EFFECTS & TECHNIQUES

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Overview

- Screen-space techniques
  - Deferred rendering
  - Screen-space ambient occlusion
  - Depth of Field

  - Translucent Shadows

Design Goals

- DX9-based
- Scalability
  - GPU families from Radeon 9800/geForce FX to latest families supported, with maximal usage of each family
- Pixel load vs. vertex load
  - Stress pixel vs. vertex/batch processing due to fluctuating, high unit counts
  - Translates into focus on stressing GPU over CPU to ensure consistent framerate
- Dual mode
  - Game mode: overhead view, many units, lot of action
  - Story mode: close-up view, few models, contemplative

Dual modes

- In-game

Dual modes

- Story mode

Lighting System Approach

- Warcraft III: bright, even coloring, few local lights
- Starcraft II: more emphasis on local lighting & shadows, without obscuring gameplay

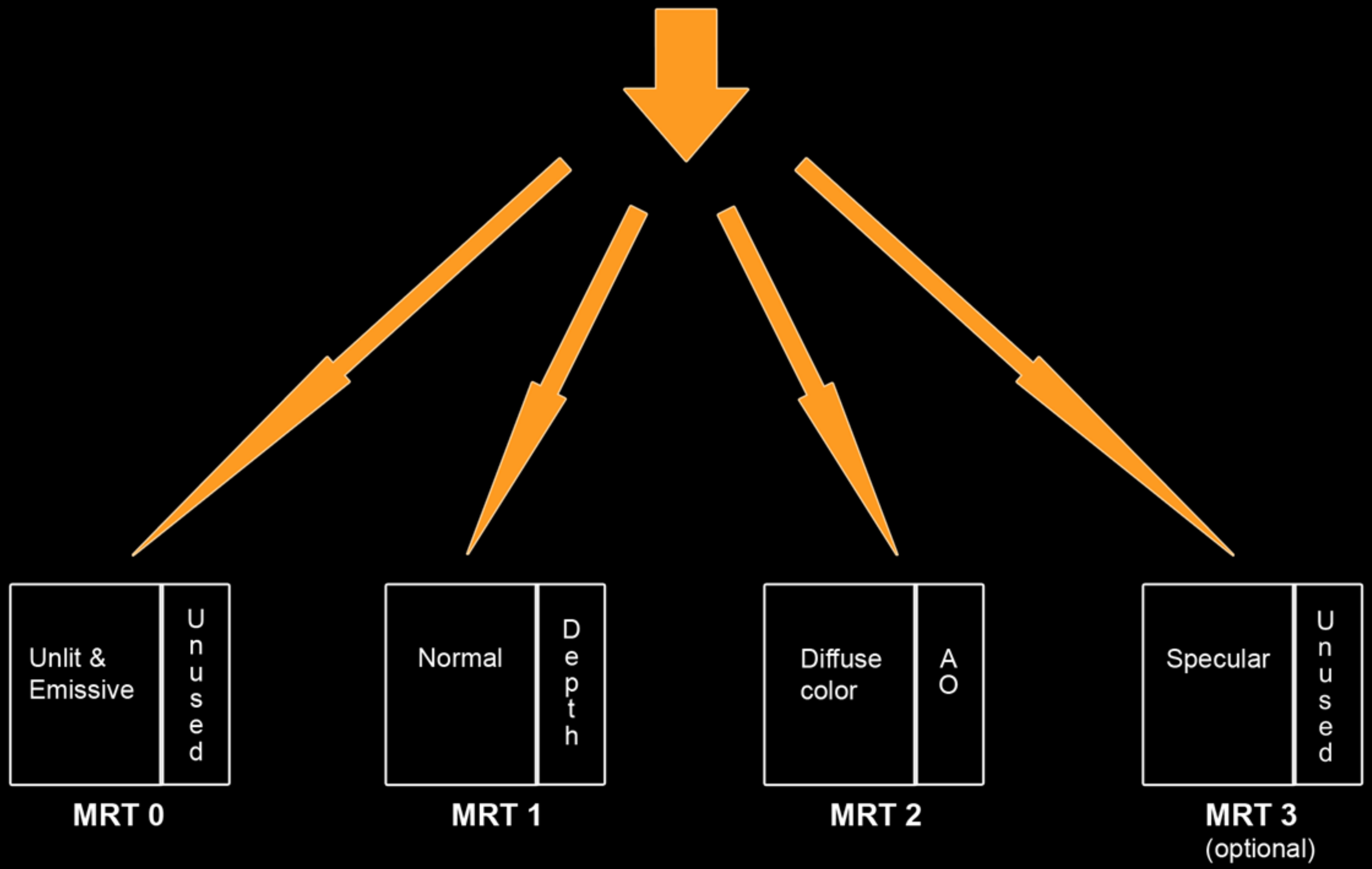
Forward vs. Deferred Lighting System

- Player controls lighting environment
- Forward renderer:
  - Discover any light interactions with every model
  - Render the model by looping over each light in the pixel shader
- Problems:
  - A light just touching a small part of a model causes the entire model to be more expensive (not just the affected part)
  - Light interactions potentially become n squared, causing uneven performance which doesn’t scale well to lower-end hardware

Forward vs. deferred renderer

- Deferred renderer:
  - Render models and store material & depth information for each rendered pixel
  - Layer lighting unto scene by rendering light shapes
  - Recover position from depth map
  - Recover material information from RTs
  - Minimal CPU work
  - Less waste of pixel cycles for complex lighting environments

Deferred MRTs



Deferred HDR

- FP16 Render Targets
- All MRTs must be same size & format
- The different MRT information will be used for a variety of effects later on
  - **Depth** is most useful; used for lighting, fog volumes, screen-space ambient occlusion, smart displacement, depth of field, projections, edge detection, thickness measurement
  - **Normals** for lighting, screen-space ambient occlusion
  - **Diffuse** & **specular** for lighting

Position Reconstruction

- VPOS semantic can be used under PS 3.0, which provides pixel coordinates for each pixel
- Normalize x, y coordinates to [-1..1] & multiply by sampled depth
- Under PS 2.0, an equivalent [-1..1] view space coordinate will need to be passed in from the vertex shader
- Transform to world space from view space if necessary

Applying Lighting

- Render the light shape
- Recover depth, normal and material information (diffuse, specular color) from sampling RTs wherever the light shape is at
- Derive the position of the lit surface point from the depth
- Calculate the light contribution and additively blend with the backbuffer

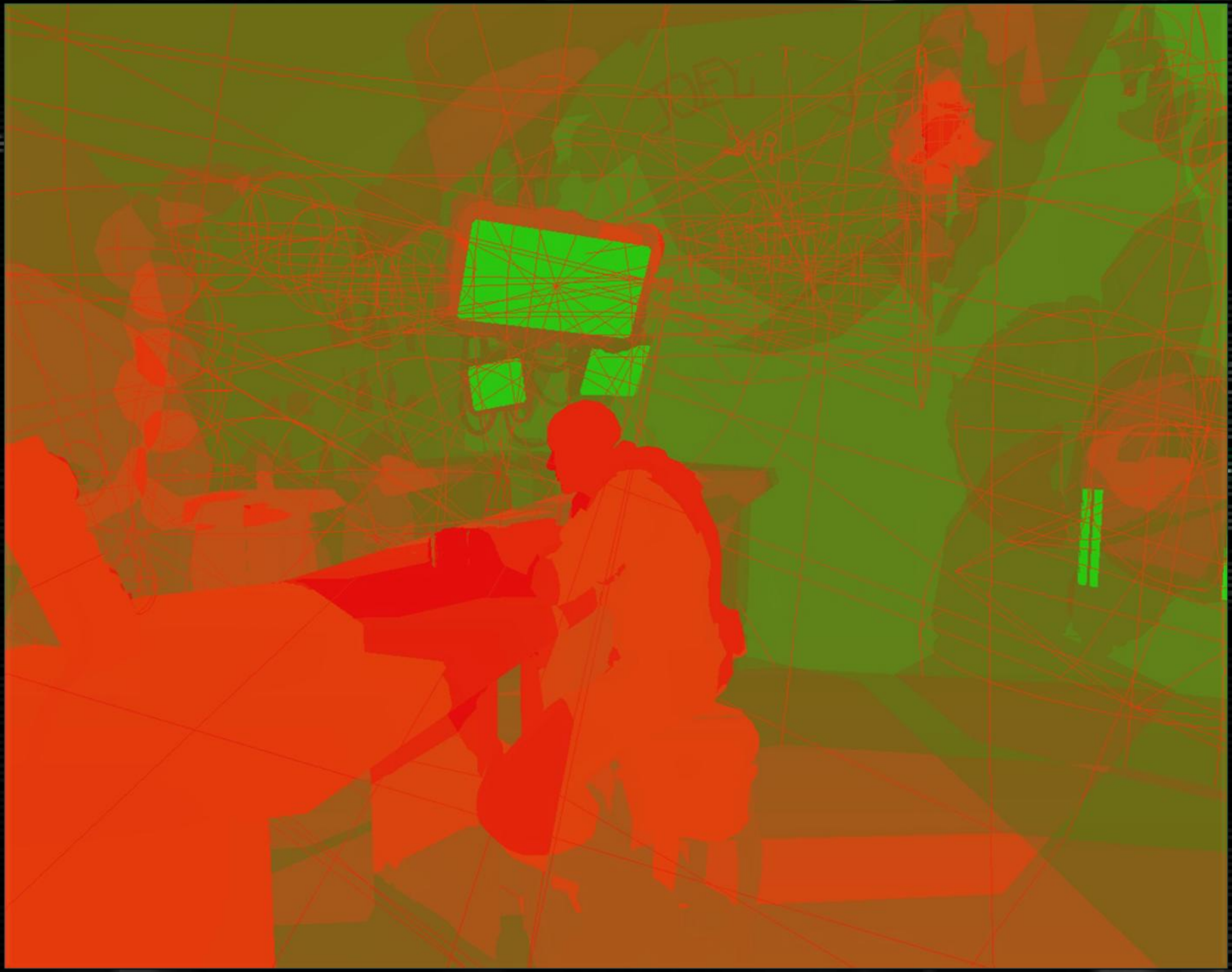
Results: Deferred rendering

Lighting Only with
Pre-generated Ambient
Occlusion maps

Results: Deferred rendering

Lighting overlap

Red is 8 or more lights



Results: Deferred rendering

Finished result

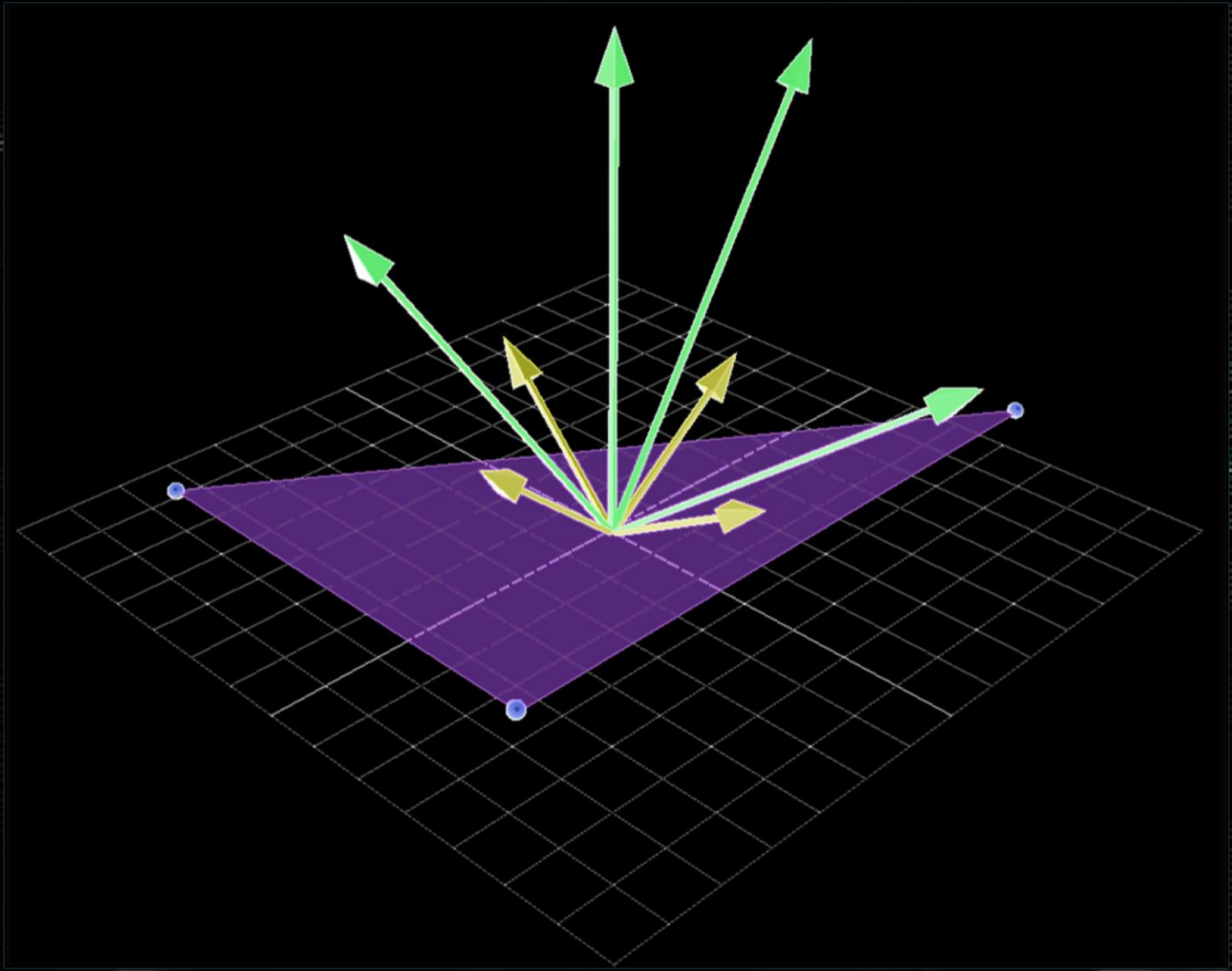
Added HDR tonemapping and colorization

Screen-Space Ambient Occlusion

- Approximate the occlusion function at points on visible surfaces by sampling the depth of neighboring pixels in screen space
- Depth map required
- Ambient occlusion term will be stored in the alpha channel so it can modulate the deferred lighting

SSAO Sampling

8 to 32 samples per pixel



SSAO Sampling

- "Flatten" occlusion ray-casting to 2D
- At any visible point on a surface on the screen, multiple samples (8 to 32) are taken from neighboring points in the scene
- Check if the depth sampled at the point is closer or further away than the depth of the sample point itself
- If the depth sampled is closer, than there is a surface that is covering the sample point, and some occlusion may be occuring

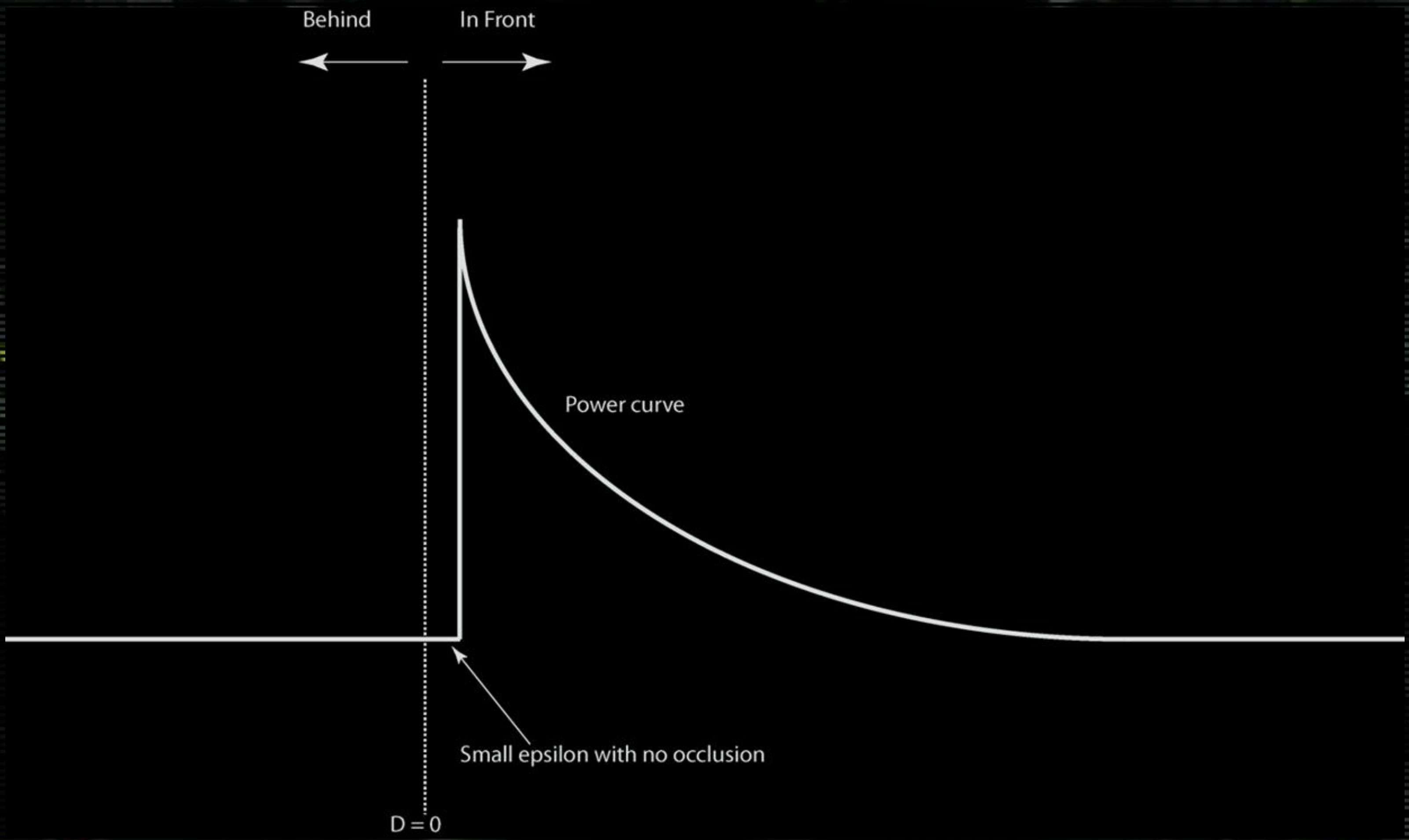
SSAO Sampling

- Compute the view space position of a pixel (2D to 3D)
- Add n (8 to 32) 3D offset vectors to this position
- Remap these offset vectors to where they are in screen space (3D back to 2D data space)
- Compare the depth of each offset vector sample with the depth at the point where the offset is
- Each offset contributes some occlusion if the sampled depth on screen is in front of the depth of the offset vector

Occlusion Function

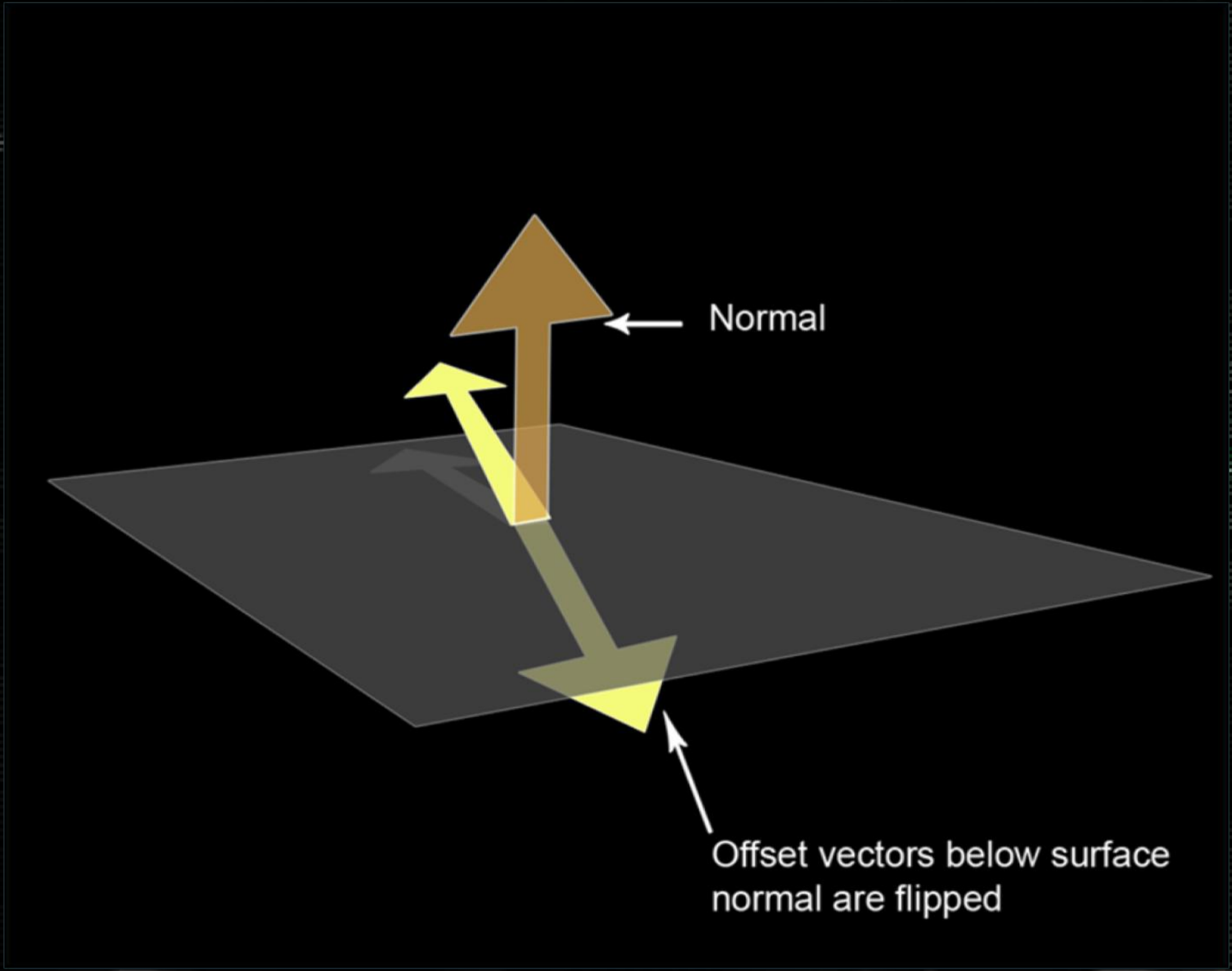
- Blockers closer to the sample should occlude more
- Blockers far from the sample don't occlude at all
- Blockers behind don't occlude at all

Occlusion Function

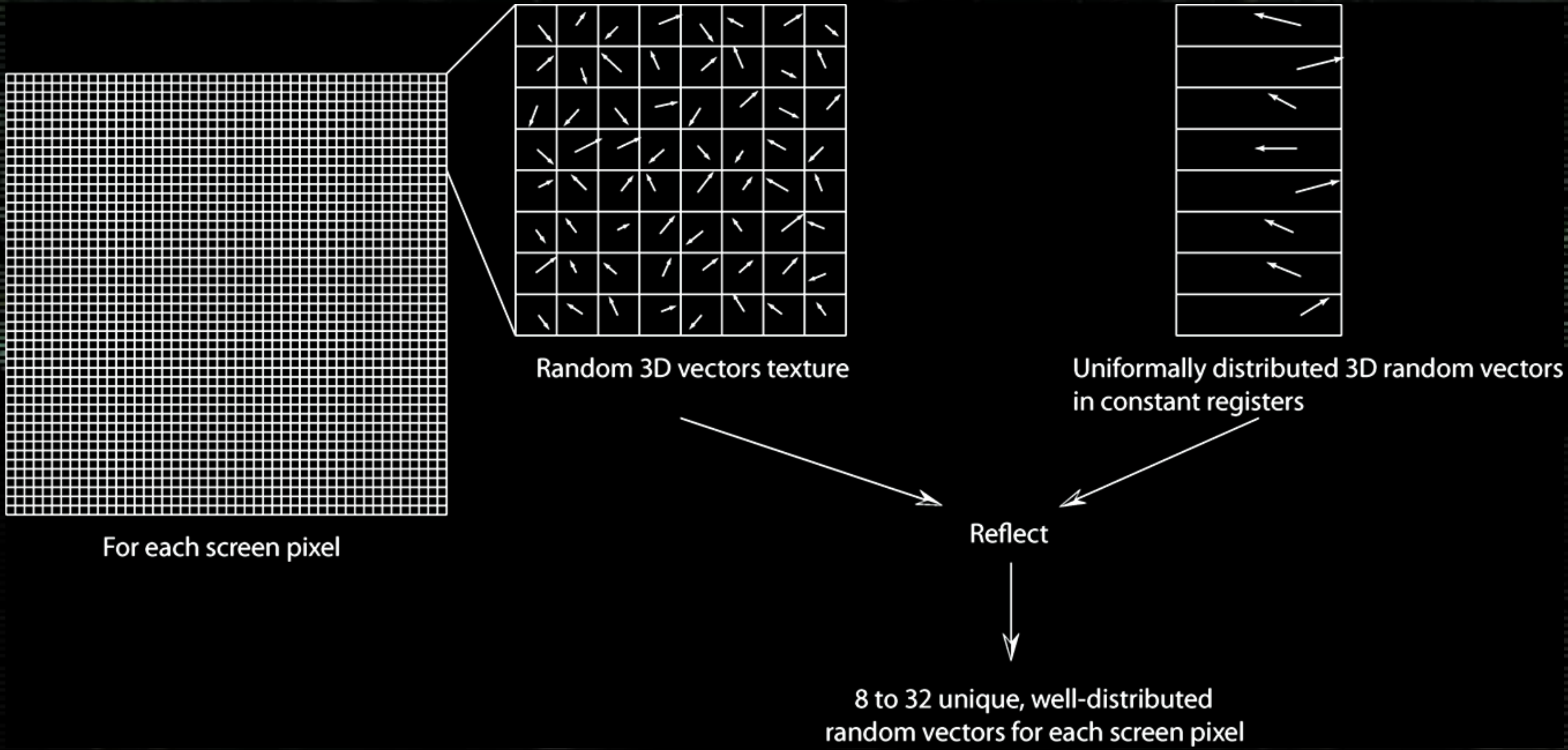


Self-Occlusion

All “ray casts” must be above the surface to avoid self-occlusion



Randomizing samples



Randomizing samples

Edge-preserving blur

- Gaussian blur
- Sample depth & normal of center tap
- Sample depth & normal of each blur sample
- Reduce Gaussian weight to zero if:
  - Depth of blur sample differs from center tap depth by a certain amount
  - Dot product of blur sample normal with center tap normal is less than a certain amount
- Renormalize Gaussian weights to account for eliminated samples
- Multiple blur passes may be required

Edge cases

- Offset vector can go outside the screen, where there is no depth information
- Best approximation is ensuring out-of-bounds samples don’t occlude
- Use “Border color” texture wrapping state and set the “color” to a high depth value

Limiters

- Close-ups lengthen the 3D offset vectors and cause the SSAO to be under-sampled
- Two possible solutions:
  - Increase sample count dynamically
  - Limit maximum screen extents of offset vectors

- Starcraft II relies on the second approach to avoid large framerate swings

Performance

- Texture sampling is a bottleneck
- Sampling pattern is not cache-friendly
- Wide sampling area makes it worse
- Leverage low-frequency aspect
- Use a reduced size depth buffer (quarter size)

Screen-Space “Global Illumination”

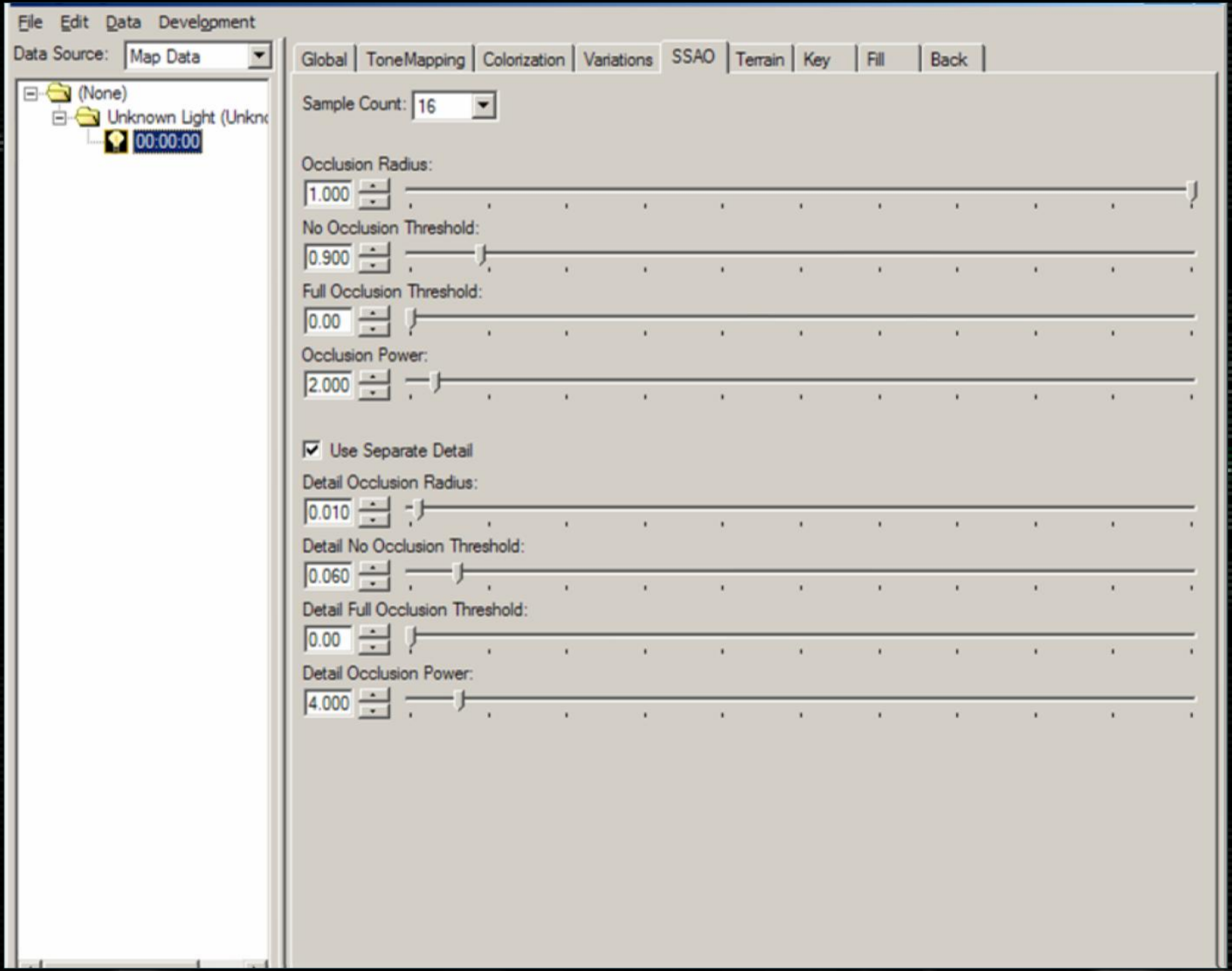
- Wide sampling area creates quasi-GI effect
- Distribute samples over two thresholds
- One half of samples over wide area for GI
- One half of samples over tight area for contrast and edge enhancement

Results: Screen space ambient occlusion

Lighting only
16 AO samples shown
(8 large and 8 small)

Results: Screen space ambient occlusion

Artist Tool UI for SSAO in real-time




JOEYRAYS
BAR

Results: Screen space ambient occlusion

32 AO samples shown
(16 large and 16 small)
Soft Shadows enabled

Camera
uck = MiddleMouseButton
uck depth = [Shift] + MiddleMouseButton
bit target = [Alt] + MiddleMouseButton
bit camera = [Control] + MiddleMouseButton
lly depth = [Control + Alt] + MiddleMouseButton
ll = [Alt + Shift] + MiddleMouseButton
eld of view = [Control + Shift] + MiddleMouseButton
rget depth = MouseWheel
ck once = MouseButtonX1
ck live = MouseButtonX1 + MiddleMouseButton
set roll = [Control] + MouseButtonX2
set camera = [Control + Alt] + MouseButtonX2 (reset free camera to game camera)
ggle mode = [Control + Alt + 7]
JOEYRAY'S
BAR

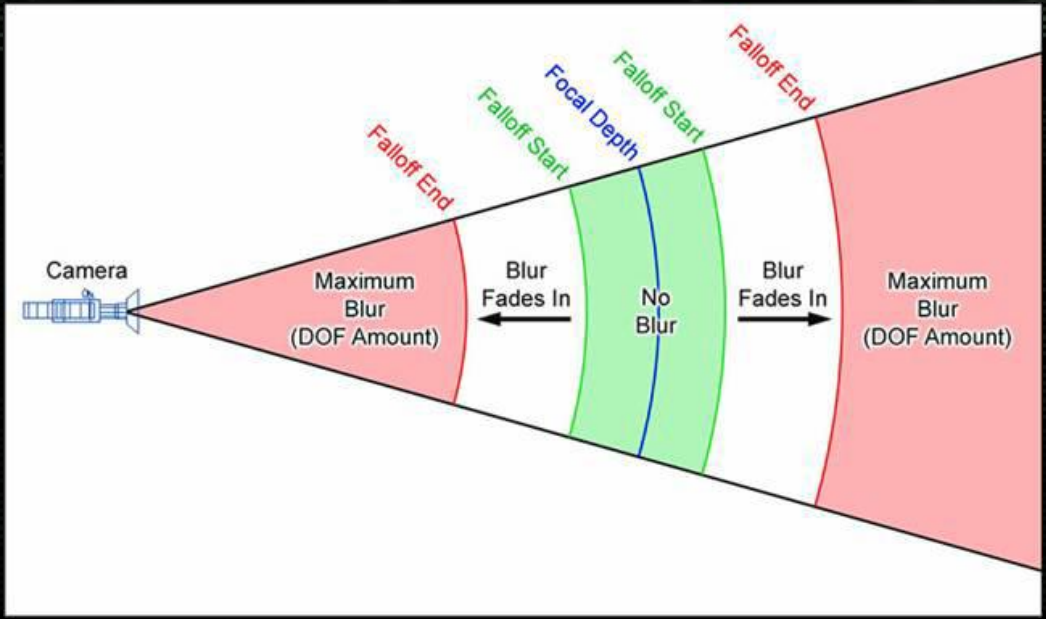
Adding cinematic feel

Artist says,

"I want this!"

Depth of Field

- Art and need-driven rather than physically driven
- One reference distance serves as focal point
- Objects grow out of focus as they move away from the focal point



Depth of Field

- Circle of Confusion is the area around each pixel for which neighboring pixels are blurred, aka. The amount of blurriness
- Function of distance from viewer; sharp detail is zero-size circle of confusion, aka no blur
- For each screen pixel, CoC is derived from depth as follows:

$$saturate\left(\frac{DofAmount \times max(0, Depth - FocalDepth - NoBlurRange)}{MaxBlurRange - NoBlurRange}\right)$$

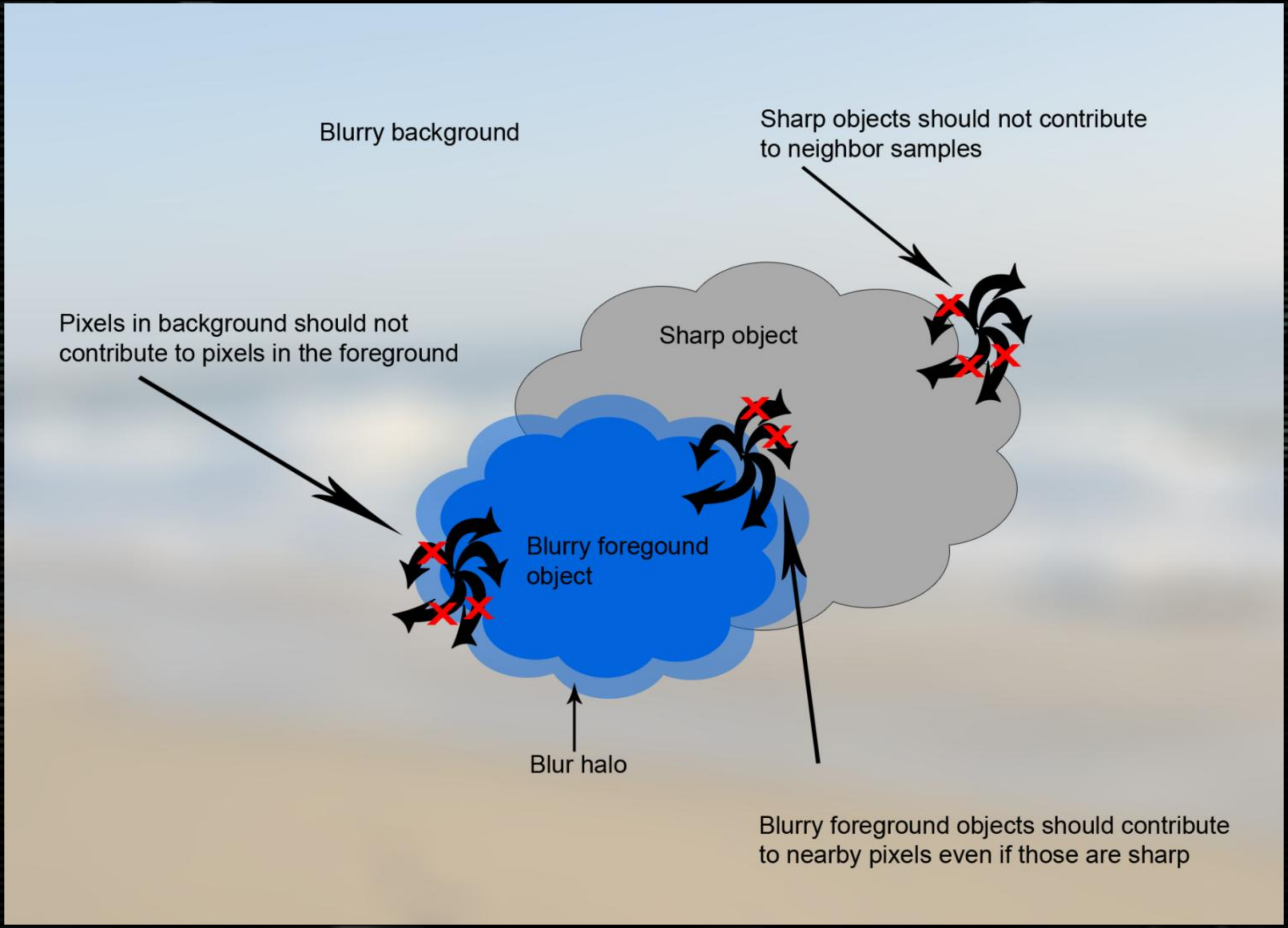
Depth of Field Blur

- One approach would be to vary the width of the blur kernel and the amount of blur samples; however, doesn't scale well to lower-end hardware
- Use three images for different levels of blur and interpolate between the images to achieve a gradual blur
- The lowest-level of blur is no blur, so the source image is a 4^{th} image that will be interpolated at the lower end of the blur range
- Use Gaussian-weighted sampling to generate the blur images

Blur regions overlap

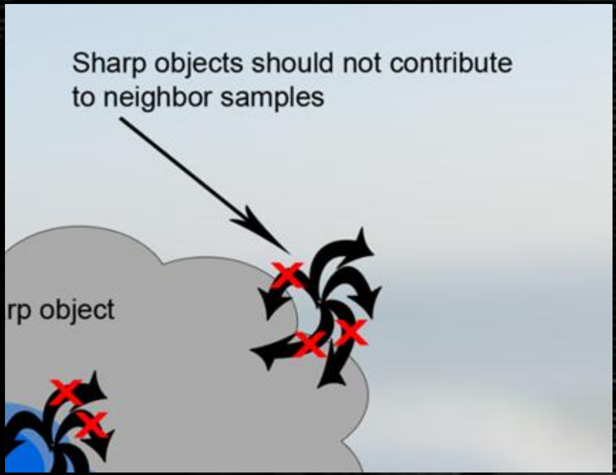
- Process works, but needs to handle some special cases to make the effect believable

Blur region overlap



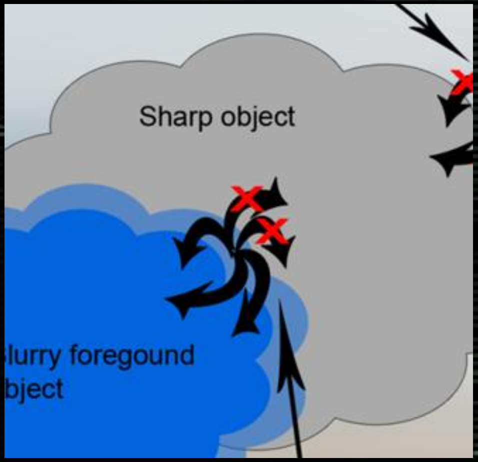
Avoid sharp halos

- Stroe CoC for every pixel in a texture
- Weigh the Gaussian samples by the corresponding CoC factors for each sampled pixel
- Gaussian weights are renormalized so they add up to one again



Creating blurry halos around blurry regions

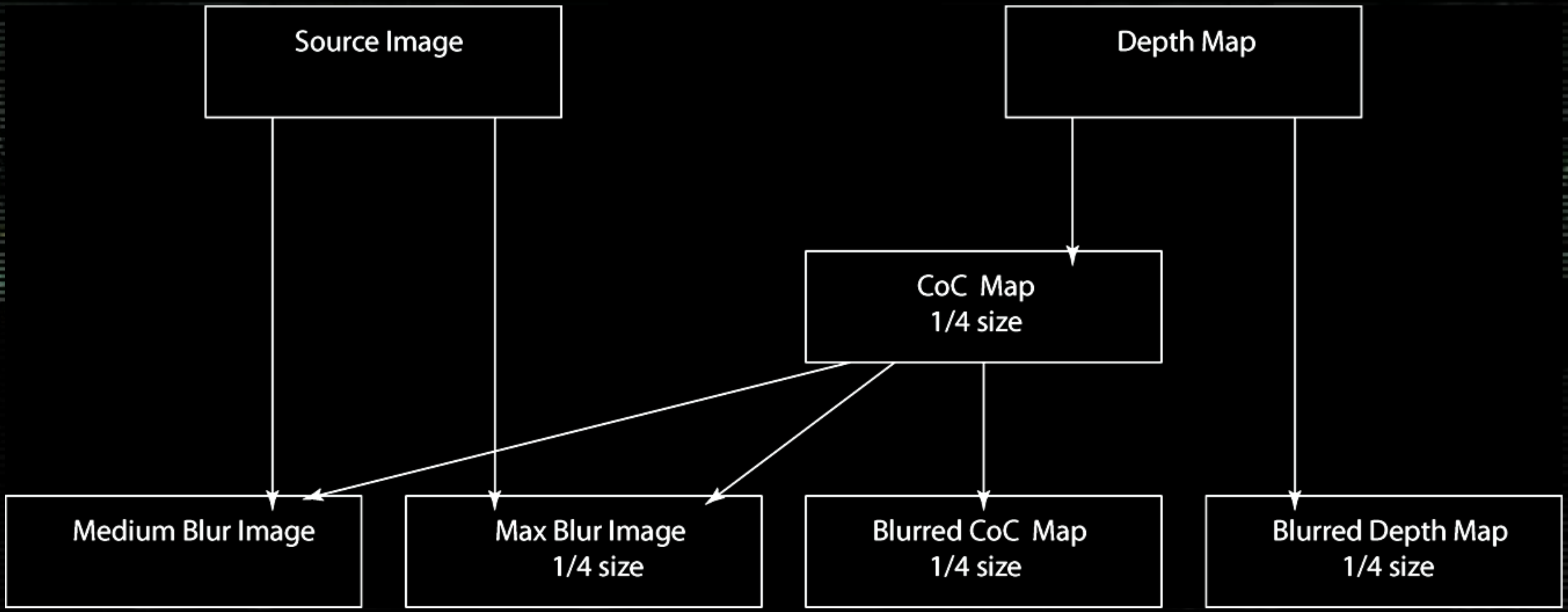
- Blur the circle of confusion factors in an image a quarter size per side, ensuring that any blurry pixels will cause neighboring pixels to become blurry as well
- This image becomes our "blurred CoC map" and assures that all blurry regions have an halo around them that extends past that blurry region



Depth ordering of blurriness

- Blurring the CoC map now creates blur regions blurring over sharp regions <u>even when the blurry region is behind the sharp region</u>
- Approximate solution, works well enough for our cases
- Downscale and blur the *depth map* in an image a quarter size per side; each pixel in the blurred depth map now represents the average depth for the area around that pixel
- Sample both the blurred and non-blurred depth maps
- If the average depth for the area is smaller (closer) than the current depth, current pixel is behind its neighbors - use the CoC from the *blurred CoC map* (aka accept neighbor halo)
- If the average depth for the area is larger (further away) than the current depth, current pixel is in front of its neighbors - compute and use the CoC for the current pixel only (no CoC blurring, and no halo from neighbor regions)

Depth of Field Texture Inputs & Outputs



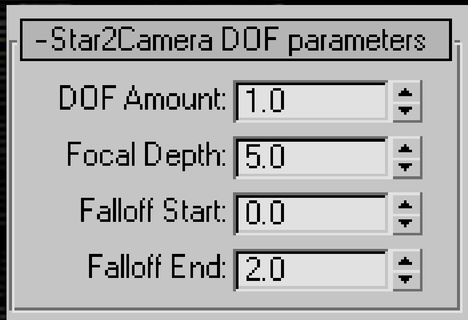
Depth of Field Full Process

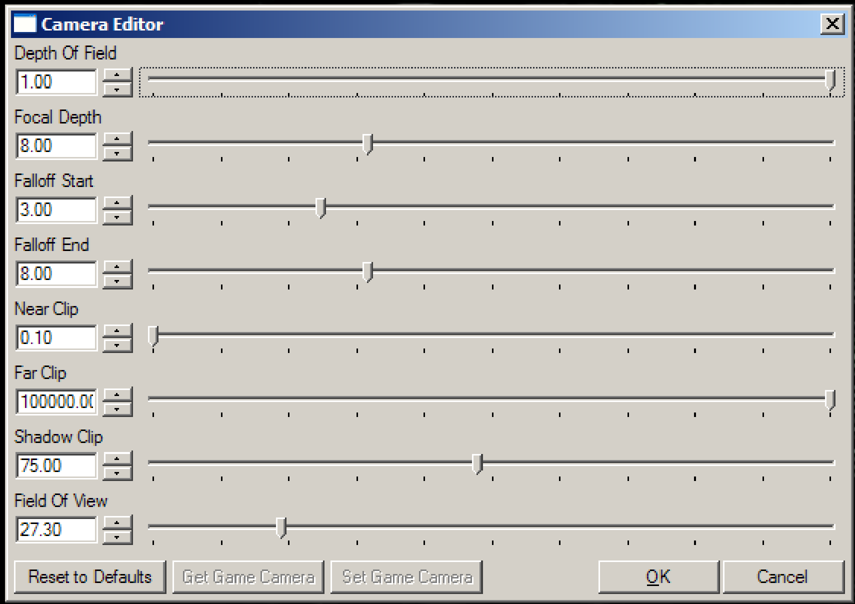
- Generate three images for each level of blur
- Compute the CoC for each pixel
- Generated blurred CoC and depth map
- Sample the source depth map and the blurred depth map and use depth ordering test to determine if the blurred or non-blurred CoC should be used
- Calculate contribution from each of the four blur sources based on the CoC factor and sum the contributions

Results: Depth of Field

DOF with maximum blur

Pipeline: Depth of Field





Simple 3dsmax rollout to save animated cameras. Slow iteration

Real-time editing in-game made DOF ultra easy to use.

Transparencies

- Transparencies are… annoying
- Only multi-pass lighting is scalable to the lowest-end hardware
- In practice, transparencies are not the point of focus for our environments
- Associating specific transparencies with an alternate, simpler set of lights is a good compromise

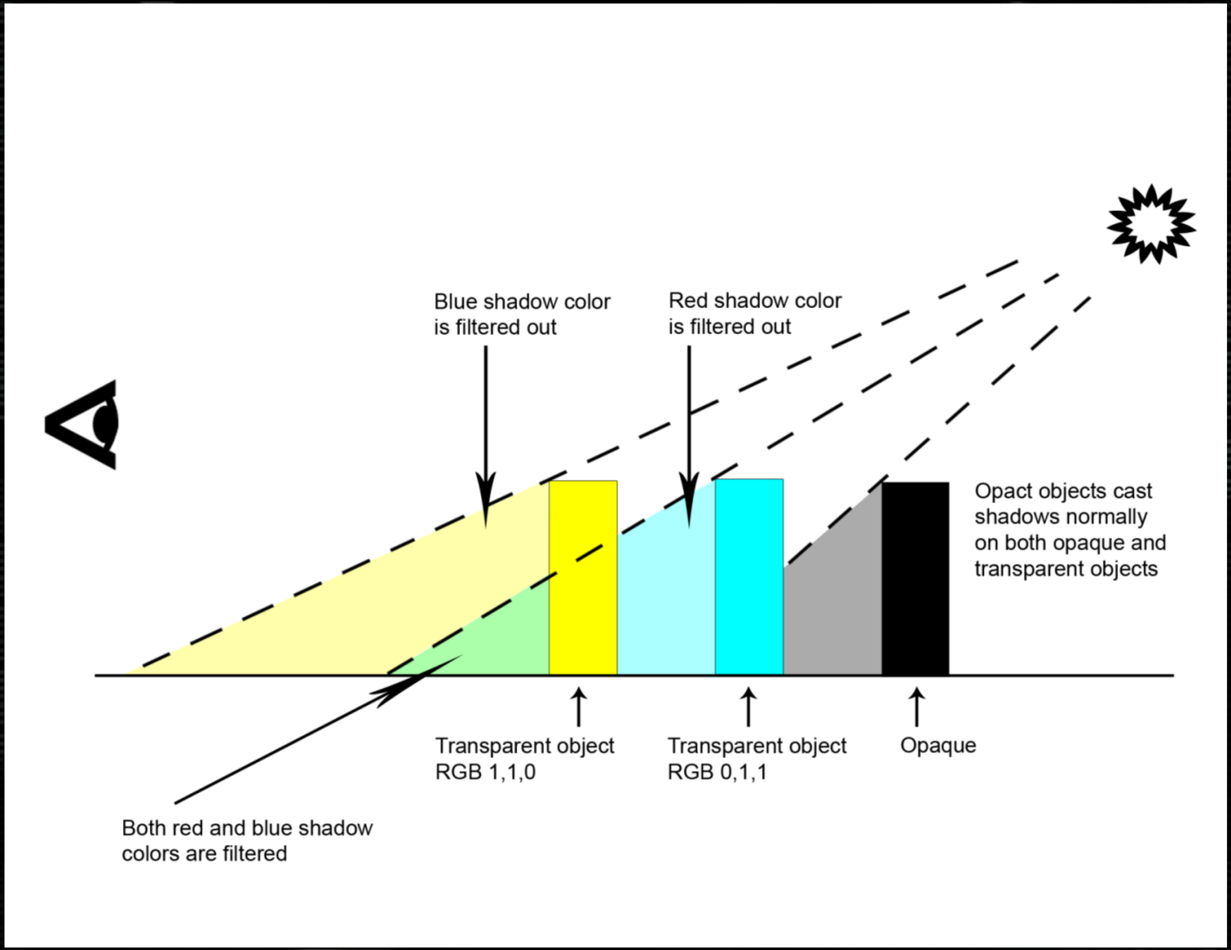
Transparencies

- Depth of field and SSAO can however produce glaring artifacts in a few cases
- Need to make compromises
- In some cases we will allow transparencies to write the depth map (not the z-buffer)
- Although there is still only one depth per pixel, this allows some key transparencies that are only slightly transparencies to handle depth of field and SSAO appropriately
- System could be broken down to support n layers but the performance characteristics become extremely variable

Translucent Shadows

- Works seamlessly with regular shadows
- Transparent objects set to cats shadows filter light through them

Translucent Shadows



Translucent Shadows

- Use a second shadow map and color buffer
- Render first, regular shadow map as normal with opaque objects
- Render transparent shadow-casting objects in second shadow map
  - Z-write on
  - No alpha-test
  - Less-equal z-test
  - Records depth of closes transparency

Translucent Shadows

- Clear color buffer associated with second shadow map to white
- Now render transparent objects again in color buffer
  - Sort front to back (inverted, these are filters)
  - Use OPAQUE shadow map as z-buffer
  - No z-write
  - Less-equal z-test
  - Records color information for transparencies in front of opaque objects

Translucent Shadows

- Finally, perform shadow test during regular rendering:
  - Test both opaque shadow map and translucent shadow map
  - If translucent shadow map test fails, modulate by color of transparent shadow color buffer
  - Module by result of opaque shadow map test (binary test)

Results: Translucent shadows

Particle effects during game-play

Results: Translucent shadows cont.

Cinematic characters

Holograph projector effect created by a shadow casting spot light through a blend mesh with a video texture

Putting it all together: Still a work in progress

Video: Depth Of Field, Translucent Shadows, and SSAO

Conclusion

- Thinking in screen-space:
  - Allows many interesting effects if approximations are acceptable
  - Simplifies existing rendering processes
  - Tends to have reliable, consistent performance

Blizzard is hiring!

- Check out www.blizzard.com for details
- Tools programmers go to the front of the line!