Hashed Alpha Testing

Chris Wyman

GDC 2017

NVIDIA

Why Alpha Test?

- Alpha testing has advantages over alpha blend
  - Order independent, cheap, for forward or deferred
  - Extends to MSAA, via alpha-to-coverage

But… Problem

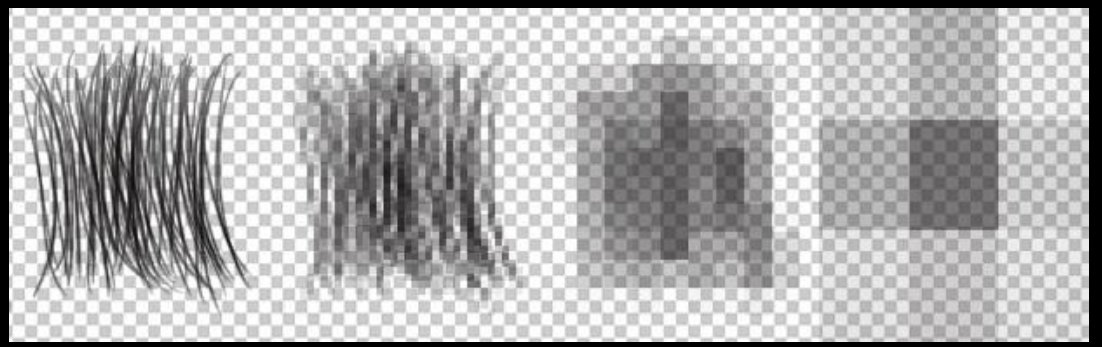
- Alpha testing has advantages over alpha blend
  - Order independent, cheap, for forward or deferred
  - Extends to MSAA, via alpha-to-coverage

- But alpha-tested geom can disappear w / distance

But… Problem

- Alpha testing has advantages over alpha blend
  - Order independent, cheap, for forward or deferred
  - Extends to MSAA, via alpha-to-coverage

- But alpha-tested geom can disappear w / distance
  - Why? Cannot prefilter binary queries



New Solution: Hashed Alpha

- Use stochastic sampling to avoid this problem

New Solution: Hashed Alpha

- Use stochastic sampling to avoid this problem
  - Basic idea is replace standard test:

```
if ( color.a < α_τ ) discard;
```

  - With this stochastic test:

```
if ( color.a < drand48() ) discard;
```

New Solution: Hashed Alpha

- Use stochastic sampling to avoid this problem
  - Basic idea is replace standard test:

```
if ( color.a < α_τ ) discard;
```

  - With this stochastic test:

```
if ( color.a < drand48() ) discard;
```

  - But this flickers like crazy
  - Want temporal stability, esp. under slight motion
  - Use stable, procedural noise:

```
if ( color.a < hash( . . . ) ) discard;
```

What Does this Look Like?

Talk Takeaways

- *Stochasm* addresses problems with alpha testing
  - Converges to ground truth (OIT) with enough random samples

Talk Takeaways

- *Stochasm* addresses problems with alpha testing
  - Converges to ground truth (OIT) with enough random samples

- *Hashing* can give noise stable over time

Talk Takeaways

- *Stochasm* addresses problems with alpha testing
  - Converges to ground truth (OIT) with enough random samples
- *Hashing* can give noise stable over time
- By *constraining* hash inputs:
  - Control noise behavior
  - Ensure samples remain largely stable between frames

Talk Takeaways

- *Stochasm* addresses problems with alpha testing
  - Converges to ground truth (OIT) with enough random samples
- *Hashing* can give noise stable over time
- By *constraining* hash inputs:
  - Control noise behavior
  - Ensure samples remain largely stable between frames
- Also applies to alpha-to-coverage, screen-door transparency, etc.

Do Stochastic Alpha Thresholds Work?

Stochastic Alpha Thresholds Work

Alpha test | 1 sample | 4 samples | 16 samples | 64 samples | OIT with alpha blend

Stochastic Alpha Thresholds Work

Traditional Alpha

```
if ( color.a < 1/2 ) discard;
```

1 sample, selected uniformly on interval [0..1]

Alpha-to-Coverage

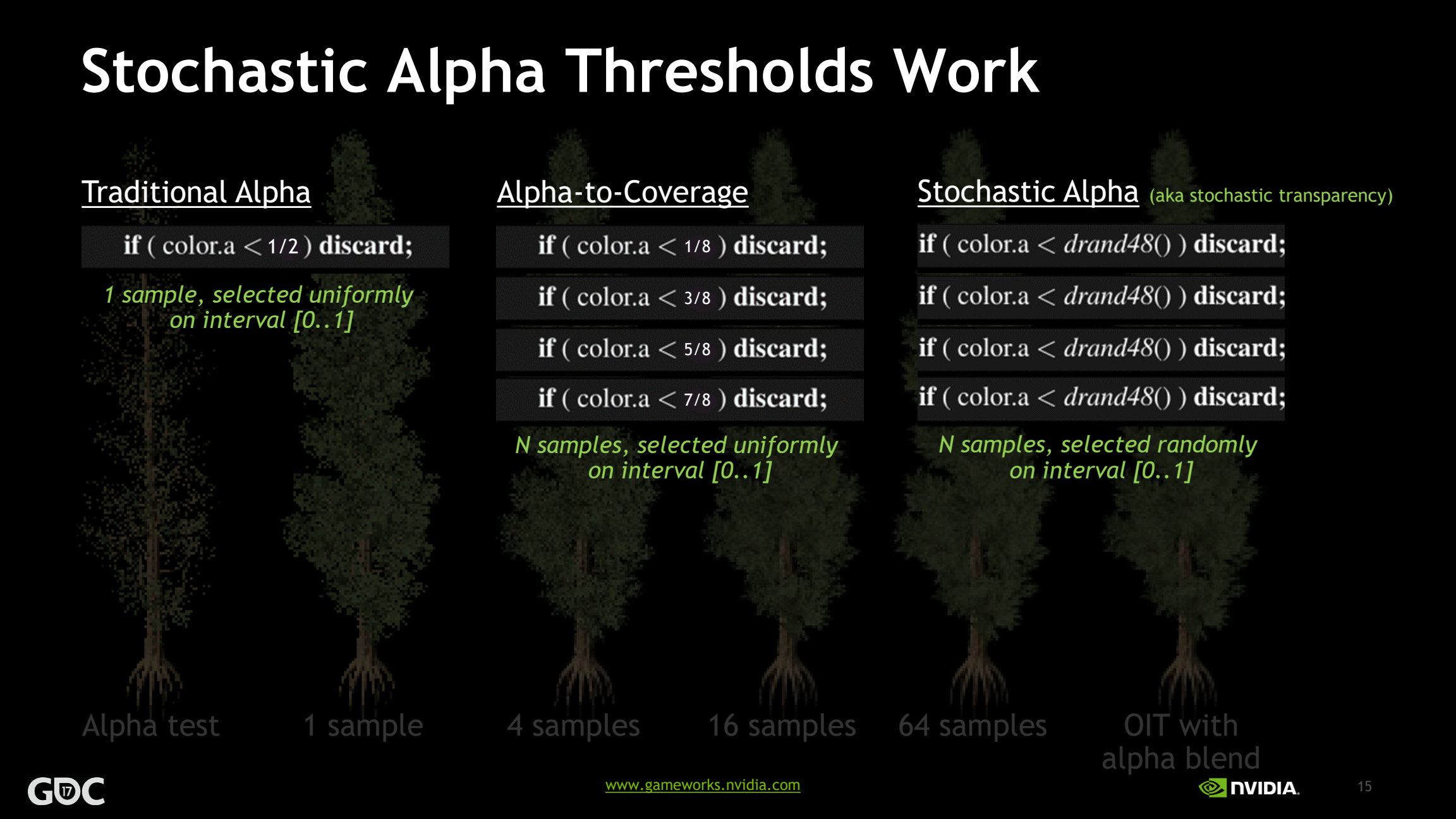
```
if ( color.a < 1/8 ) discard;
if ( color.a < 3/8 ) discard;
if ( color.a < 5/8 ) discard;
if ( color.a < 7/8 ) discard;
```

N samples, selected uniformly on interval [0..1]

Stochastic Alpha (aka stochastic transparency)

```
if ( color.a < drand48() ) discard;
if ( color.a < drand48() ) discard;
if ( color.a < drand48() ) discard;
if ( color.a < drand48() ) discard;
```

N samples, selected randomly on interval [0..1]



Stochastic Alpha Thresholds Work

Traditional Alpha

```
if ( color.a < 1/2 ) discard;
```

1 sample, selected uniformly on interval [0..1]

Alpha-to-Coverage

```
if ( color.a < 1/8 ) discard;
if ( color.a < 3/8 ) discard;
if ( color.a < 5/8 ) discard;
if ( color.a < 7/8 ) discard;
```

N samples, selected uniformly on interval [0..1]

Stochastic Alpha (aka stochastic transparency)

```
if ( color.a < drand48() ) discard;
if ( color.a < drand48() ) discard;
if ( color.a < drand48() ) discard;
if ( color.a < drand48() ) discard;
```

N samples, selected randomly on interval [0..1]

But stochastic algorithms change each frame, causing severe temporal flickering!

Alpha test | 1 sample | 4 samples | 16 samples | 64 samples | OIT with alpha blend

Why Hashing?

- Hashing long known as a way of ‘randomizing’
  - See *“Numerical Recipes”* for an example PRNG using DES encryption

Why Hashing?

- Hashing long known as a way of ‘randomizing’
  - See *“Numerical Recipes”* for an example PRNG using DES encryption

- Good hash function properties:
  - Determinism given fixed input — i.e., gives same value each frame
  - Defined range of outputs — i.e., in range [0…1)
  - Uniformity over output range — i.e., uniform outputs in range [0…1)

What Does This Mean?

- Consider the following, with good hash function `hash( )`:

```
float hashSample = hash( myPosition );
```

- Gives noisy `hashSample` like RNG per sample, but stays fixed between frames

What Does This Mean?

- Consider the following, with good hash function `hash( )`:

```
float hashSample = hash( myPosition );
```

- Gives noisy `hashSample` like RNG per sample, but stays fixed between frames

- Important caveat! Tiny camera or object motions change hash sample, as

$$\text{hash}(\text{myPosition}) \neq \text{hash}(\text{myPosition} + \Delta)$$

- So these give different random values → flicker under motion

What Does “Stability” Look Like?

Frame-to-frame diff

Unstable

Stable

Frame-to-frame diff

Achieving Hash Stability

- Key: Discretize hash inputs in appropriate coordinate frame
  - For small Δ:

```
hash( floor( myPosition ) ) = hash( floor( myPosition + Δ ) )
```

  - Tweaking this, allows us to control the *scale* of the stable noise, e.g.:

```
hash( floor( myPosition / scale ) * scale )
```

What Does A Hash Scale Look Like?

Key: Coordinate Choice For Hash Input

- Need to discretize in appropriate coordinates

- Same geometry should yield same hash, under:
  - Camera translation or rotation
  - Object translation or rotation
  - Ideally object skinning and deformation

Key: Coordinate Choice For Hash Input

	Are hash outputs fixed under…					
	Camera Translate	Camera Rotate	Object Translate	Object Rotate	Object Skinning	Object Deform
Screen-Space Coords	✓*	✗	✗	✗	✗	✗
Eye-Space Coords	✓*	✗	✗	✗	✗	✗
Norm. Device Coords	✓*	✗	✗	✗	✗	✗
Texture-Space Coords	✓	✓	✓	✓	✓	?
World-Space Coords	✓	✓	✗	✗	✗	✗
Object-Space Coords	✓	✓	✓	✓	✓	?

? ’s work for deformation (and skinning) assuming hashing of pre-deformed coordinates

* = being somewhat generous

Key: Coordinate Choice For Hash Input

	Are hash outputs fixed under…					
	Camera Translate	Camera Rotate	Object Translate	Object Rotate	Object Skinning	Object Deform
Screen-Space Coords	✓*	✗	✗	✗	✗	✗
Eye-Space Coords	✓*	✗	✗	✗	✗	✗
Norm. Device Coords	✓*	✗	✗	✗	✗	✗
Texture-Space Coords	✓	✓	✓	✓	✓	?
World-Space Coords	✓	✓	✗	✗	✗	✗
Object-Space Coords	✓	✓	✓	✓	✓	?

Clear choices:

? ’s work for deformation (and skinning) assuming hashing of pre-deformed coordinates

* = being somewhat generous

Key: Coordinate Choice For Hash Input

	Are hash outputs fixed under…					
	Camera Translate	Camera Rotate	Object Translate	Object Rotate	Object Skinning	Object Deform
Screen-Space Coords	✓*	✗	✗	✗	✗	✗
Eye-Space Coords	✓*	✗	✗	✗	✗	✗
Norm. Device Coords	✓*	✗	✗	✗	✗	✗
Texture-Space Coords	✓	✓	✓	✓	✓	?
World-Space Coords	✓	✓	✗	✗	✗	✗
Object-Space Coords	✓	✓	✓	✓	✓	?

We selected object coordinates; can discuss why, offline

? ’s work for deformation (and skinning) assuming hashing of pre-deformed coordinates

* = being somewhat generous

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

Compute ideal scale to get 1-pixel sized noise

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

Compute ideal scale to get 1-pixel sized noise

Use 2 scales, one smaller & one larger than desired scale; akin to mipmapping

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float α_τ = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids α_τ == 0.  Could also do α_τ=1-α_τ
α_τ = clamp( α_τ, 1.0e-6, 1.0 );
```

Compute ideal scale to get 1-pixel sized noise

Use 2 scales, one smaller & one larger than desired scale; akin to mipmapping

Compute hashed noise samples at 2 discrete scales

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

Compute ideal scale to get 1-pixel sized noise

Use 2 scales, one smaller & one larger than desired scale; akin to mipmapping

Compute hashed noise samples at 2 discrete scales

Linearly interpolate between noise scales

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

Compute ideal scale to get 1-pixel sized noise

Use 2 scales, one smaller & one larger than desired scale; akin to mipmapping

Compute hashed noise samples at 2 discrete scales

Linearly interpolate between noise scales

Interpolating between two uniform distributions does not give a new uniform distribution

This math corrects for this non-uniformity

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

Compute ideal scale to get 1-pixel sized noise

Use 2 scales, one smaller & one larger than desired scale; akin to mipmapping

Compute hashed noise samples at 2 discrete scales

Linearly interpolate between noise scales

Interpolating between two uniform distributions does not give a new uniform distribution

This math corrects for this non-uniformity

Clamp; alpha threshold of 0 makes no sense

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
               ((x < a) ? cases.x : cases.y) :
               cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

Specific hash not important, if uniform and takes $\mathbb{R}^3 \rightarrow [0\ldots1)$

We use:

```
float hash( vec2 in ) {
   return fract( 1.0e4 * sin( 17.0*in.x + 0.1*in.y ) *
                 ( 0.1 + abs( sin( 13.0*in.y + in.x ))
               );
}

float hash3D( vec3 in ) {
   return hash( vec2( hash( in.xy ), in.z ) );
}
```

Hashed Alpha Test Code

```
// Find the discretized derivatives of our coordinates
float maxDeriv = max( length(dFdx(objCoord.xyz)),
                      length(dFdy(objCoord.xyz)) );
float pixScale = 1.0/(g_HashScale*maxDeriv);

// Find two nearest log-discretized noise scales
vec2 pixScales = vec2( exp2(floor(log2(pixScale))),
                       exp2(ceil(log2(pixScale))) );

// Compute alpha thresholds at our two noise scales
vec2 alpha=vec2(hash3D(floor(pixScales.x*objCoord.xyz)),
                hash3D(floor(pixScales.y*objCoord.xyz)));

// Factor to interpolate lerp with
float lerpFactor = fract( log2(pixScale) );

// Interpolate alpha threshold from noise at two scales
float x = (1-lerpFactor)*alpha.x + lerpFactor*alpha.y;

// Pass into CDF to compute uniformly distrib threshold
float a = min( lerpFactor, 1-lerpFactor );
vec3 cases = vec3( x*x/(2*a*(1-a)),
                   (x-0.5*a)/(1-a),
                   1.0-((1-x)*(1-x)/(2*a*(1-a))) );

// Find our final, uniformly distributed alpha threshold
float αT = (x < (1-a)) ?
                ((x < a) ? cases.x : cases.y) :
                cases.z;

// Avoids αT == 0.  Could also do αT=1-αT
αT = clamp( αT, 1.0e-6, 1.0 );
```

User parameter to control size of noise:

1.0 = roughly pixel sized noise

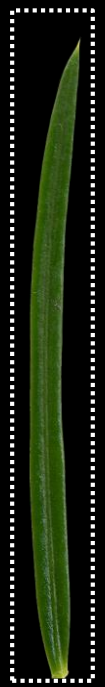
2.0 = roughly 2x2 pixel sized noise

Results

Alpha test $\alpha_t = 0.5$

Hashed alpha test

Ground truth OIT



0.06 ms @ 1024^2

0.08 ms @ 1024^2

1.3 ms @ 1024^2

Performances not optimized; only demonstrative of relative costs

Results

Adjust alpha [Castaño 2010]

0.06 ms @ 1024^2

Hashed alpha test

0.08 ms @ 1024^2

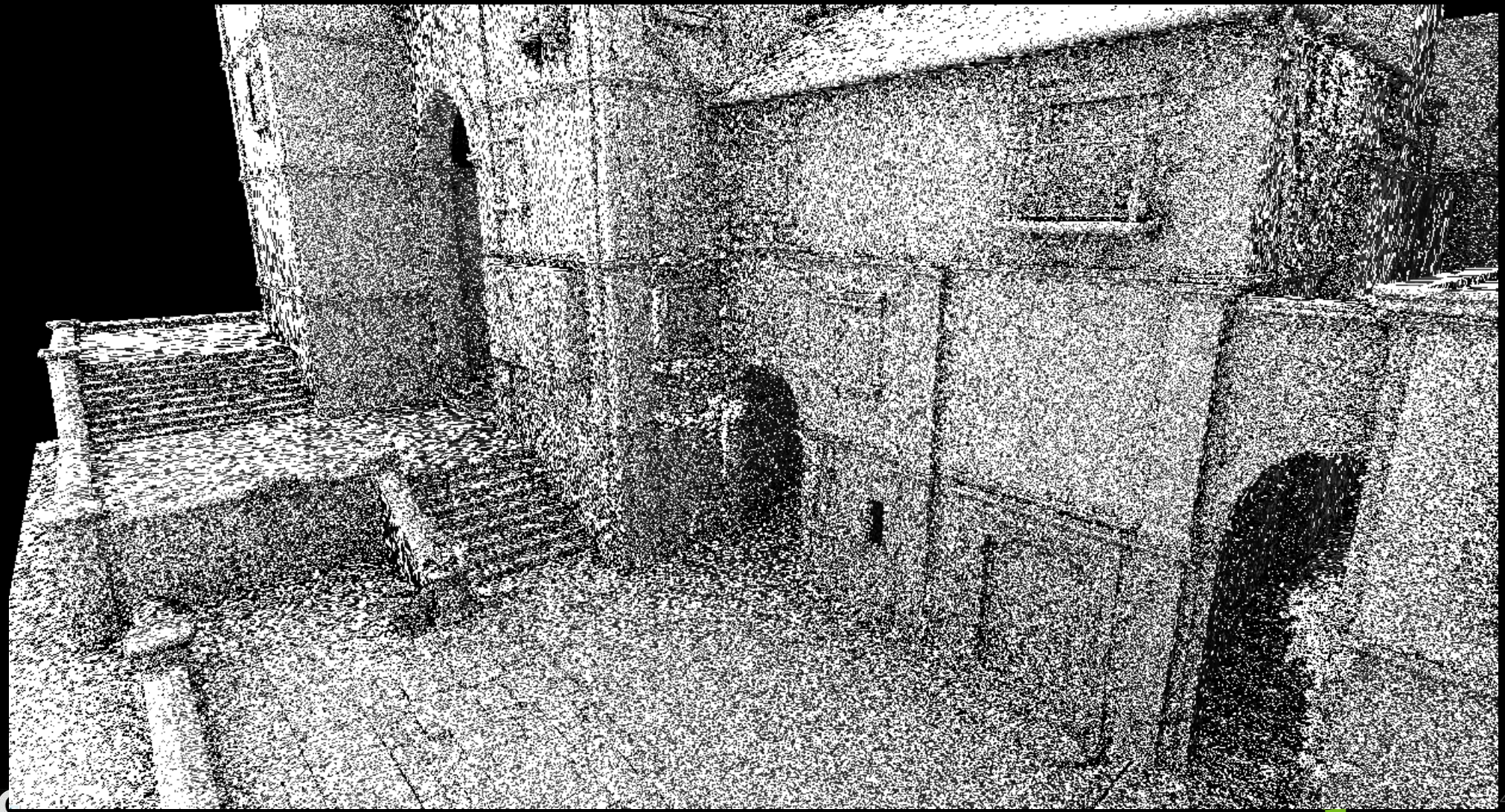
Ground truth OIT

1.3 ms @ 1024^2

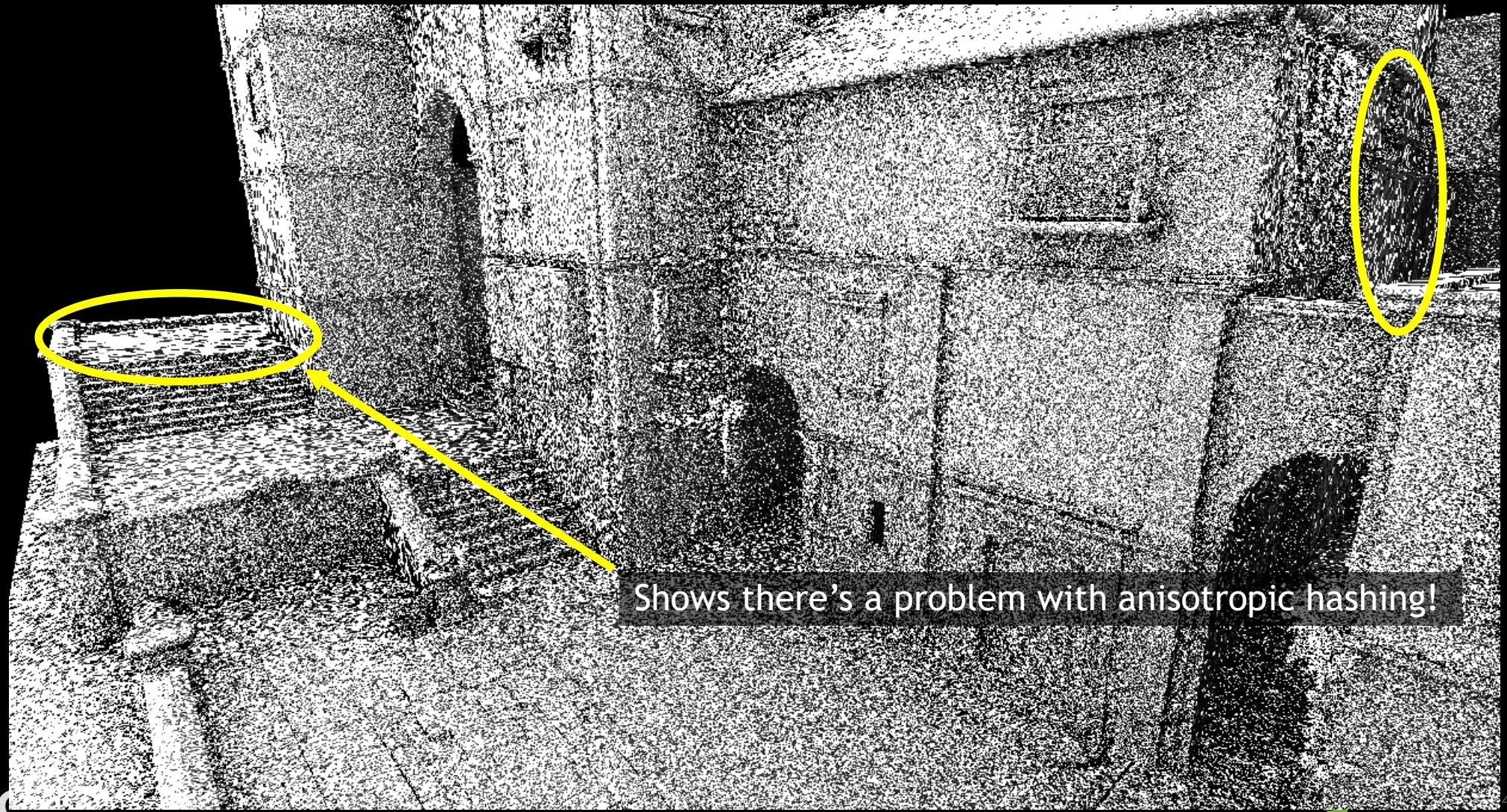
Performances not optimized; only demonstrative of relative costs

But Not Just Alpha!

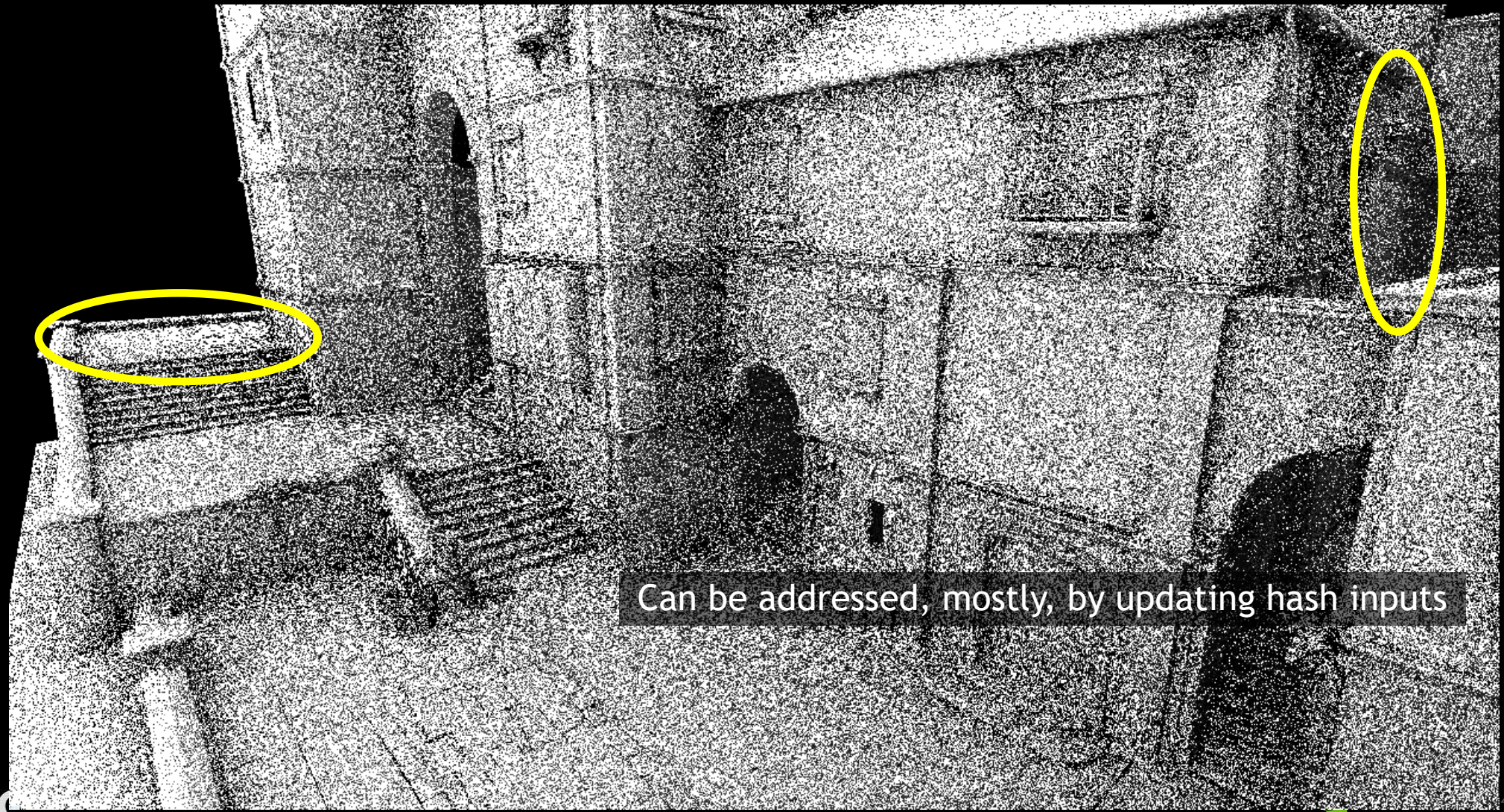
Hashed Sampling Has Other Uses



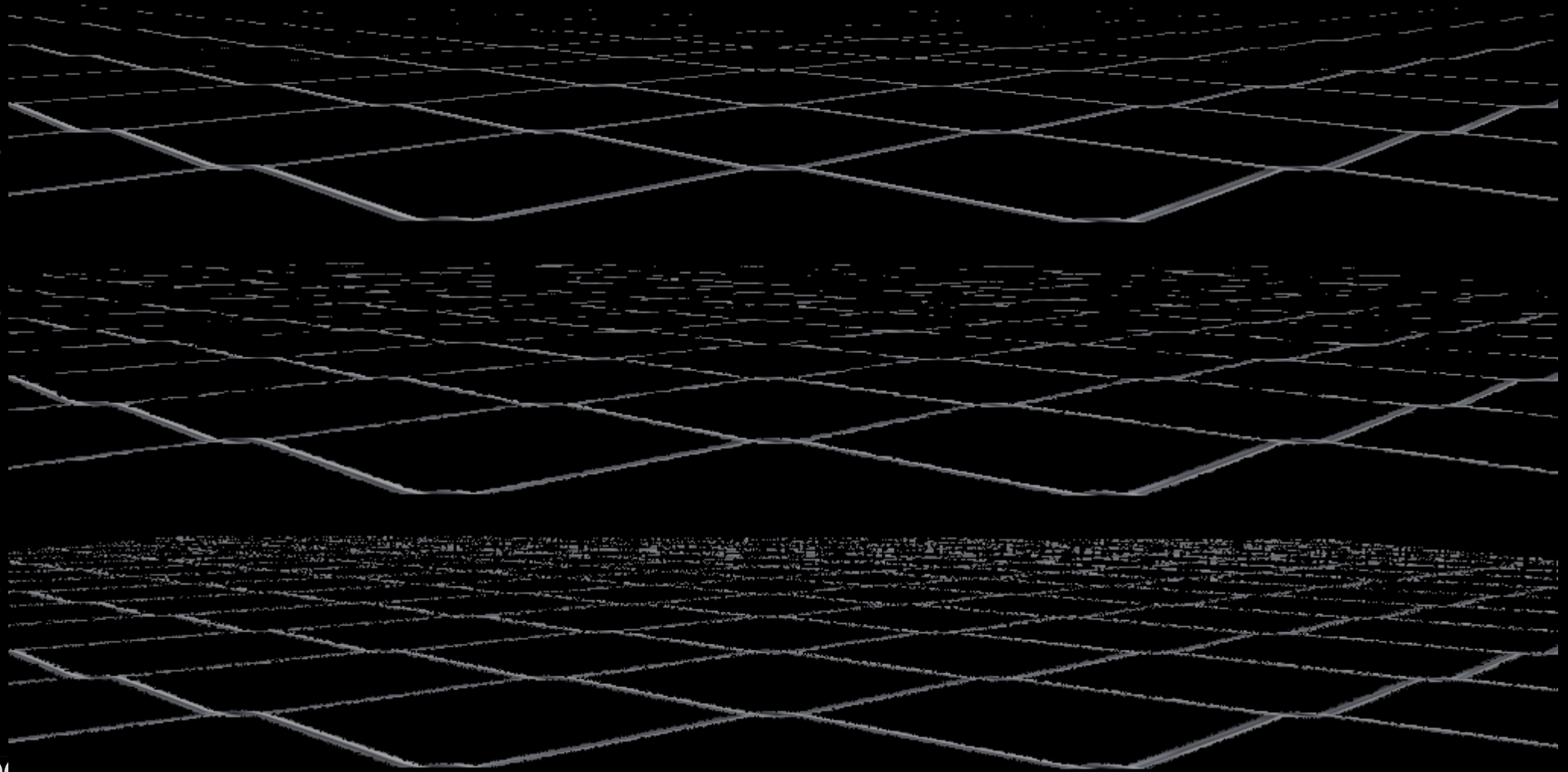
Hashed Sampling Has Other Uses



Hashed Sampling Has Other Uses



Hashing At Grazing Angles

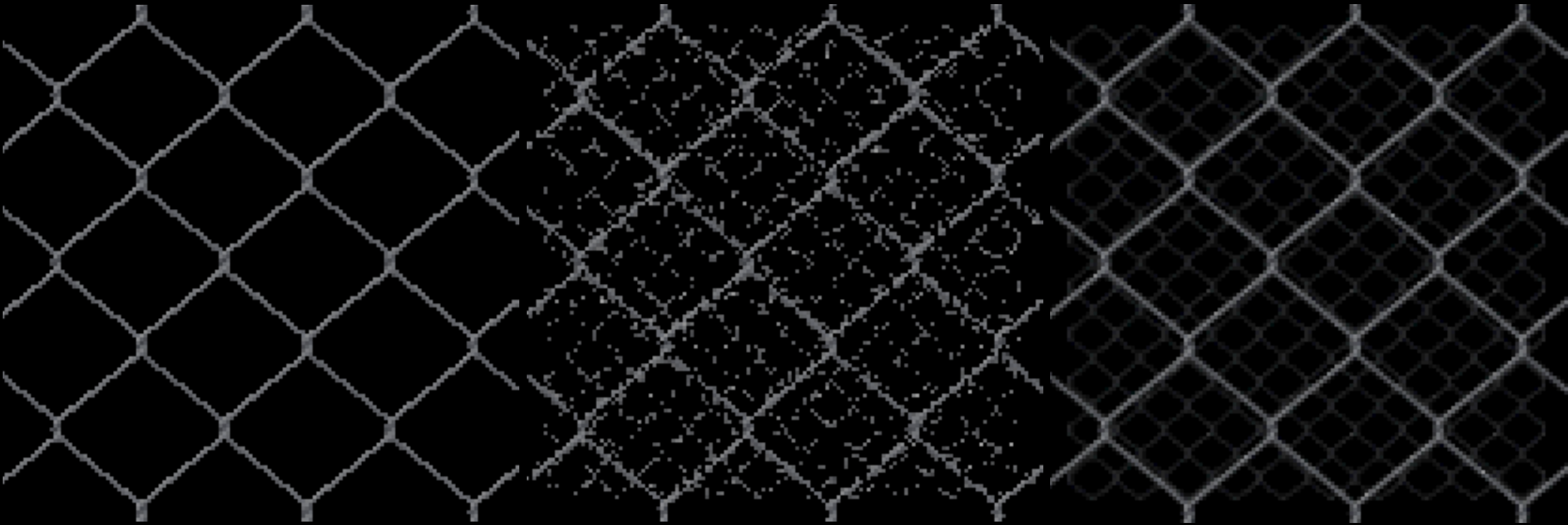


Results

Alpha test $\alpha_t = 0.5$

Hashed alpha test

Ground truth OIT

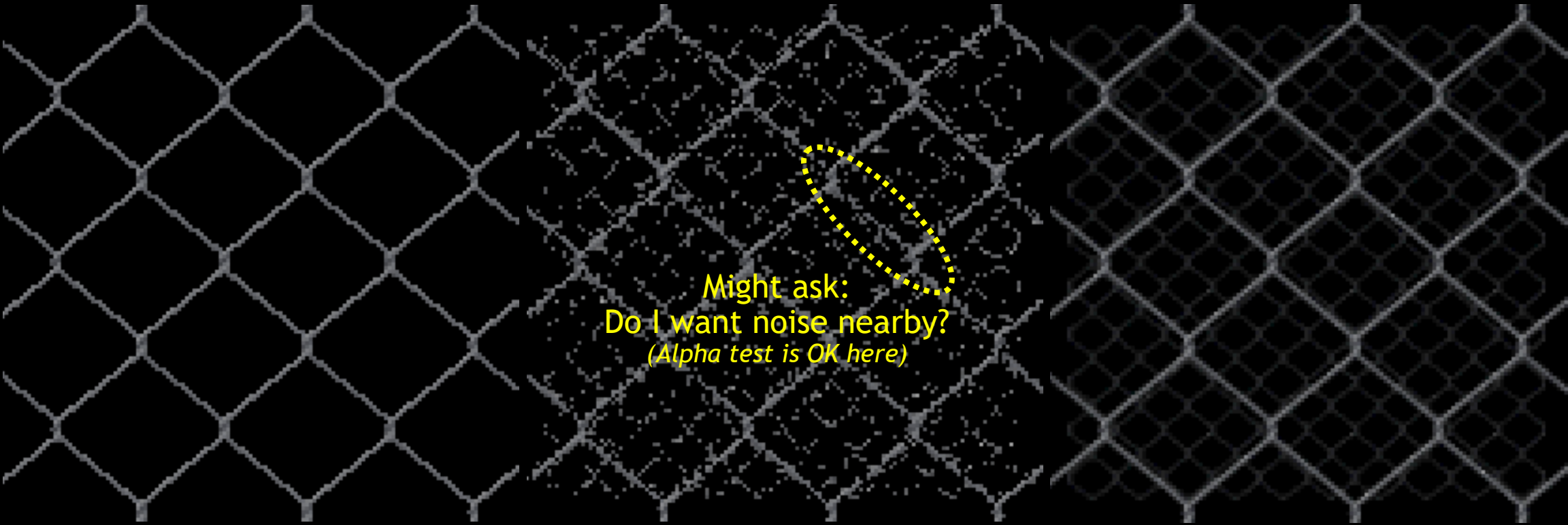


Results

Alpha test $\alpha_t = 0.5$

Hashed alpha test

Ground truth OIT

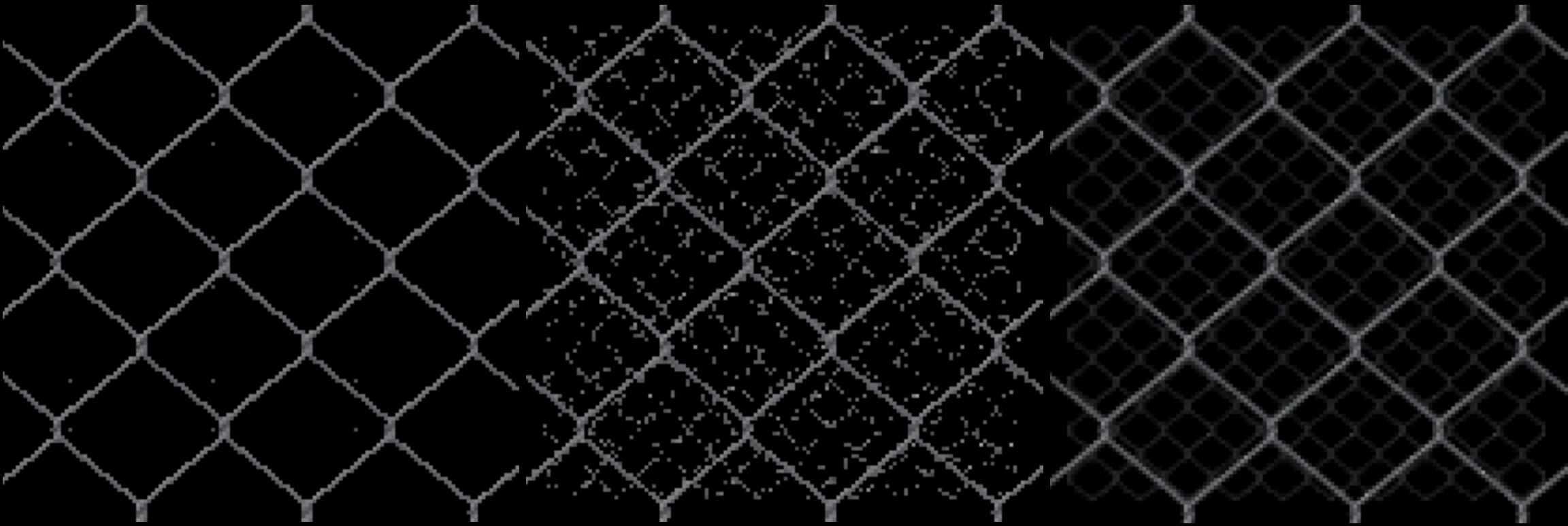


Results

Adjust alpha [Castaño 2010]

Hashed alpha test
(Faded in with LOD)

Ground truth OIT

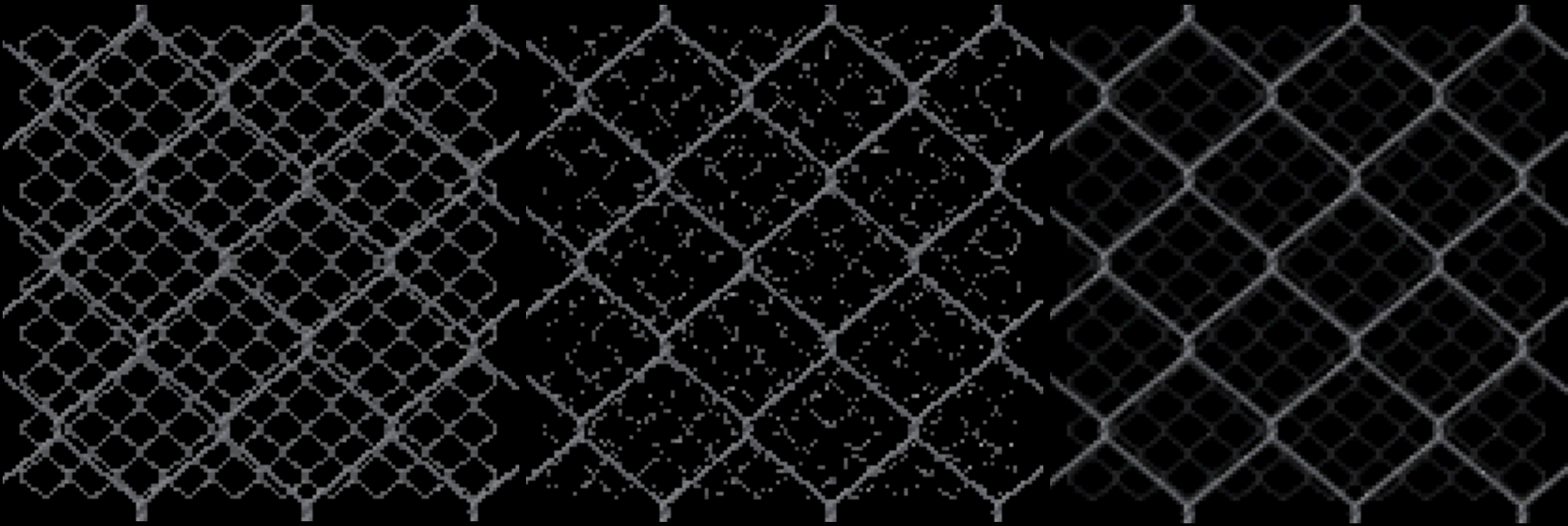


Results

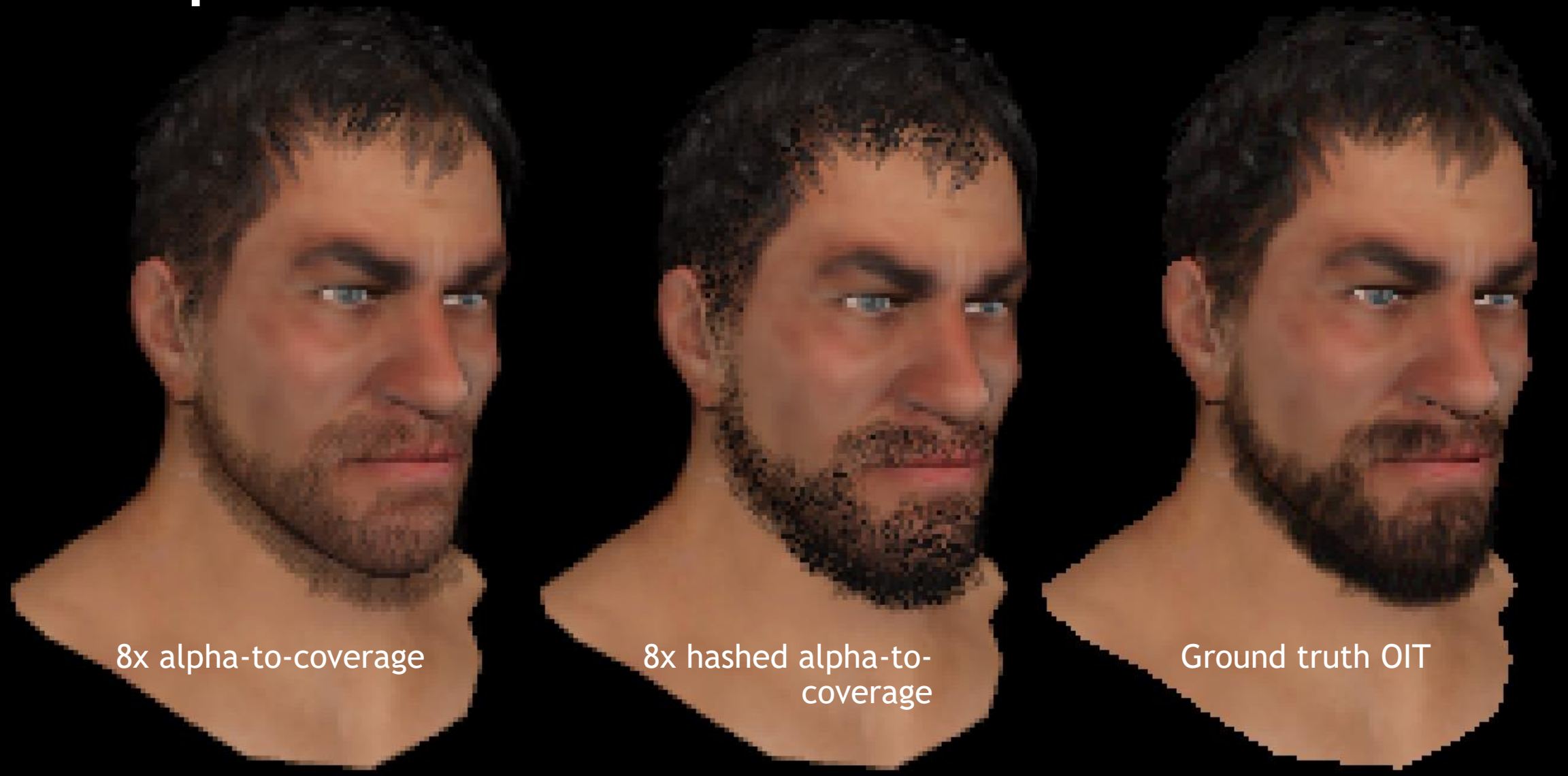
Per-LOD threshold adjust
(Manual, “artist” driven)

Hashed alpha test
(Faded in with LOD)

Ground truth OIT



Helps With MSAA and A2C



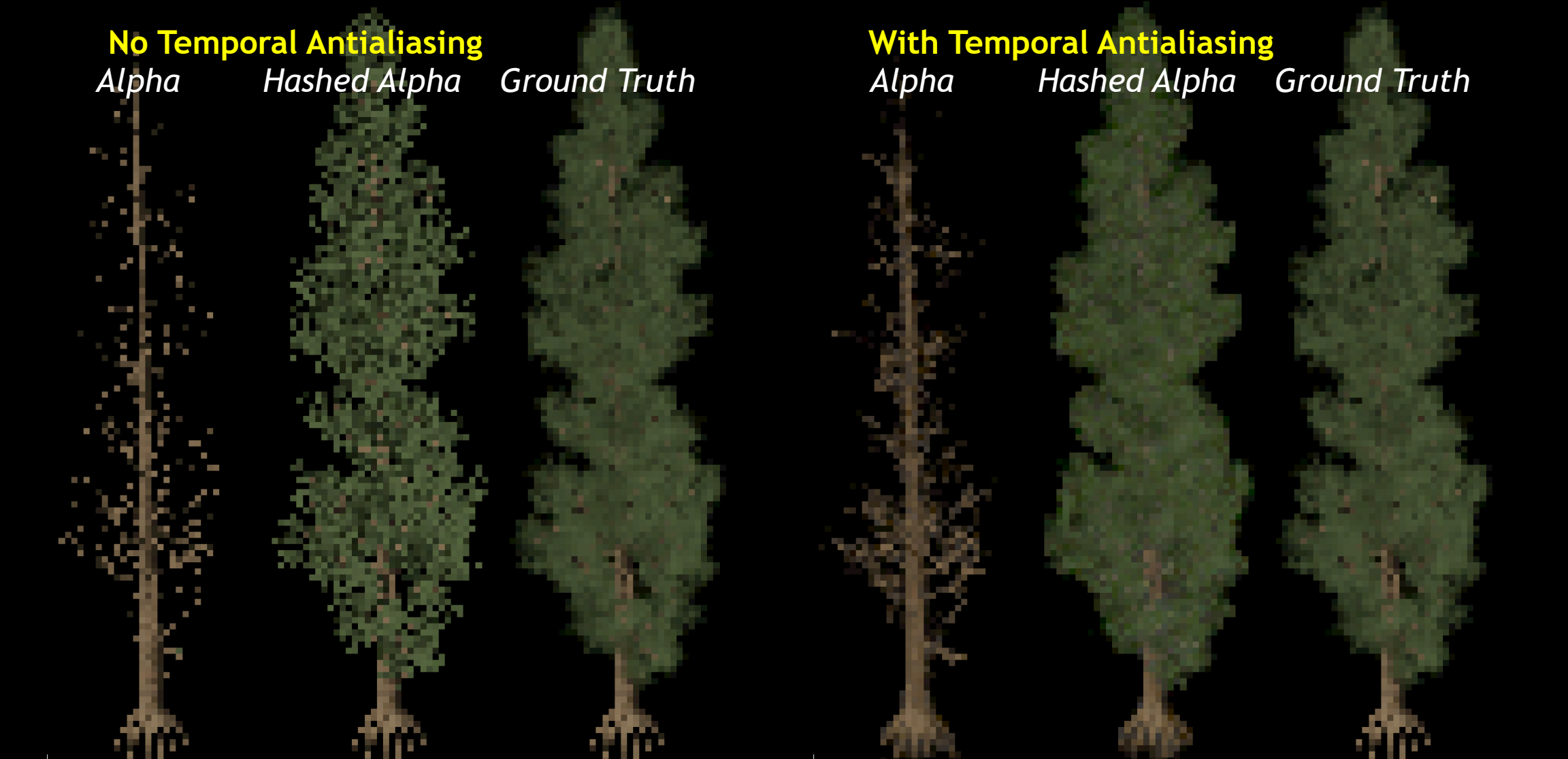
Temporal Antialiasing

No Temporal Antialiasing

Alpha *Hashed Alpha* *Ground Truth*

With Temporal Antialiasing

Alpha *Hashed Alpha* *Ground Truth*



Temporal Antialiasing

- Might think, “based on stochastic sampling; of course TAA works well!”
  - But hashed alpha designed for *stability* under tiny camera motions, e.g. TAA jitter

Temporal Antialiasing

- Might think, “based on stochastic sampling; of course TAA works well!”
  - But hashed alpha designed for *stability* under tiny camera motions, e.g. TAA jitter
- A couple approaches:
  - Reduce global noise scale to < 1 pixel
    - TAA integrates sub pixel noise samples
  - Jitter offset in hash space;
    - Hash on objPos+offset[i] rather than objPos for relatively large, uncorrelated offset[i]
  - Jitter the alpha threshold
    - Compute α_T = hash(objPos), use thresholds fract(α_T + i/N) for i in [0…N)

Summary

- Introduce new approach for alpha testing:
  - Alpha threshold cheaply & procedurally selected via a hash function
  - Gives stable noise; roughly as stable as traditional alpha test

Summary

- Introduce new approach for alpha testing:
  - Alpha threshold cheaply & procedurally selected via a hash function
  - Gives stable noise; roughly as stable as traditional alpha test
- Still use one alpha test per pixel, allowing:
  - Use in both deferred and forward pipelines
  - Run on older hardware; no new (or recent) features required

Summary

- Introduce new approach for alpha testing:
  - Alpha threshold cheaply & procedurally selected via a hash function
  - Gives stable noise; roughly as stable as traditional alpha test
- Still use one alpha test per pixel, allowing:
  - Use in both deferred and forward pipelines
  - Run on older hardware; no new (or recent) features required
- Requires nothing in asset pipeline
  - Directly uses mip-chain's alpha channels representing pre-filtered visibility

For Questions:

Email: cwyman@nvidia.com *Twitter:* @_cwyman_

Paper: http://www.cwyman.org/papers/i3d17_hashedAlpha.pdf

Thanks!