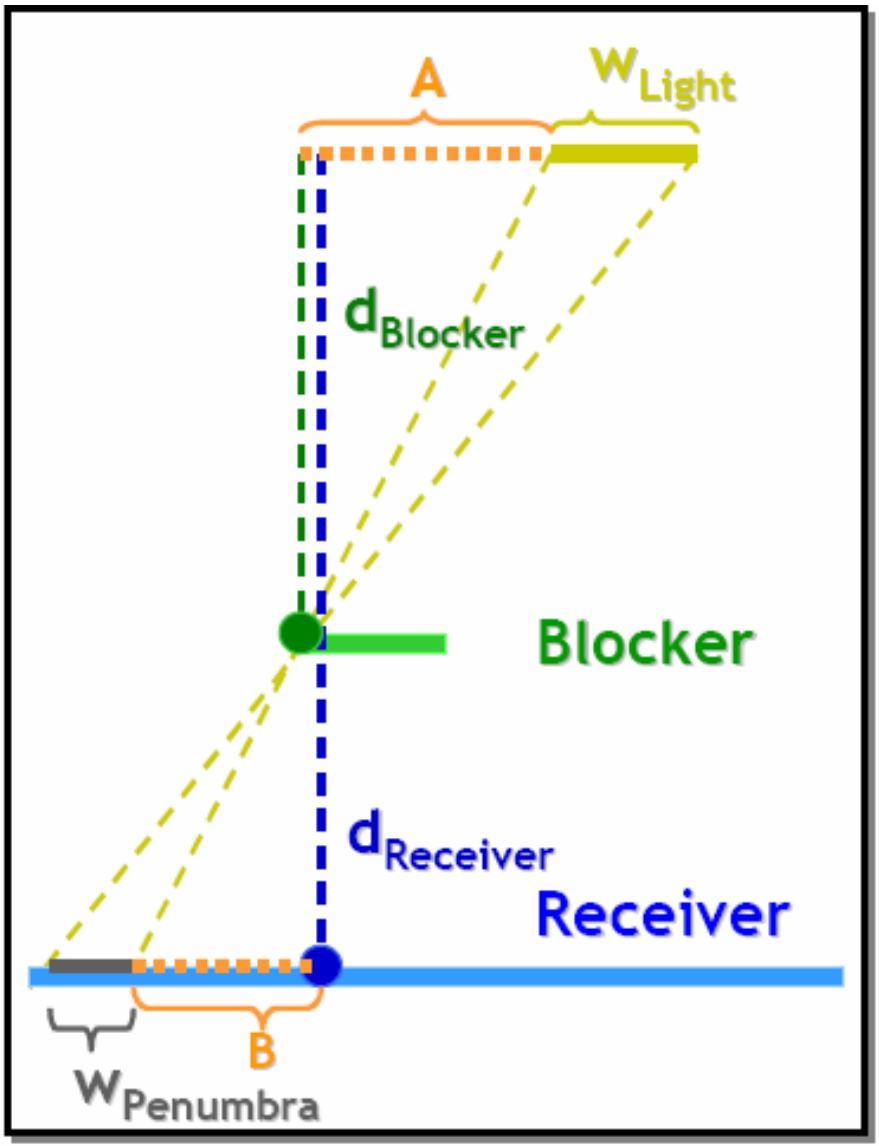
Penumbra Size Estimation



$$w_{Penumbra} = \frac{(d_{Receiver} - d_{Blocker}) \cdot w_{Light}}{d_{Blocker}}$$

- Assumes that blocker, receiver, and light are parallel

Penumbra Size Estimation

$$w_{Penumbra} = \frac{(d_{Receiver} - d_{Blocker}) \cdot w_{Light}}{d_{Blocker}}$$

- We need:
  - Distance from blocker to light source
    - Don’t know this… yet.
  - Distance from receiver to light source
    - Depth of the point we’re shading
  - Light size
    - Uniform input to the shader

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Main Algorithm

- Generate a shadow map (as usual)
- When shading each pixel on the screen:
  - Blocker Search
  - Penumbra Size Estimation
  - Variable Percentage-Closer Filtering

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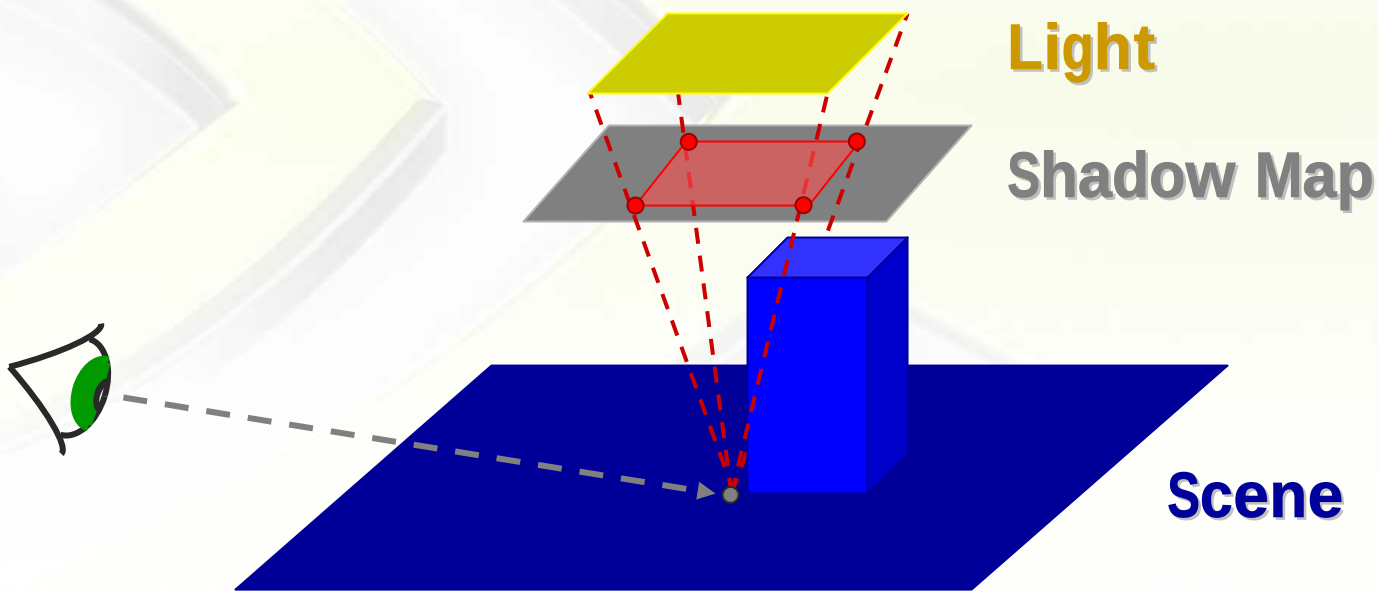
Blocker Search

- **Search region** depends on light size and distance to light



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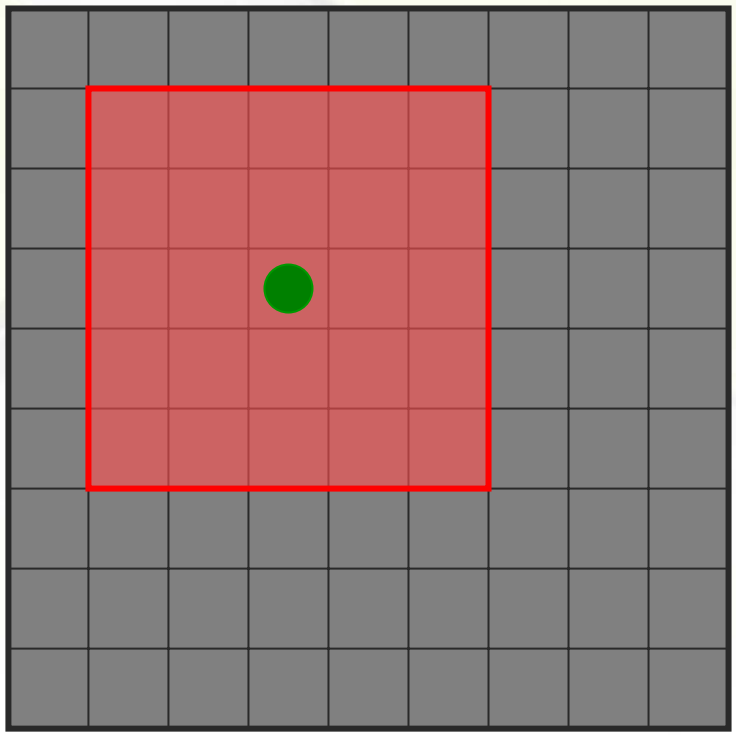
Blocker Search

- Iterate through all texels in search region
- Do something with the depth values…



Shadow Map

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What to do with Blockers?

- Take minimum?
  - Artifacts when transitioning between blockers
- Need some kind of average
  - Average all blockers (depth < receiver)
  - Flag the case if no blockers were found
    - Fully lit – no need to perform filtering
  - Gives good results
  - Further exploration in progress…

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Penumbra Size Estimation

$$w_{Penumbra} = \frac{(d_{Receiver} - d_{Blocker}) \cdot w_{Light}}{d_{Blocker}}$$

- We have:
  - Distance from blocker to light source
    - Result of blocker search
  - Distance from receiver to light source
    - Depth of the point we're shading
  - Light size
    - Uniform input to the shader
- Estimate penumbra per pixel
  - Change PCF kernel based on the result

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Variable Percentage-Closer Filtering

- Use a flexible PCF kernel that can vary:
  - Filter width
  - Number of samples
- Vary kernel parameters based on penumbra estimate
  - Actually, projection of penumbra in screen space (but not yet implemented)

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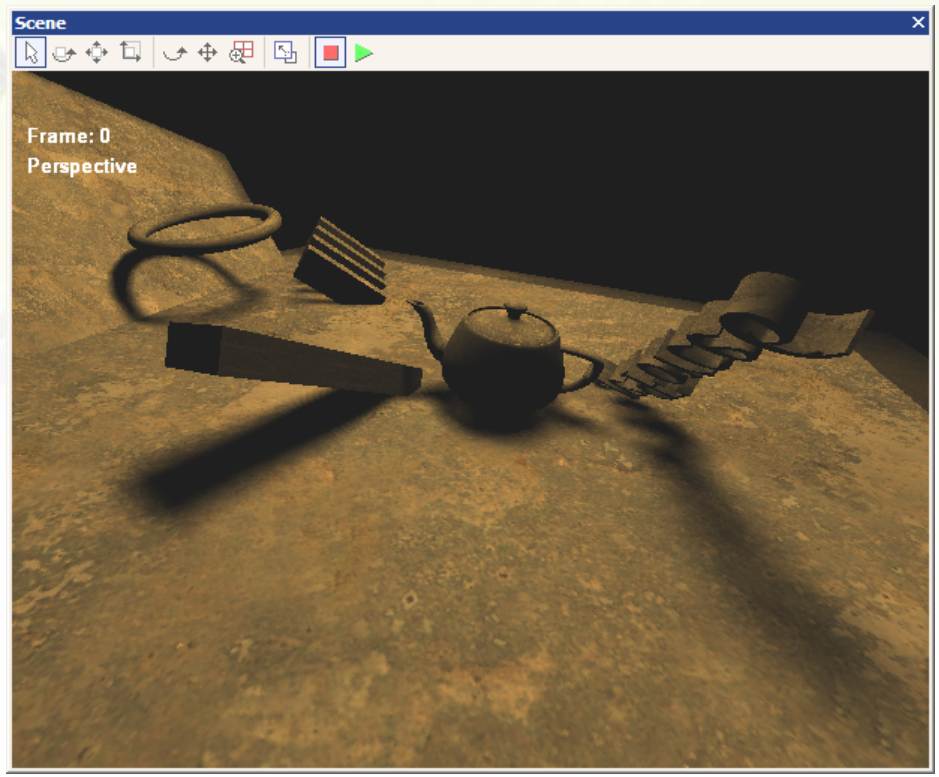
Demo

- Observed current performance in FX Composer (on GeForce 6800 Ultra):
  - ~20 fps @ 640 x 480
    - 64 blocker search samples
    - 144 PCF samples
    - Great results (see image) Especially with a texture!
  - ~8 fps @ 640 x 480
    - 144 blocker search samples
    - 256 PCF samples
    - For high-quality screenshots



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Improvements

- Performance
  - Need to implement early exit for PCF
    - Currently very wasteful (256 samples always!)
  - No profiling/tuning done yet
  - Mask out umbras and fully-lit regions
- Quality
  - Better blocker-search heuristics
  - Better filtering to remove banding in large penumbras

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Parting Thoughts

- Algorithm is completely encapsulated in one shader file for easy integration
- Try it out – please let us know what you find
- Tweak “Near Plane Factor” and “Shadow Map Bias” to match your scene
- Applications: DCC/CAD applications, pre-visualization, future games
- Improved version, video, and slides on the way…

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Suggestions/Questions Welcome

- Lots of relevant references in:
  - http://www.randima.com/MastersThesis.pdf
- Slides and code on
  http://developer.nvidia.com
  The Source for GPU Programming
- E-mail: rfernando@nvidia.com
- Thanks to Kevin Bjorke, whose basic PCF shader I based this work on.
- Thanks to Chris Maughan and FX Composer for making shader development so easy.

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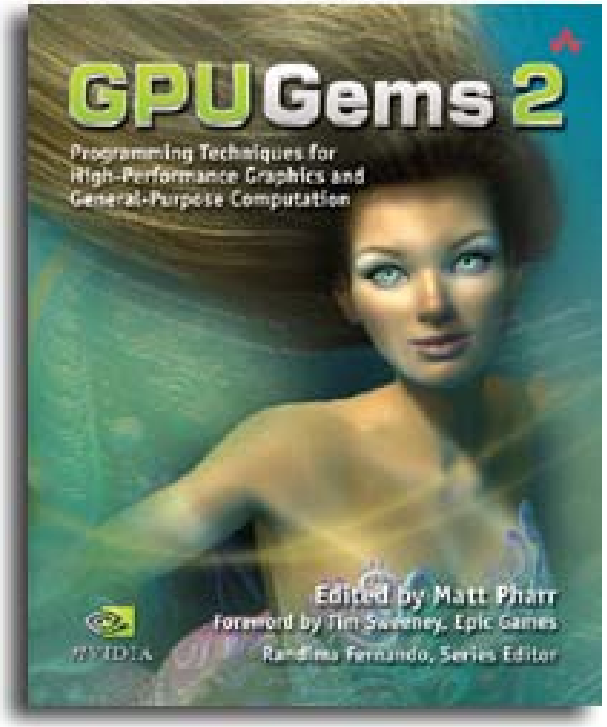

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