Percentage-Closer Soft Shadows

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Demo

Frame: 0
Perspective
Algorithm Comparison

- Regular Shadow Maps
  - Always hard
  - Noticeable Aliasing

- Uniform Soft Shadows
  - Always soft
  - Aliasing is hidden

- Percentage-Closer 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…
Ordinary Shadow Mapping

Light

Shadow Map

Scene
Percentage-Closer Filtering

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

**Typical Shadow Map Test**

- Pixel to be Shaded

- Perform 4 Depth Tests

- Shaded Pixel (0, 0.25, 0.50, 0.75, 1.0)

- 4-Sample PCF

- Shaded Pixel (Black or White)
Basic Idea

• Soften shadows by varying PCF kernel width

Small Kernel (Narrow Filter)  Large Kernel (Wide Filter)
Penumbra Estimation

- Vary amount of softening
  - Based on penumbra size

- Penumbra size estimate based on:
  - Blocker depth
  - Receiver depth
  - Light size
“Blockers” and “Receivers”
Penumbra Size Estimation

\[ w_{\text{Penumbra}} = \frac{(d_{\text{Receiver}} - d_{\text{Blocker}}) \cdot w_{\text{Light}}}{d_{\text{Blocker}}} \]

- 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
Main Algorithm

- Generate a shadow map (as usual)

- When shading each pixel on the screen:
  - Blocker Search
  - Penumbra Size Estimation
  - Variable Percentage-Closer Filtering
Blocker Search

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

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

[Image of a shadow map with a search region highlighted]
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…
Penumbra Size Estimation

\[ w_{\text{Penumbra}} = \frac{(d_{\text{Receiver}} - d_{\text{Blocker}})}{d_{\text{Blocker}}} \cdot w_{\text{Light}} \]

- **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
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)
Demo

- Observed current performance:
  - ~8 fps @ 640 x 480 in FX Composer
  - GeForce 6800 Ultra
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
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...
Suggestions/Questions Welcome

- Lots of relevant references in:

The Source for GPU Programming

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