Rendering Techniques in Gears of War 2

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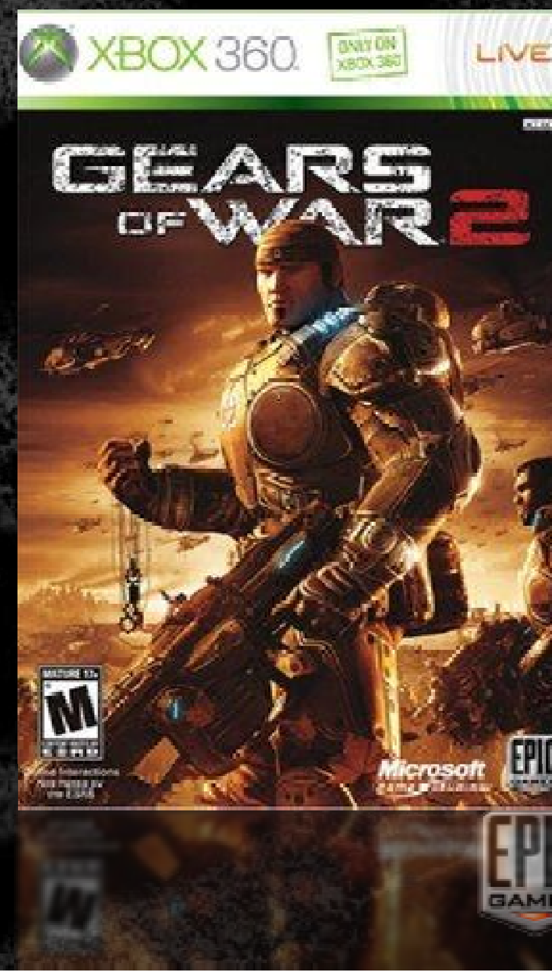
About Epic Games

- 19th year of business
- 110 employees in NC and still hiring
- Creators of Unreal Engine 3
- Shipped Gears of War 2
- Shipped Unreal Tournament 3
  – Xbox 360, PC and PS3
- External studios in Poland, Shanghai, and Utah

About Gears of War 2

- 93% Metacritic rating
- Over 4 million copies sold
- 117 award wins and nominations
- Shipped in two years by Gears 1 team



About Niklas Smedberg

- A.k.a. "Smedis"
- C64 Swedish demo scene
- Went pro 1997
- Moved to the US in 2001
- Shipped titles for PS1, PC, Xbox, Xbox 360, PS3
- Joined Epic Games 2005

Topics

Niklas Smedberg

- Gore techniques
- Blood techniques
- Character lighting
- Screen Space Ambient Occlusion optimizations

THE FOLLOWING PRESENTATION HAS NOT BEEN RATED FOR

ALL AUDIENCES

VIEWER DISCRETION IS ADVISED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Gore Goals

- Goals:
  - No seams between breakable pieces
    (Gears of War 1 used rigid 1-bone skinning)
  - Dismember skinned meshes (e.g. ragdolls)
  - Hand-modeled internals
  - Minimal impact on undamaged meshes

Gore Mesh

- Artists make two versions of the skinned mesh
- Undamaged mesh with no overhead
- Gore mesh with additional information:
  - Completely independent of the undamaged mesh
  - Full freedom to hand-model cuts and guts
  - Can use different/additional textures and shaders
  - Pre-cut with all gore pieces separated


GEARS OF WAR 2
ART DIRECTOR: CHRIS PERNA | THERON CONCEPT: JAY HAWKINS
ORIGINAL THERON MODEL: KEVIN LANNING & CHRIS PERNA
PALACE GUARD MODEL & TEXTURE MOD: MARK MORGAN | GORE: PETE HAYES
EPIC GAMES

Gore Mesh

- Skeleton with breakable joint constraints
  - Broken by script code - not using physics engine (as in Gears 1)
  - More control of when/how to break the constraints
- Info per gore piece:
  - Hit points
  - Type of special effect
  - Dependency of other gore pieces
  - Etc
- An extra set of bone weights for all vertices:
  - Hand-made 4-bone weights
  - Weighted to properly separate all gore pieces along the cuts


GEARS OF WAR 2
ART DIRECTOR: CHRIS PERNA | UBER REAVER CONCEPT: JAY HAWKINS
UBER MODEL: KEVIN LANNING, | UBER TEXTURE: CHRIS PERNA & MIKE BUCK
GORE HI POLY, LOW POLY, UNWRAP, PROCESS & RTT: PETE HAYES
EPIC GAMES

Tearing off a limb

- Switch to the gore mesh
- Determine which constraint to break
- Get the pair of broken bones
- Create a separate vertexbuffer for vertex weights
  - Unique per gore mesh instance
  - Replaces all weights in the original vertexbuffer
  - Used as a separate vertex stream
- For each vertex:
  - If influenced by a broken bone, copy 2nd set of weights
  - Otherwise, copy 1st set of weights
- Add physics impulse to the torn-off limb
  - Let physics move the limb away

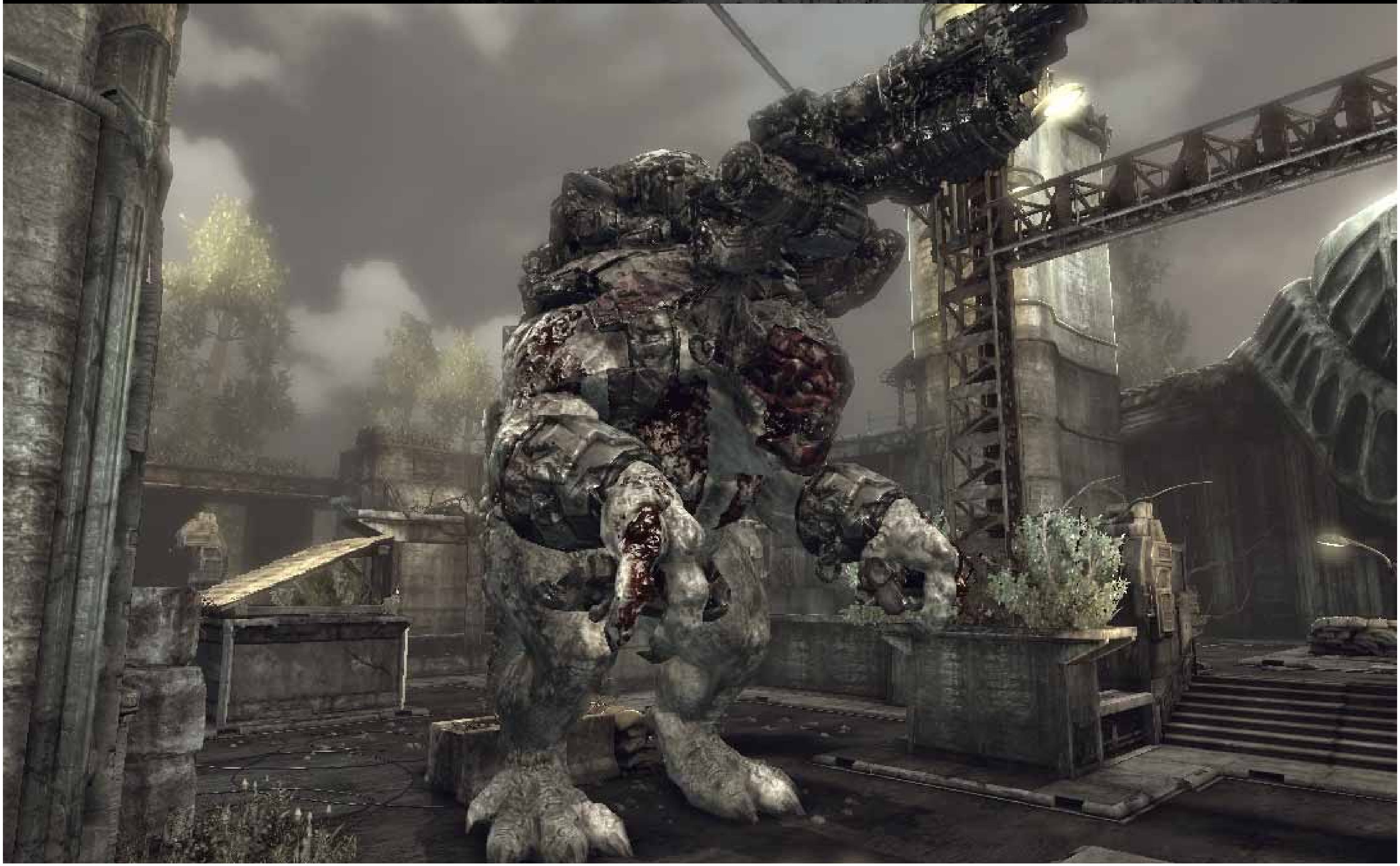
Data-driven Gore

- Set up in the Unreal Editor
- Only used for really big enemies (e.g. Brumak)
- Used as visual “damage states”
  - Not necessarily to break off whole limbs
- Gore pieces stacked on top of each other
  - Break “armor pieces”, damage flesh, etc.
- Hit-points, impact radius, dependency links (leaf first), etc

Data-driven Gore, 1 of 3

Data-driven Gore, 2 of 3

Data-driven Gore, 3 of 3



Scripted Gore

- Set up in gameplay code (Unreal Script)
- Only dismember dead people
  - No animation/gameplay consequences
- Different damage types break constraints differently
  - Complete obliteration (e.g. grenade-tag)
  - Partial obliteration (e.g. shotguns)
- Headshots spawn additional effects (gibs)
  - Hand-made gib meshes can be specified per Pawn
- Chainsaw breaks specific constraints
- Ragdolls break constraints based on hit location

Next Example: Meatshield

- Meatshields break constraints in a pre-determined sequence
  - Based on overall “health” for the entire meatshield
  - Used as gory visual indicator instead of a boring “health bar”


00:42
350


00:37
344


00:31
335


00:27
332


00:23
329


00:18
324


00:08
322

Next Example: Chainsaw

- Chainsaw kill:
  - Gameplay code choosing a specific constraint to break


WAVE 1
CORE 616
ORDE 2
071
rcus628 Drone + 30

Topics

Niklas Smedberg

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- Blood techniques
- Character lighting
- Screen Space Ambient Occlusion optimizations

Blood Techniques

- Many different techniques used in combination:
  - Projected blood decals
  - Screen-space blood splatter
  - World-space particle effects
  - Surface-space shader effects
  - Fluid simulations
  - Morphing geometry

[redacted]

Decal Features

- Decal system much improved over Gears 1
- Much easier to spawn decals on anything
- Supports any artist-created material (shader), lighting, blend mode, normal maps, animated, render-to-texture, etc
- Three decal pools:
  - Blood decals, explosion decals, bullet decals
  - Blood splatter unaffected by the number of bullet hit-marks
- Heuristic to replace oldest decal (when necessary):
  - Oldest not visible decal (LastRenderTime)
  - Oldest visible decal (Lifetime)
- Proximity check to avoid multiple decals on top of each other

Decal Optimizations

- AABB tree to find triangles within the decal frustum
  - These triangles are not clipped
- Decals have their own index buffers
  - Re-use whole triangles from the base mesh vertexbuffers
- Frustum-clipping handled by GPU:
  - clip(), early-out branch, scissor test
- Decal visibility tests:
  - Re-use base mesh visibility test
  - Decal-specific frustum and distance check
- Decals on fractured meshes:
  - Re-use the fragment-visibility check
  - Upon fracture, re-calculate affected decals only

Decal Optimizations

- One drawcall per decal, but:
  - This allows for scissoring
  - Each decal is fully featured
- Statically lit decals re-use lightmaps from underlying surface
- Dynamically lit decals use additive multi-pass lighting
- Decals on dynamic objects:
  - Projections are in local space
  - Re-use matrix to follow the mesh
- Decals on static objects:
  - Placed in the various static drawlists ("fire and forget")
- Static decals (manually placed in editor):
  - Pre-clipped geometry (no clipping on GPU)

Example: Blood Smears

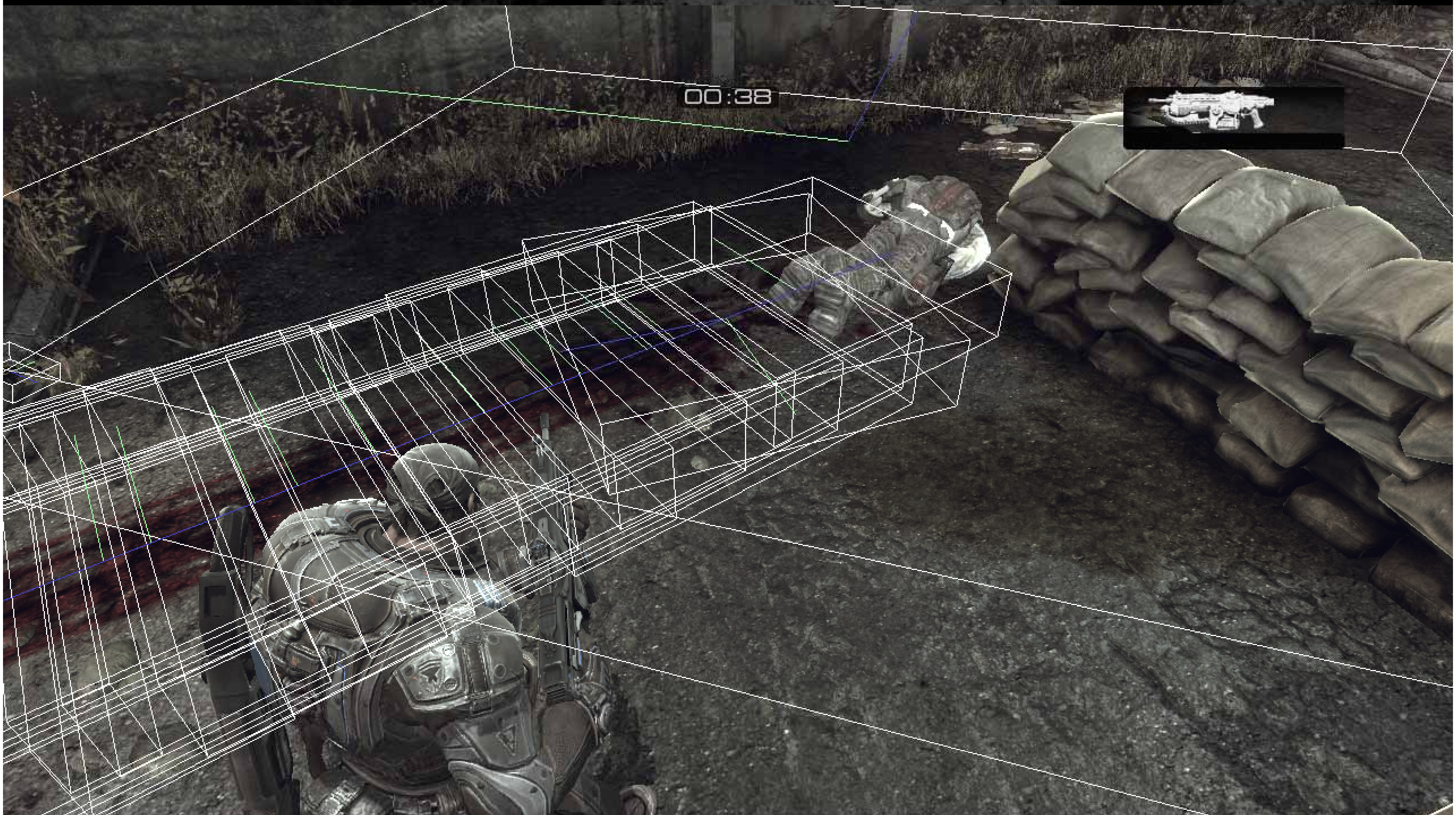
- Project decals on ground and on cover walls when you’re hurt
- Project a new decal every 0.5s while moving
- Using fading “paintbrush” effect along movement direction
  - Overall fade + “paintbrush” fade
  - Shader parameter curves exposed to artists
- Mix with standard blood decals to break up pattern

Blood Smears, 1 of 4

Blood Smears, 2 of 4

Blood Smears, 3 of 4

Blood Smears, 4 of 4



Screen-space Blood Effects

- Screen-space blood splatter:
  - Spawned by level design (Kismet), animation (AnimNotify nodes) or script code
  - 3D particle effects that use camera-facing particles
  - Game code re-positions these camera-effects each frame
  - Allows for more dynamic “screen-space” effects
    - Full-featured 3D particle effects
    - Artist-made materials (shaders)
    - Like any material, can take shader parameters from gameplay script code
    - Meshes, sprites, movie textures, normal-mapping, etc

World-space Blood Effects

- World-space 3D particle effects
- Use world-space coordinates for fake lighting on sprites and gibs
  - Can make up-facing pixels brighter, etc
  - Normal-mapped sprites helps
- 4x6 “movie frames” in a sub-UV texture to get realistic motion
  - 2048x1024 color map + 1024x512 normal map
  - Re-used for most liquid-type effects
- Mix meshes and sprites to achieve a better 3-D feeling
- Mix additive and translucent blending to work well in both dark and bright areas

Surface-space Blood Effects

Example: Surface-space

- Inside the Riftworm, characters use a blood shader
- One scalar shader parameter (0-1) to indicate amount of blood
- Texture masks for bloody regions and pattern
- Scroll textures downwards in texture-space
  - Gradient pattern & normalmap
  - (Roughly correlates to down in world-space)
- Masks and shader parameter multiply
  - Used as lerp factor between a constant blood color and un-bloodied color
- Blood color have negative Blue and Green components
  - Produces slight discoloration in the transition areas

- ALL_SoldierShaders.SinglePlayer.Bloody.SoldierShader_Bloody

Fluid Simulation

- Using our Unreal Engine 3 fluid simulation feature
  - Allows the player to wade through large pools of blood
- Ability to raise / lower the entire fluid
  - Controlled by a triggered cinematic
- Simulated on separate thread
- Height-field tessellated on GPU
  - No vertex buffer to update, all vertices are created on-the-fly on GPU
  - The height-field is used as a dynamic vertex texture
  - (Not all platforms)

Example: Riftworm Heart Chamber

- Many different techniques in combination:
  - Gore mesh
  - Screen-space blood splatter
  - World-space blood particle effects
  - Surface-space shader effect on the main character
  - Blood fluid simulation
- Note: Cutting through an artery is not done with gore mesh
  - Skeleton animation
  - Throbbing is morphing geometry

[redacted]

Morphing Blood Geometry

- Morphing:
  - Animate individual vertices, not a skeleton
  - Blend between “morph targets” (or “blend shapes”)
- Usage examples:
  - Throbbing guts inside the Riftworm
  - Some cinematics use morph targets
  - Meatshield, to prevent it from intersecting the holder

- Final example: Exit from the Riftworm
  - Notice blood pouring out (morphed geometry)

[redacted]

In Conclusion

- Achieving the right look for blood and gore:
  - Mix many different techniques
  - Use highly featured and flexible tools

About Daniel Wright

- Joined Epic Games in 2006
- Huge graphics nerd
- Optimized graphics for Xbox 360, PS3 and PC

Topics

Daniel Wright

- Gore techniques
- Blood techniques
- Character lighting
- Screen Space Ambient Occlusion optimizations

Topics

Daniel Wright

- Gore techniques
- Blood techniques
- Character lighting
  - Game lighting
  - Shadows
  - Cinematic lighting
- Screen Space Ambient Occlusion optimizations

Game Character Lighting Goals

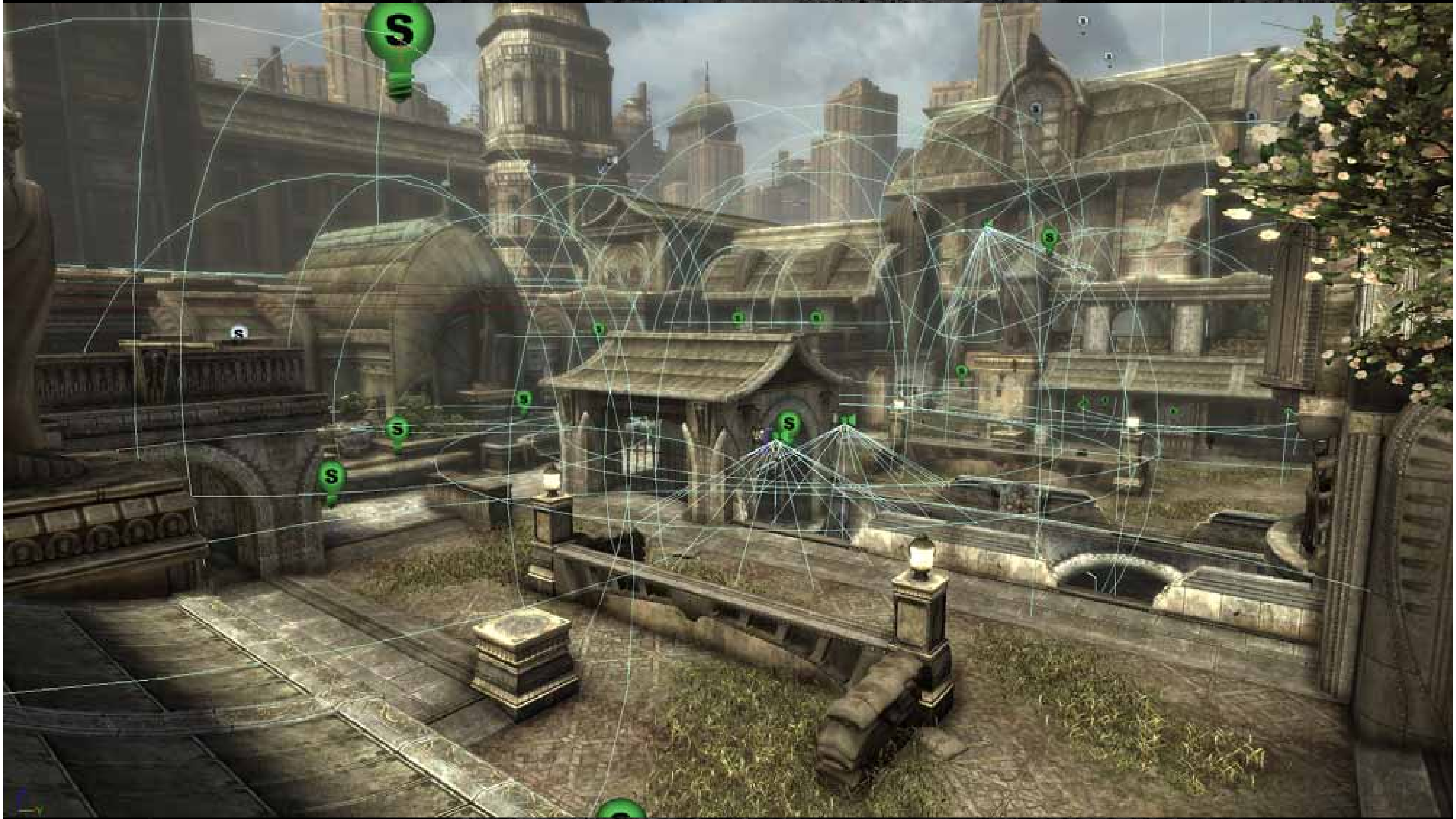
- Integrate closely with environment
- Minimal artist effort, should ‘just work’
- Upper bound on shading cost

Background

- Hundreds of static local light sources in Gears of War 2 levels

Background

- Hundreds of static local light sources in Gears of War 2 levels



Background

– Some of these are dominant light sources

Background

– The rest are fill (bounce) lights

Background

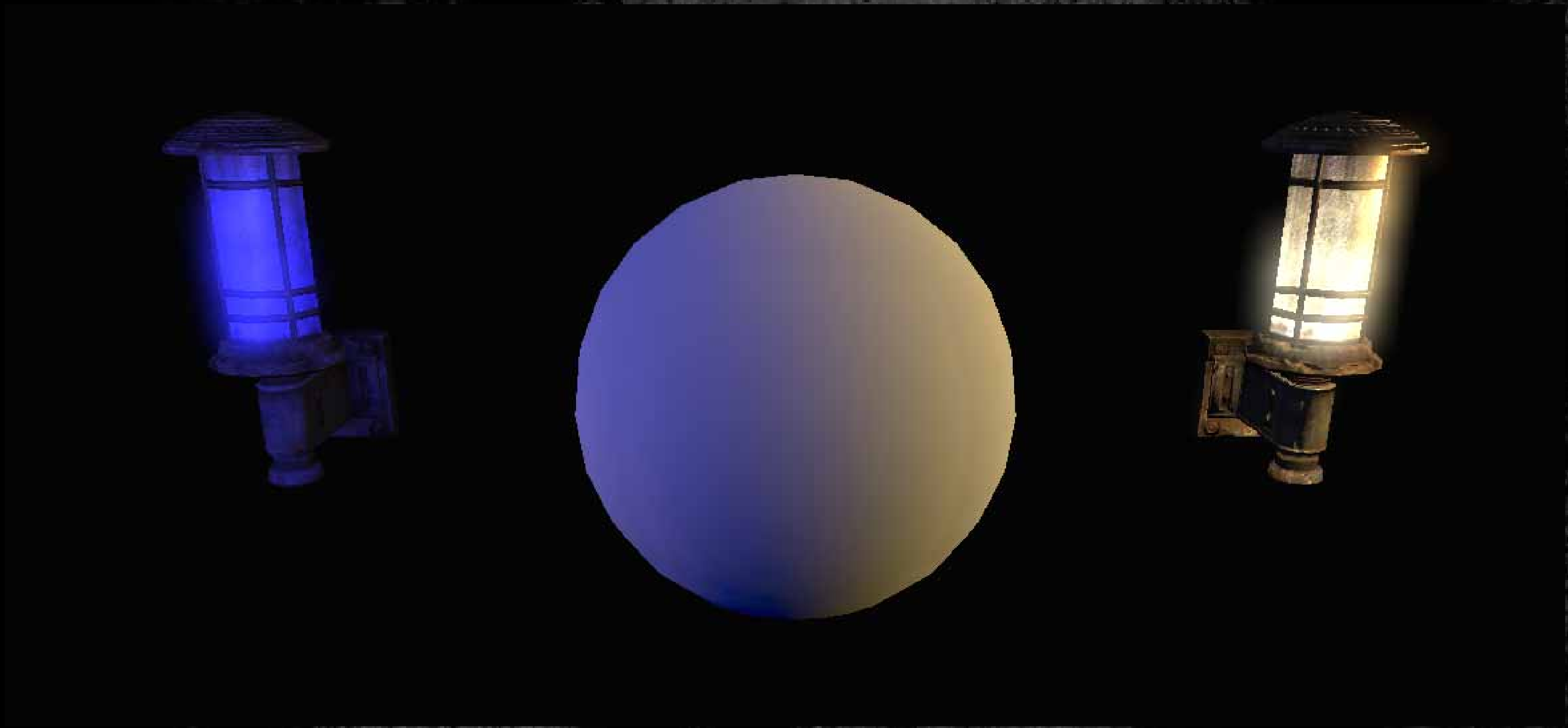
- Hundreds of static local light sources in Gears of War 2 levels
- Too many to light the character dynamically with all of them!

Introducing the Light Environment

- A Light Environment consists of:
  - The incident lighting for the object it is responsible for lighting
  - Update and apply logic

Incident Lighting Representation

- Used a Spherical Harmonic basis
- 9 coefficients



Incident lighting stored in a spherical harmonic basis for two lights

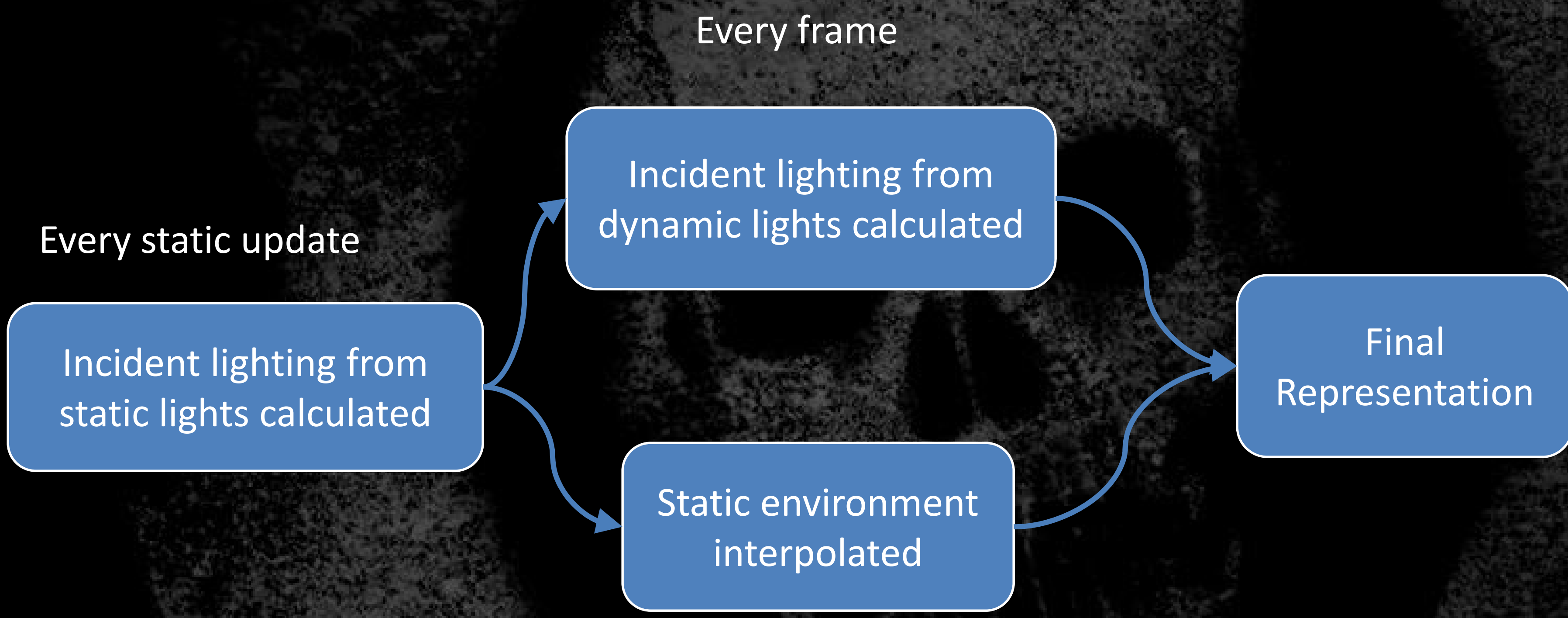
Creating the Light Environment

- Dynamically composite relevant lights into the spherical harmonic basis unique for each character
- Light visibility determined with ray traces
- Separate static and dynamic environments

Creating the Light Environment

- Static lights go into the static environment
- For the static environment:
  - Update cost is spread across multiple frames
  - Update rate is determined by visibility, distance to the viewer, and object importance

Creating the Light Environment

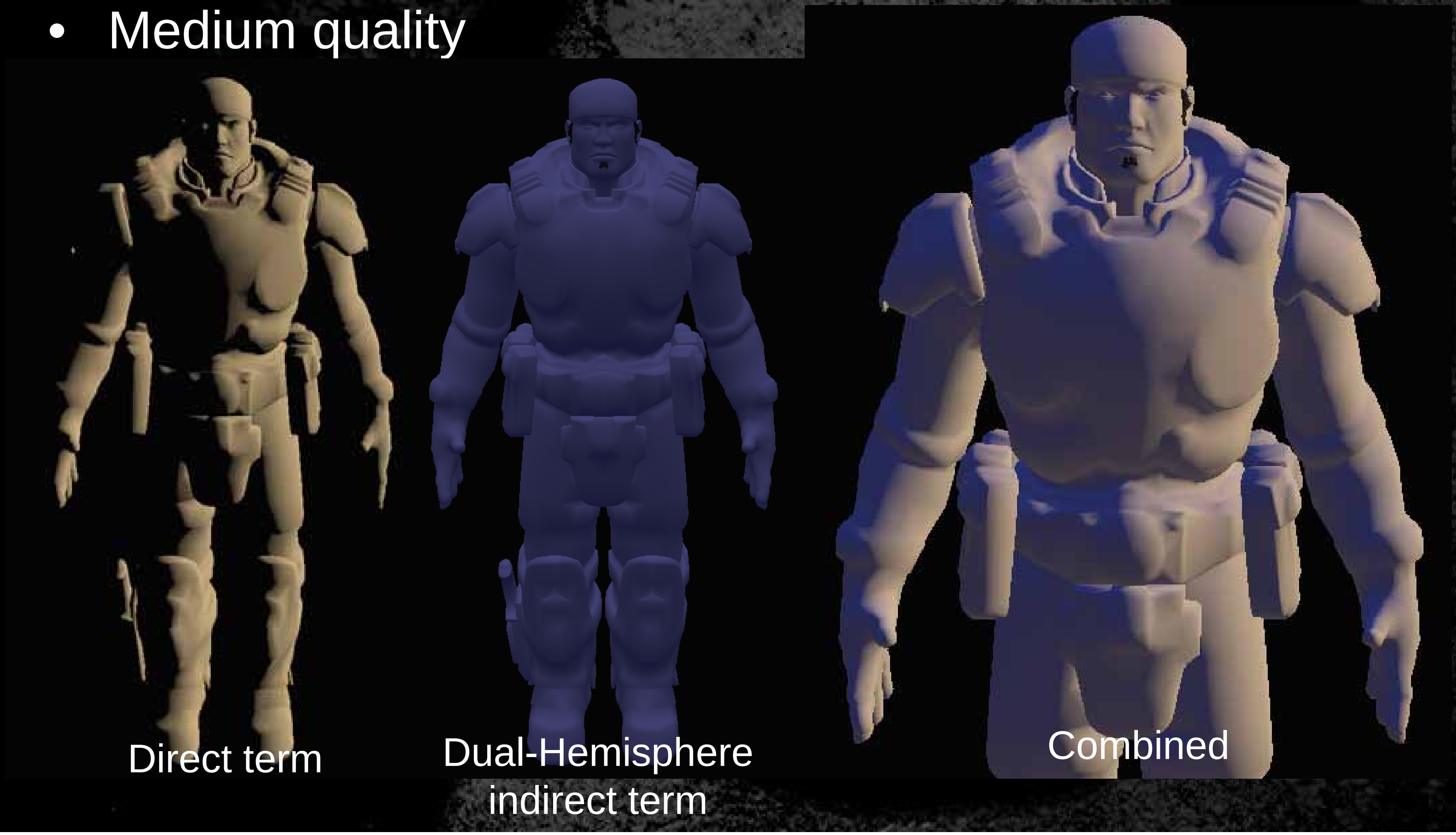


Applying the Light Environment

- Directional light for dominant direction

Applying the Light Environment

- Dual-Hemisphere light for remaining environment
- Medium quality



Applying the Light Environment

- Directly evaluate remaining SH environment per-pixel
- Gives highest quality

Direct term

Spherical Harmonic Indirect term

Combined

Applying the Light Environment

Applying the Light Environment

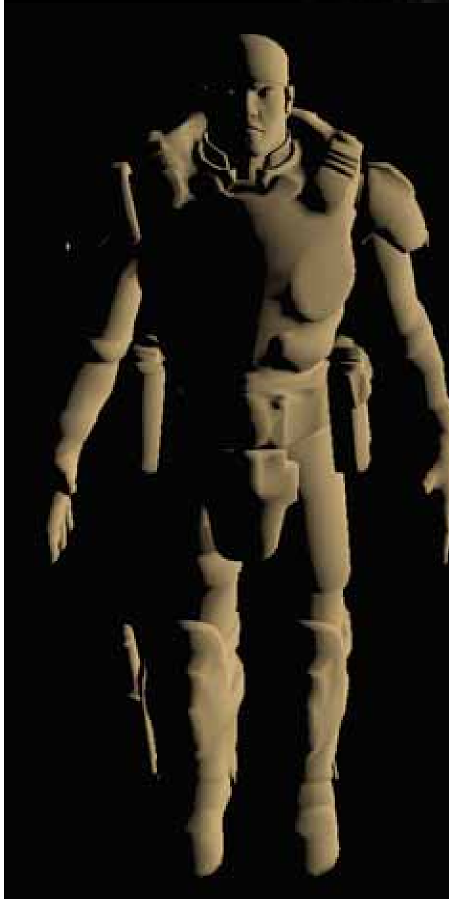
- Additional dynamic lights can be applied
  - Useful for quickly changing gameplay lights like muzzle flashes
  - Artist's discretion

Character Shadowing

- Shadow direction
  - Determined by dominant light direction
  - Fill lights are excluded

Character Shadowing

Dominant light



Dominant light
and shadow

Dominant light, shadow,
and unshadowed secondary light

Cinematic Character Lighting

- Mix of light environments and multiple shadowed dynamic lights
  - Whatever looks best for each cinematic

In Conclusion

- Combine relevant lights into one efficient representation

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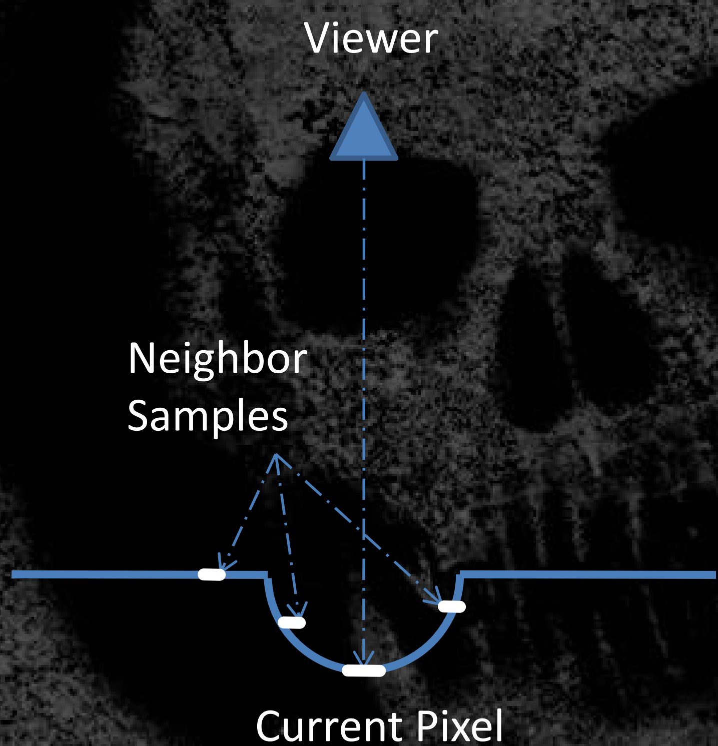
Topics

Daniel Wright

- Gore techniques
- Blood techniques
- Character lighting
- Screen Space Ambient Occlusion optimizations
  - Review
  - Motivation
  - Down sampling
  - Temporal filtering
  - Computation masking

Screen Space Ambient Occlusion Review

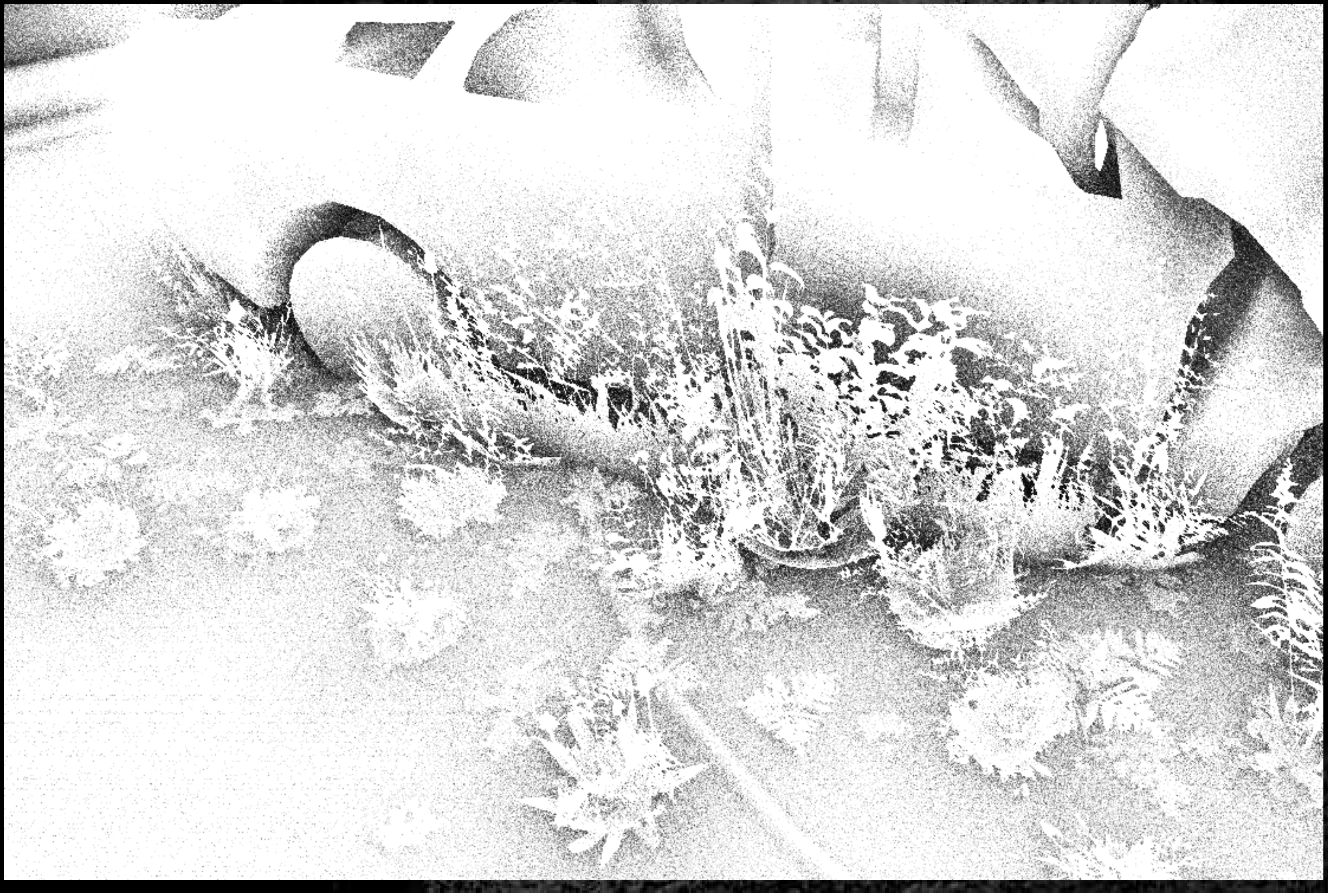
- Sample neighbor depths
- Compare depth differences



Occlusion

Screen Space Ambient Occlusion Review

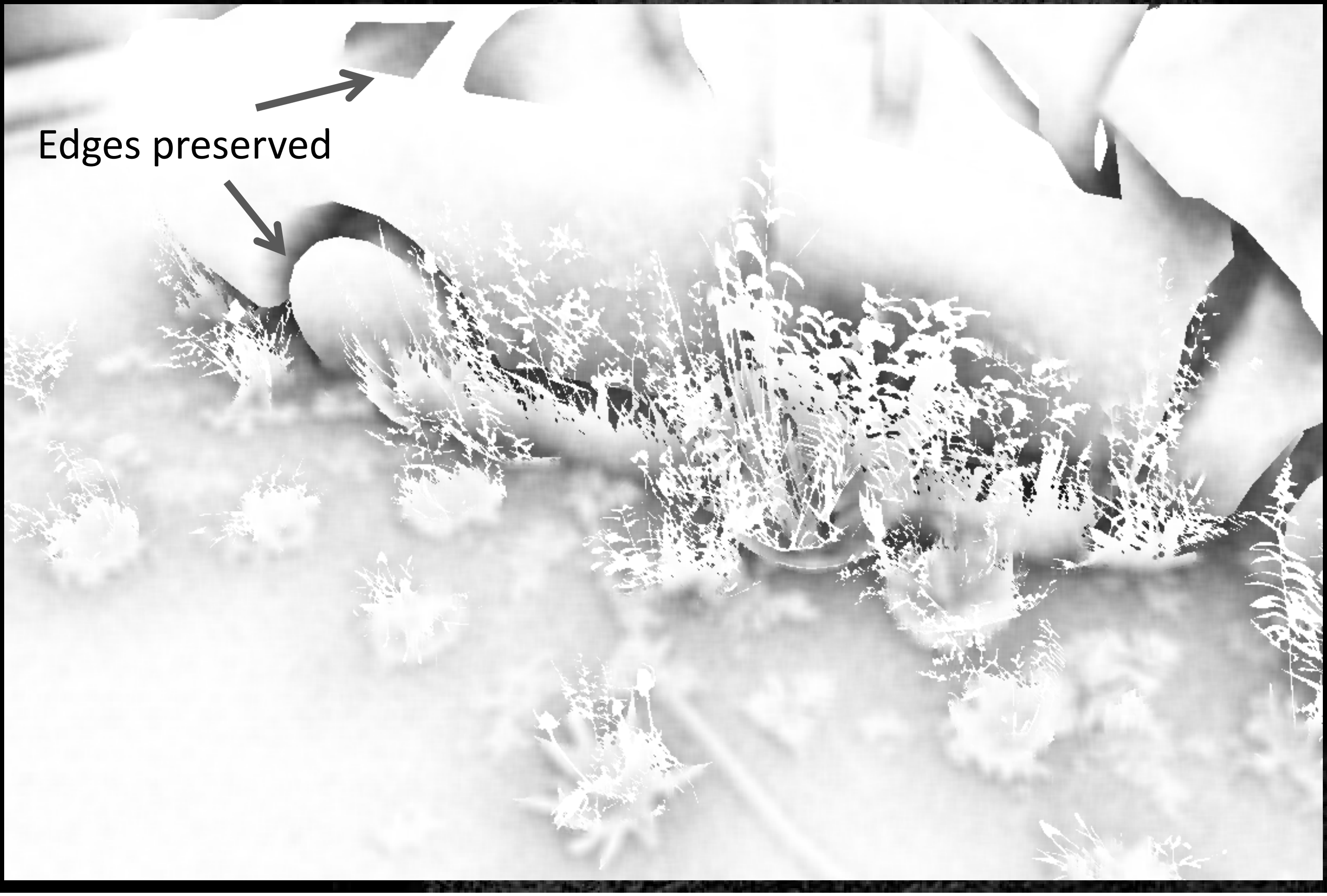
- Noisy output

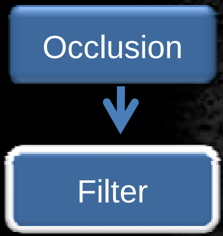


Occlusion

Screen Space Ambient Occlusion Review

- Spatial filter passes
  - Removes high frequency noise



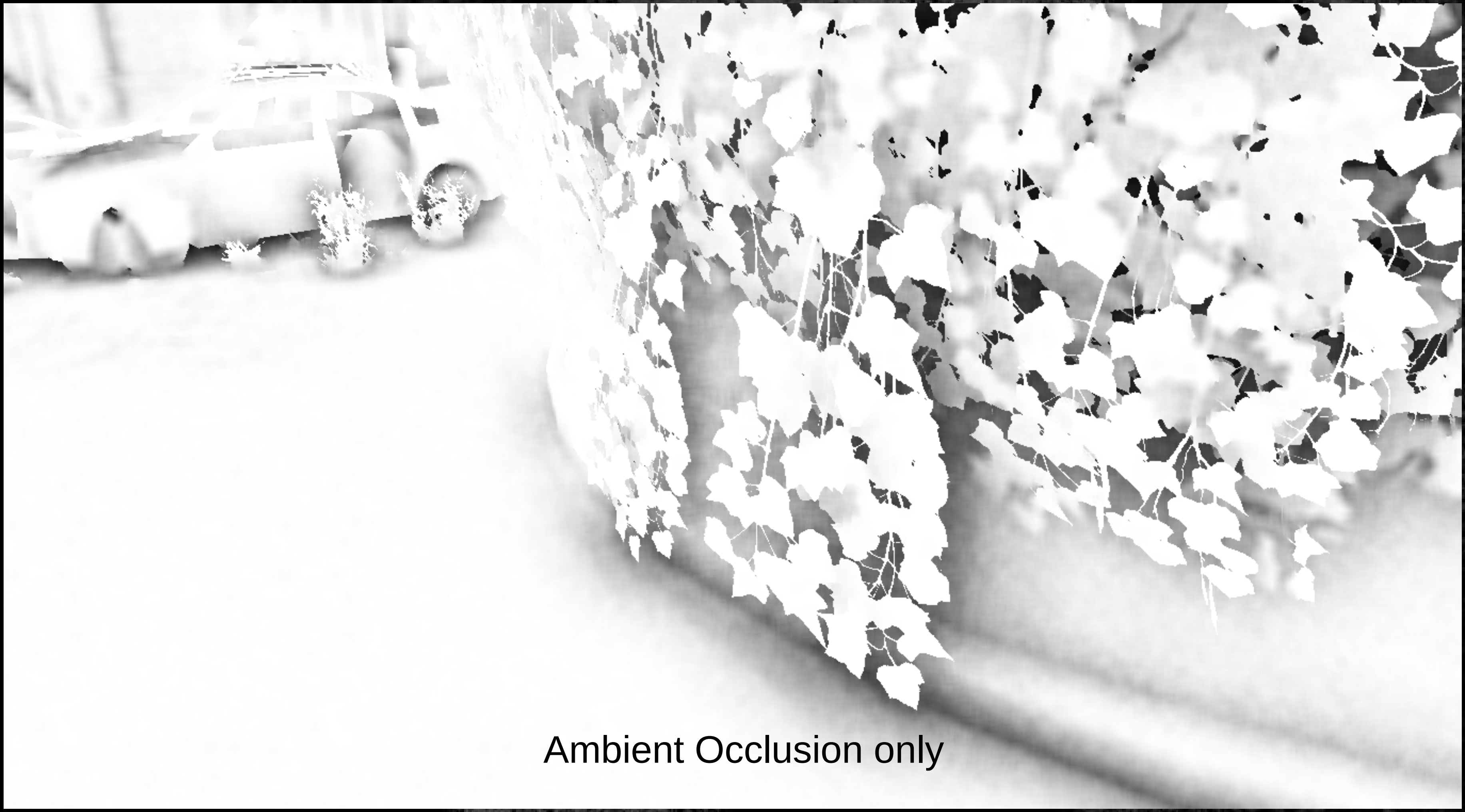


Screen Space Ambient Occlusion Review

- PC games have shipped with SSAO as a high end feature
- Gears 2 first console game (that we’re aware of)
  - Many more coming soon!
- Lots of available information on making it look good
- Only talking about optimizing here

Baseline

- 720p, 16 occlusion samples, full res, 20 filter samples



Baseline

- 720p, 16 occlusion samples, full res, 20 filter samples

Baseline

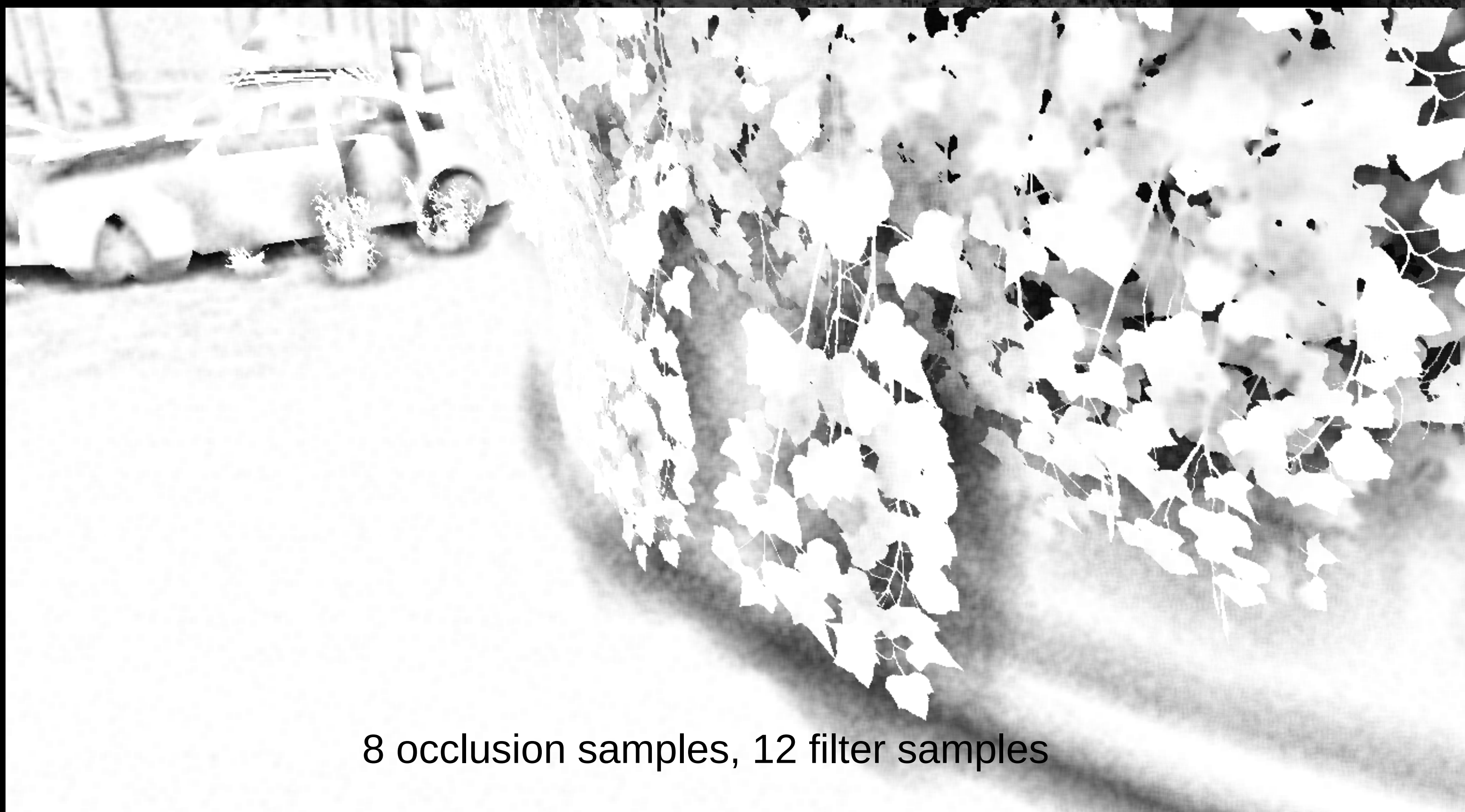
- 720p, 16 occlusion samples, full res, 20 filter samples

Screen Space Ambient Occlusion Optimizations

- Motivation
  - Shortage of GPU resources
  - Targeting console hardware
- Trade off quality for performance

Occlusion Pass

- Reduce neighbor samples
  - Multi-frequency occlusion is lost



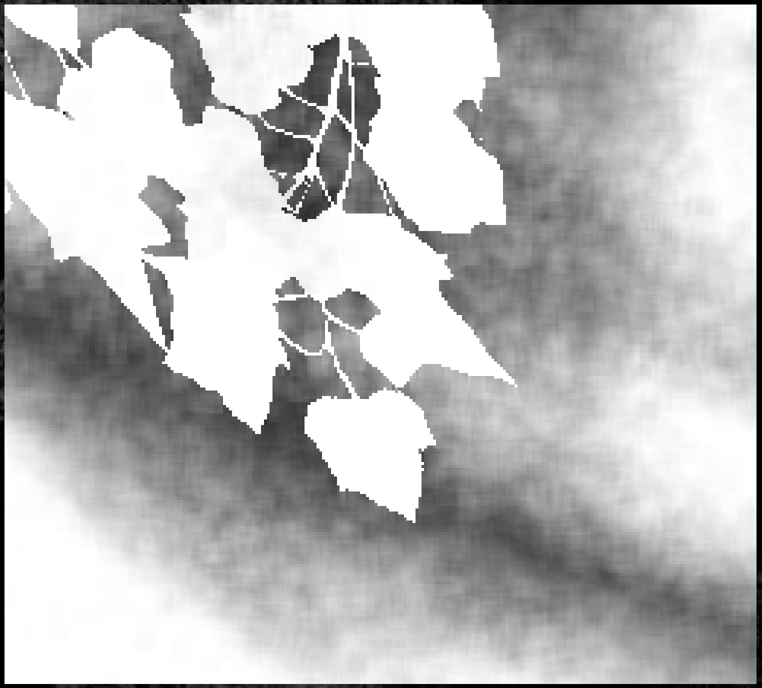
8 occlusion samples, 12 filter samples

Occlusion Pass

- Reduce neighbor samples
  - Multi-frequency occlusion is lost

16 occlusion samples, 20 filter samples

8 occlusion samples, 12 filter samples



Occlusion Pass

- Texture cache thrashing
  - Due to random per-pixel offsets
- Clamp offset radius in screen space

Down sampling

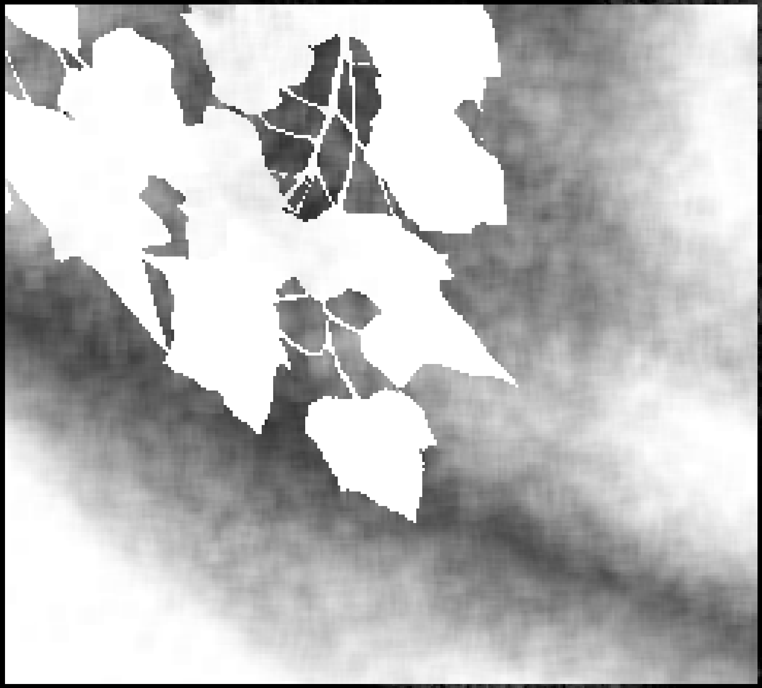
- Downsized render target
  - AO is mostly low frequency

Down sampled by a factor of two

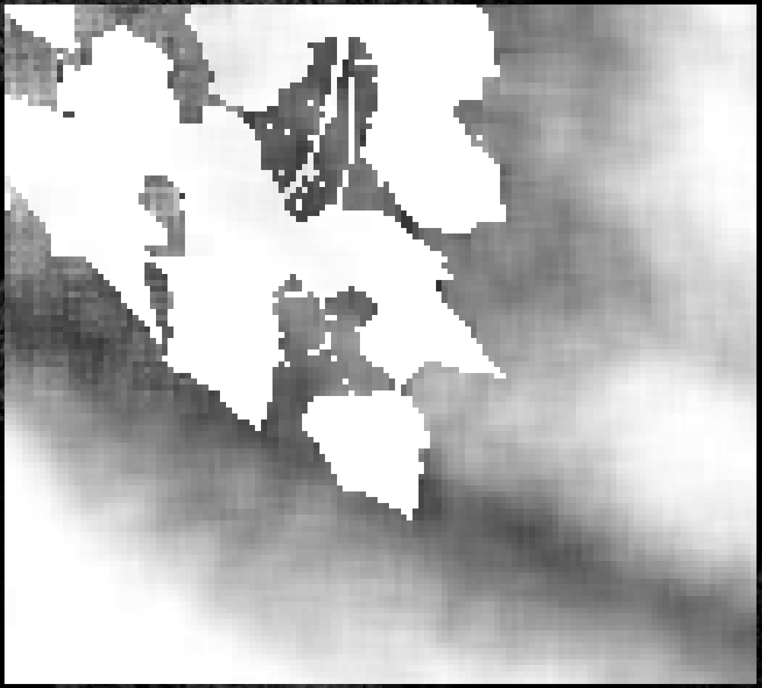
Down sampling

- Downsized render target
  - AO is mostly low frequency

Full resolution



Down sampled by a factor of two



Down sampling

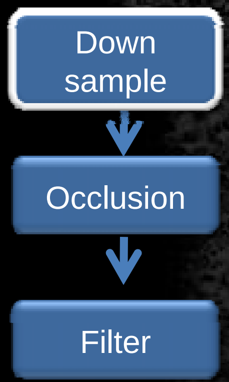
- Downsized render target
  - Use furthest of source depths
    - Effectively shrinks silhouettes of nearby objects

Using one source depth

Using furthest of source depths

Down sampling

- Downsized render target
  - Store depth in same render target as occlusion
    - Occlusion and filtering passes can reuse
    - Later passes can get occlusion and depth with one texture lookup
    - Using RG16F
  - Ended up using a down sample factor of two
  - Reduces Xbox 360 resolve cost by a factor of four



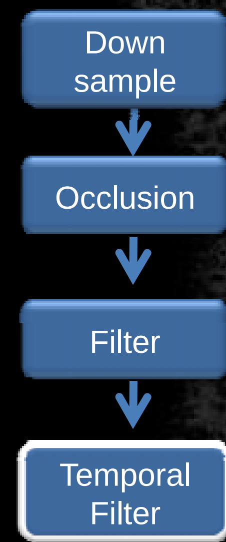
Results

Temporal Filter

- Motivation
  - Large spatial filters needed to hide low occlusion samples
  - Detail is lost with large filters
  - Lots of variance between frames

Temporal Filter

- Filter the occlusion factor over time
  - Reverse Reprojection Caching
    - Use as a filter instead of an optimization



Temporal Filter

- Reverse Reprojection Caching

Lookup this frame and last frame's occlusion values

If last frame's value is invalid, throw it away

Otherwise
New = lerp(Current, Old, Rate)

Update the history with new occlusion

Temporal Filter

- Reverse Reprojection Caching

Lookup this frame and last frame's occlusion values

If last frame's value is invalid, throw it away

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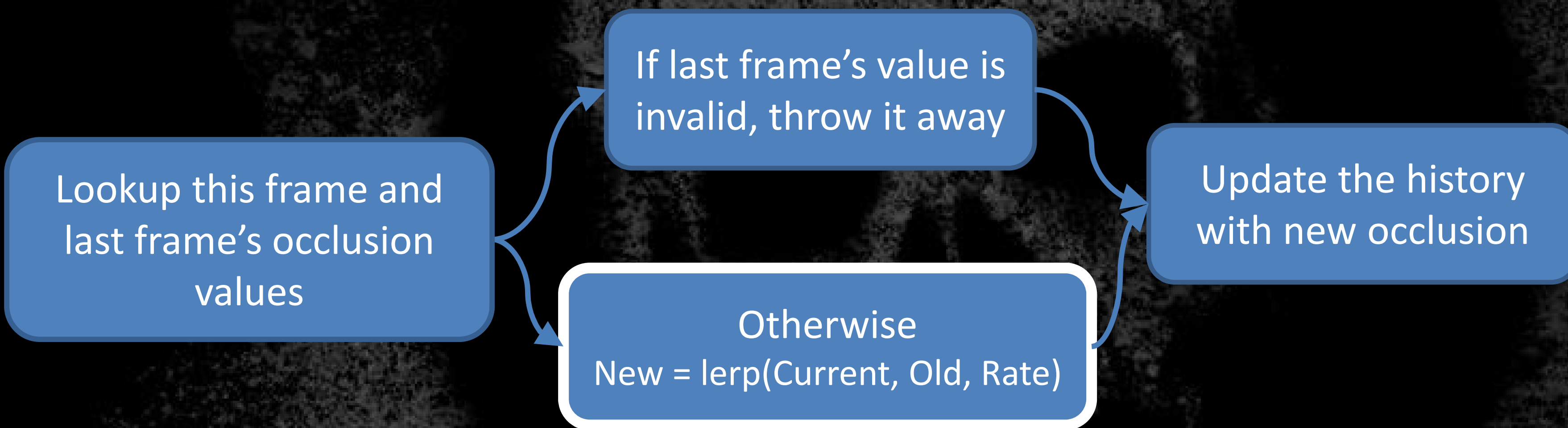
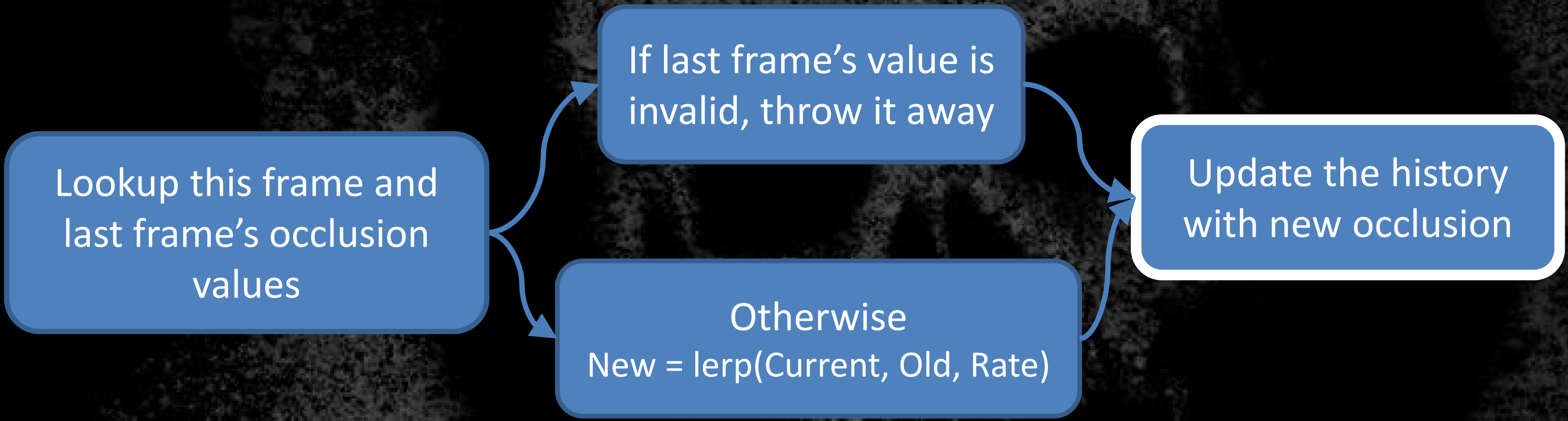
Temporal Filter

- Reverse Reprojection Caching



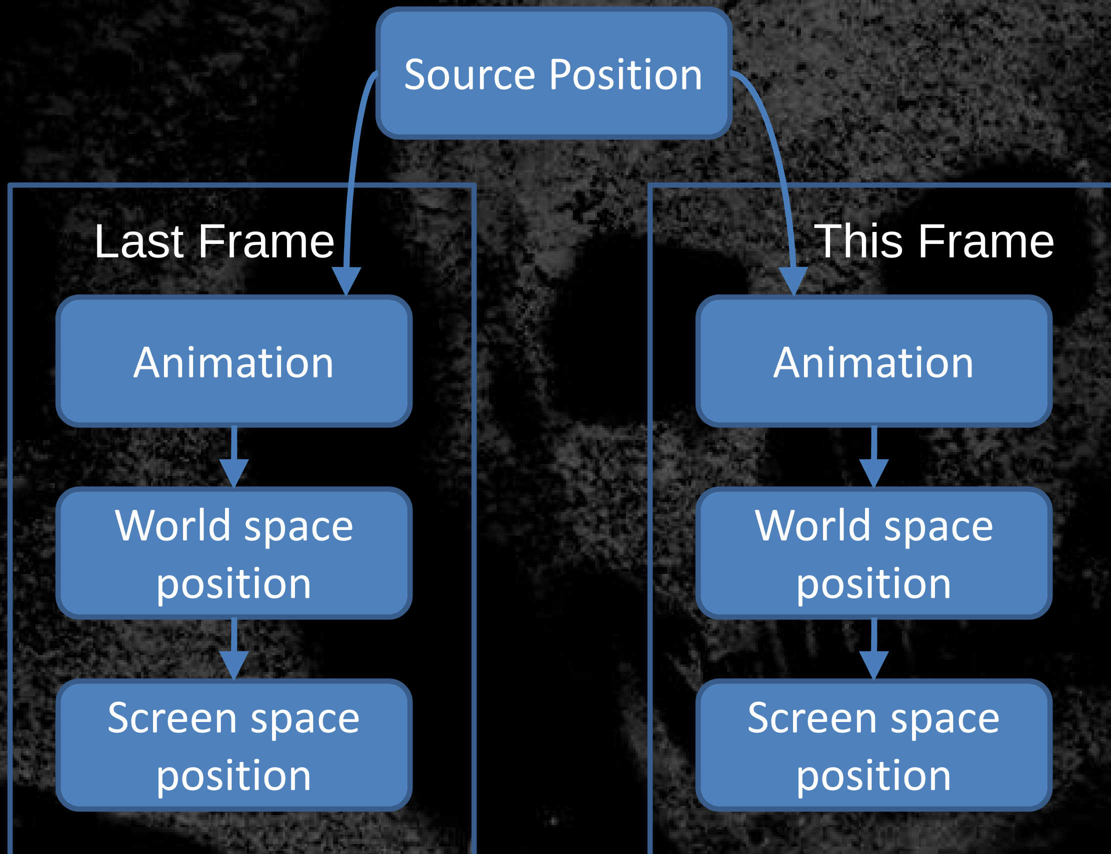
Temporal Filter

- Reverse Reprojection Caching



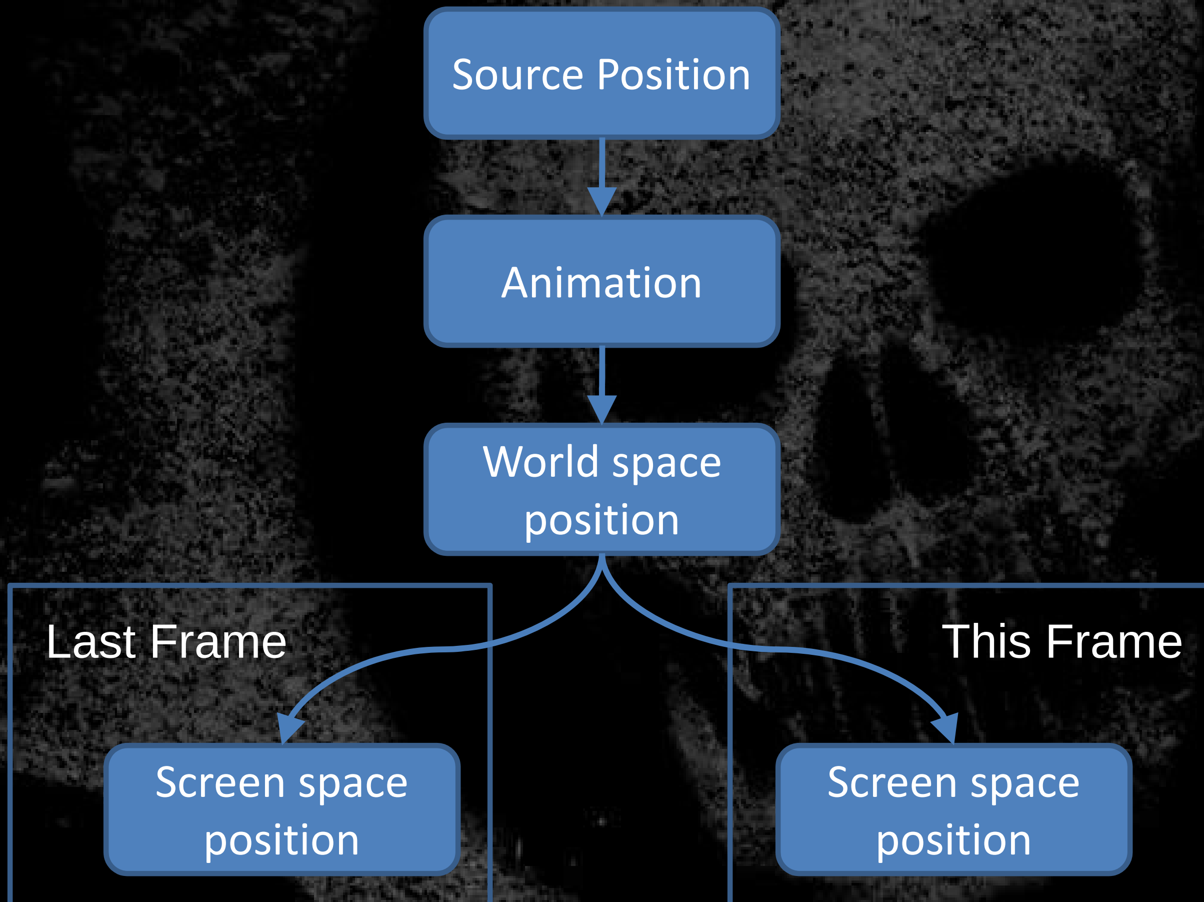
Temporal Filter

- Dynamic objects



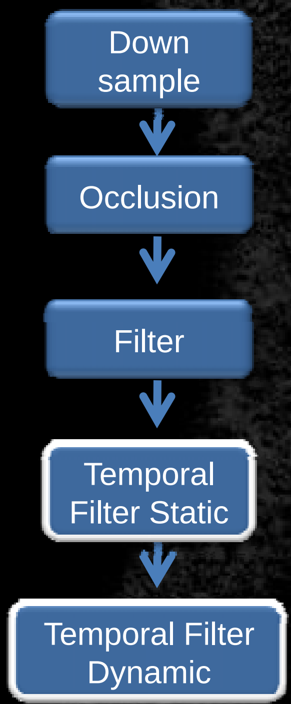
Temporal Filter

- Static objects



Temporal Filter

- Update history of all pixels as if they were static
- Overwrite with correct value for dynamic objects
  - Depth testing



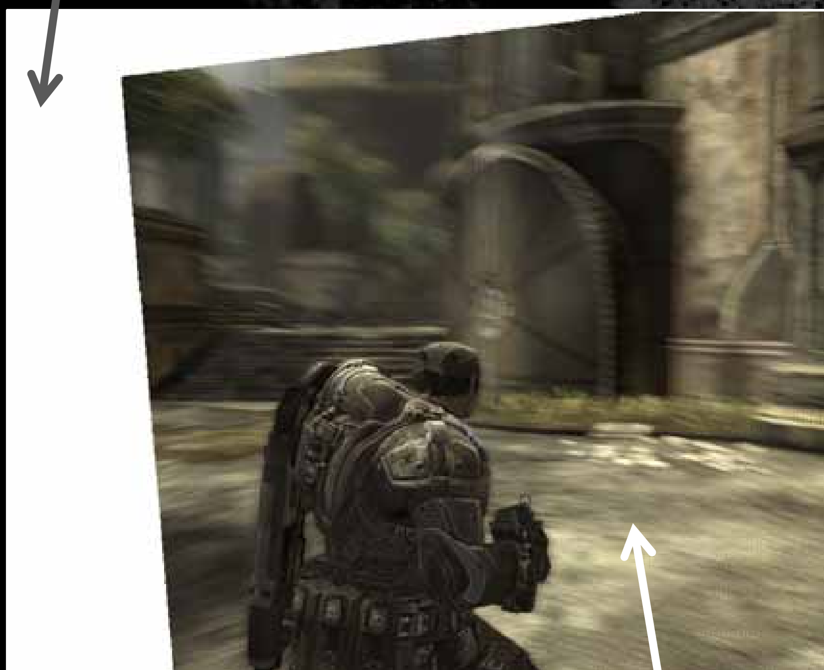
Temporal Filter

- Newly Unoccluded pixels

Temporal Filter

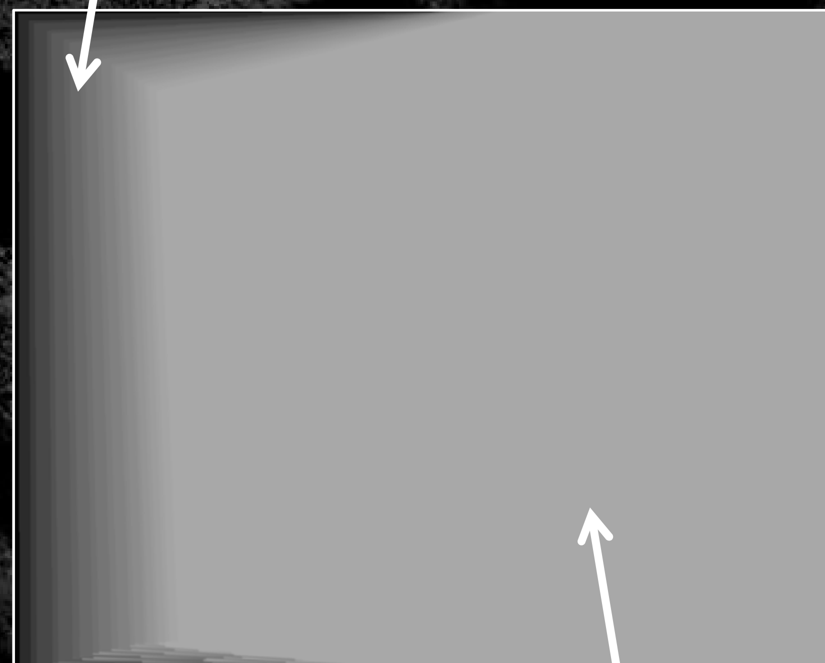
- Additional convergence control

New pixels from camera
rotation for one frame



Pixels with an existing history

Accelerating Convergence
over multiple frames



Constant Convergence Rate

Without Temporal Filter

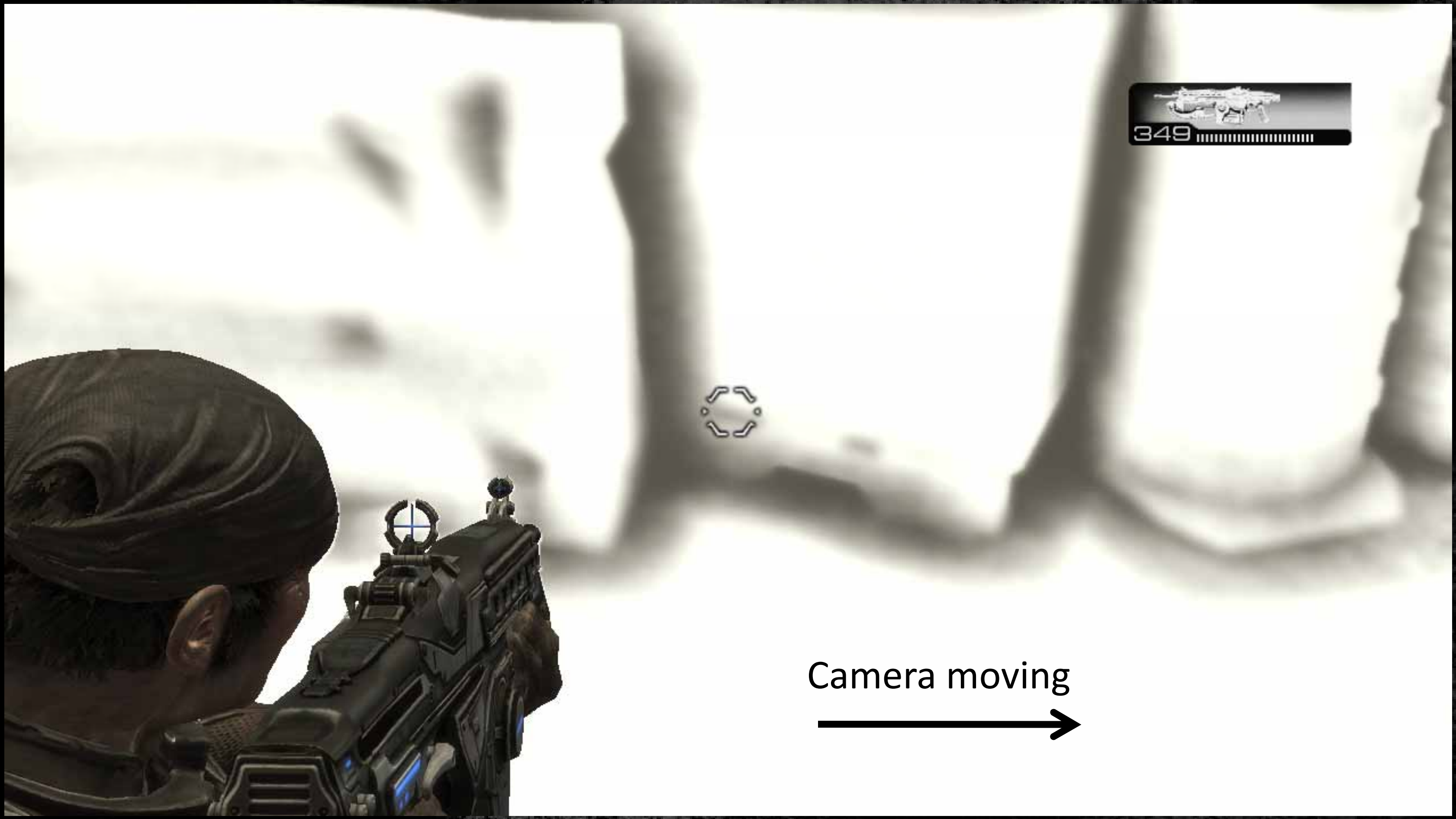
With Temporal Filter

Temporal Filter

- Doesn’t help with static camera/objects

Temporal Filter

- Almost all flickering gone with moving camera
- Can get away with less occlusion samples, less filter samples

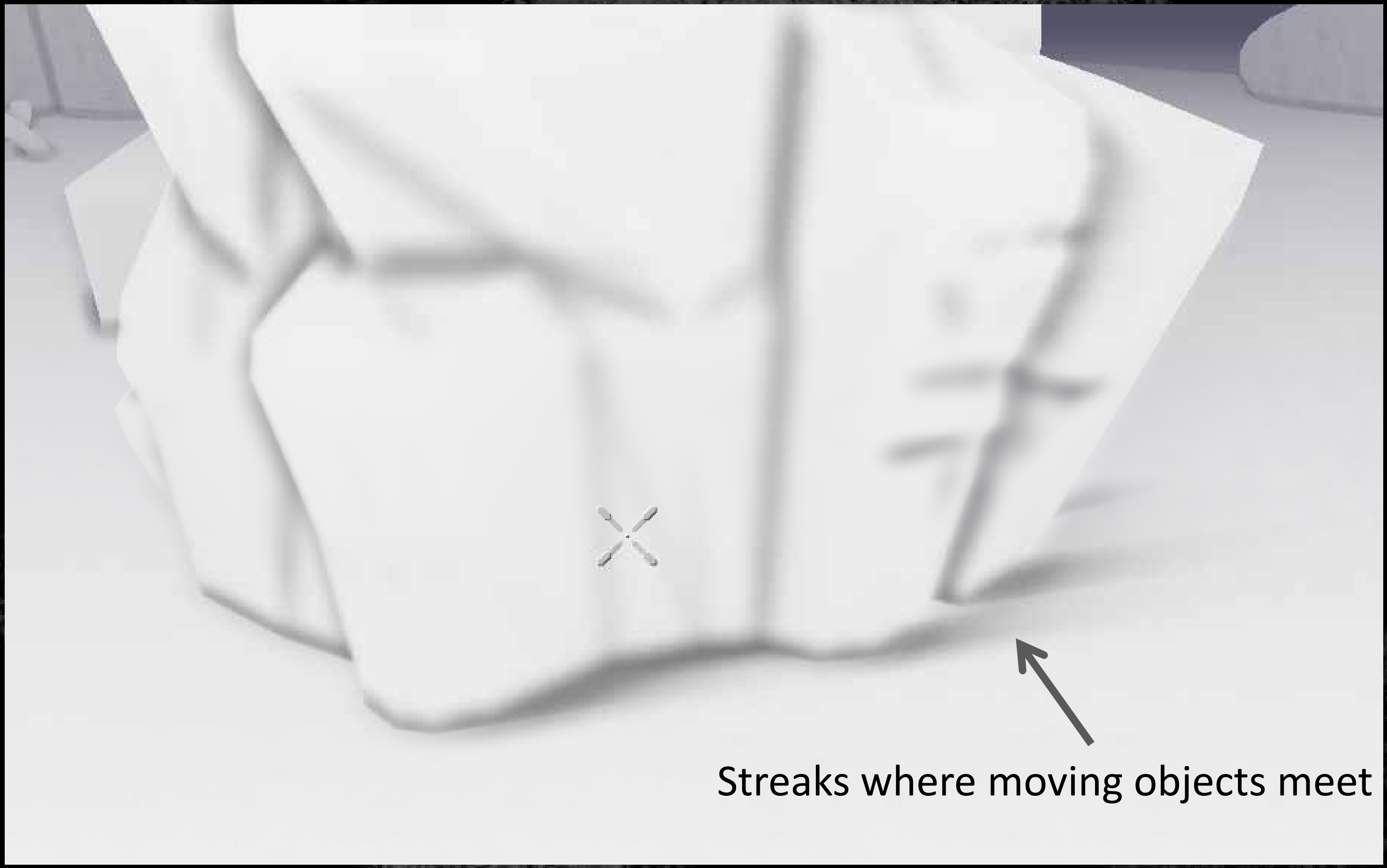


Temporal Filter Gotchas

- Accurate last frame position
- Bilinear filtering
- Double buffer
- World space precision

Temporal Filter Limitations

- Skeletal meshes
- Not detecting cache misses for every sample



Computation Masking

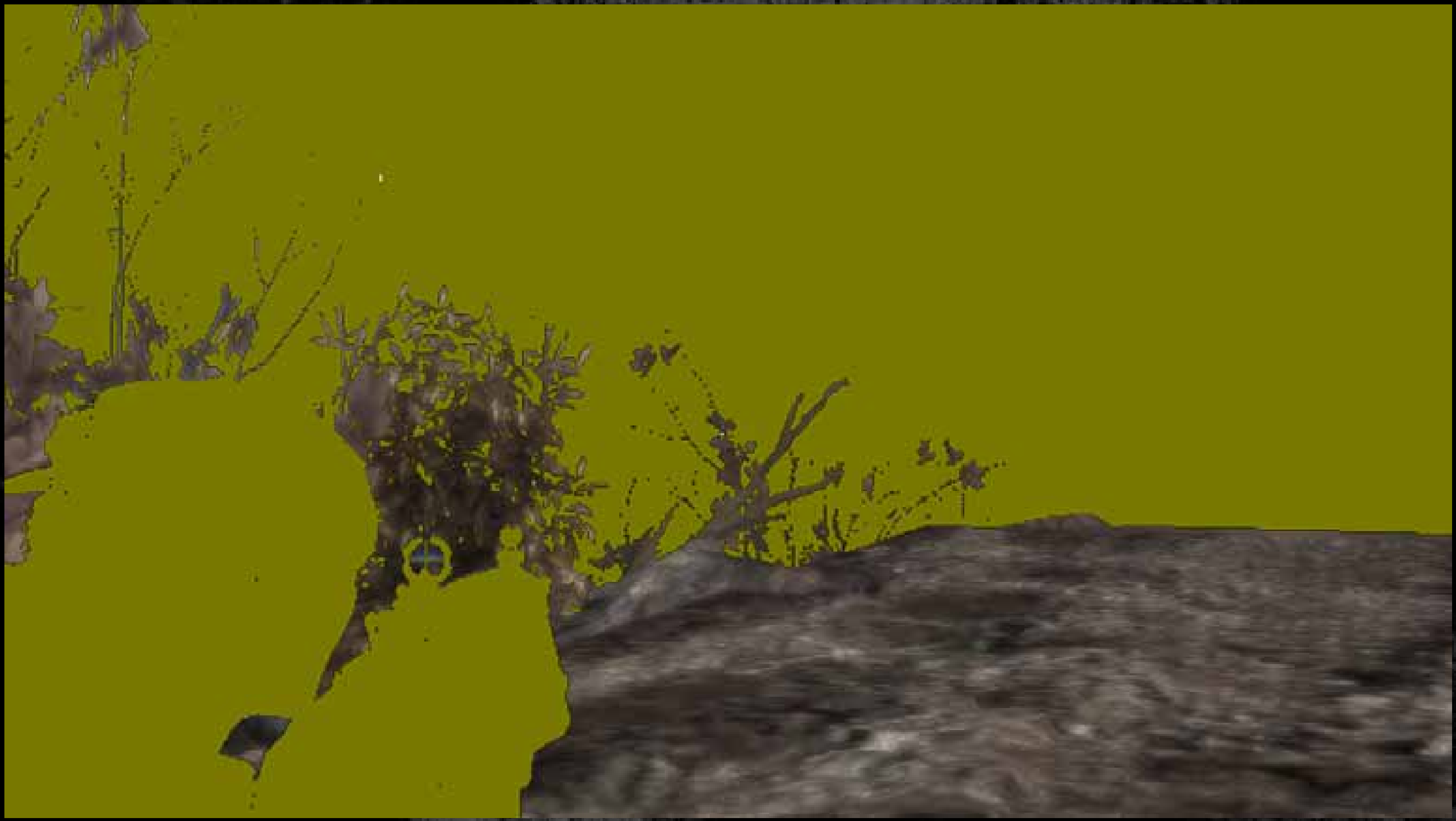
- Pixels with minimal occlusion

Computation Masking

- First person weapon

Computation Masking

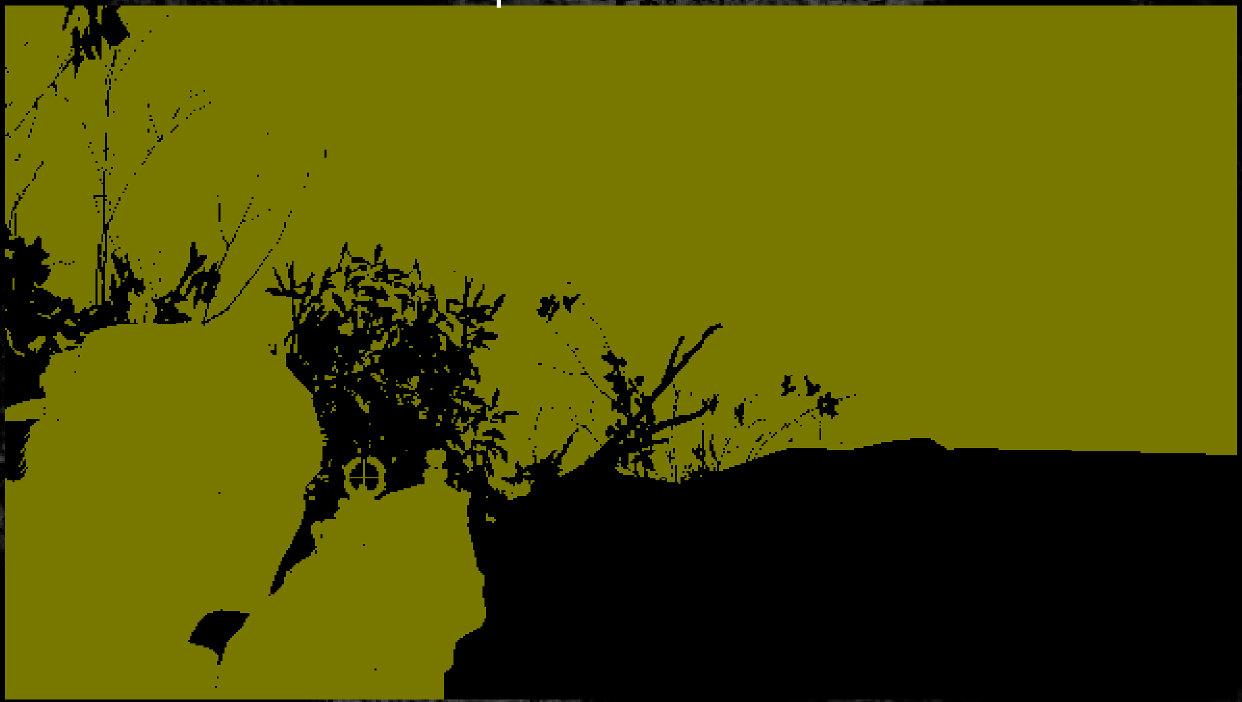
- Distant pixels



Computation Masking

- Cull these pixels with Hi-Stencil
  - Requires use of down sampled depth/stencil buffer
  - Special fast case for distance

Computation mask



In Conclusion

- Use Reverse Reprojection Caching as a temporal filter
- Use Computation Masking to avoid doing work where it won't be noticed

Questions?

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