Hashed Alpha Testing

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GDC 2017

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

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- But alpha-tested geom can disappear w / distance

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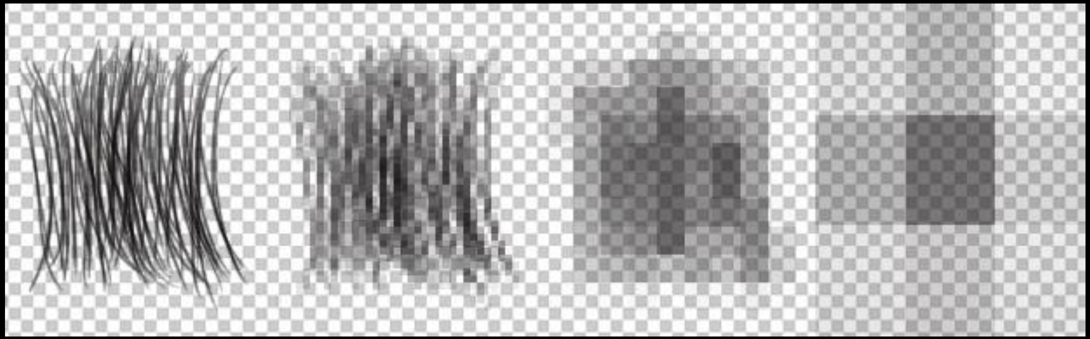
- But alpha-tested geom can disappear w / distance
  - Why? Cannot prefilter binary queries



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$$\textbf{if} \text{ (color.a } < \textit{drand48}() \text{) } \textbf{discard;}$$

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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;**

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What Does this Look Like?

Alpha Test

Hashed Alpha

Ground Truth

Talk Takeaways

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  - Converges to ground truth (OIT) with enough random samples

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- 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?

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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)

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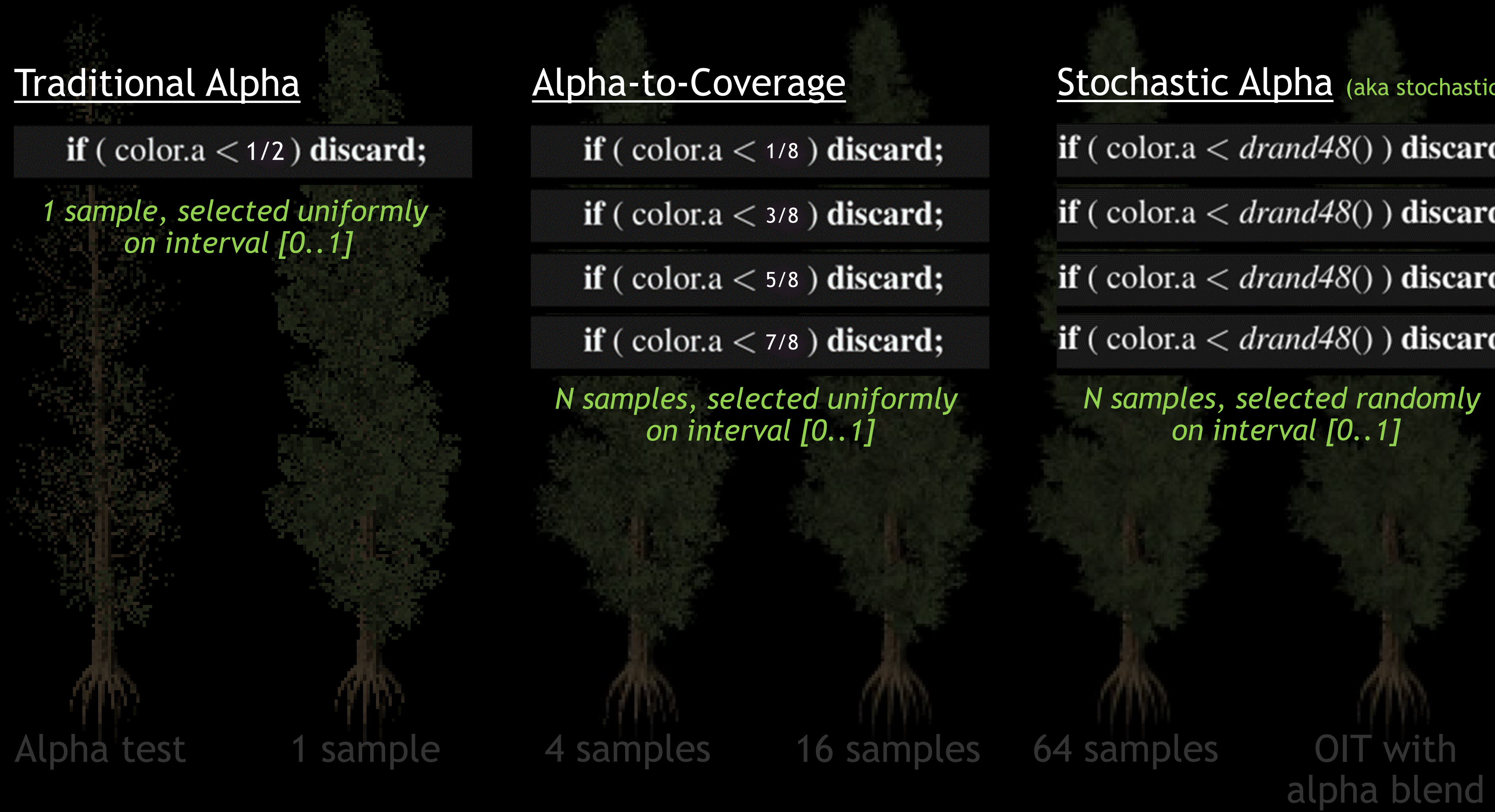

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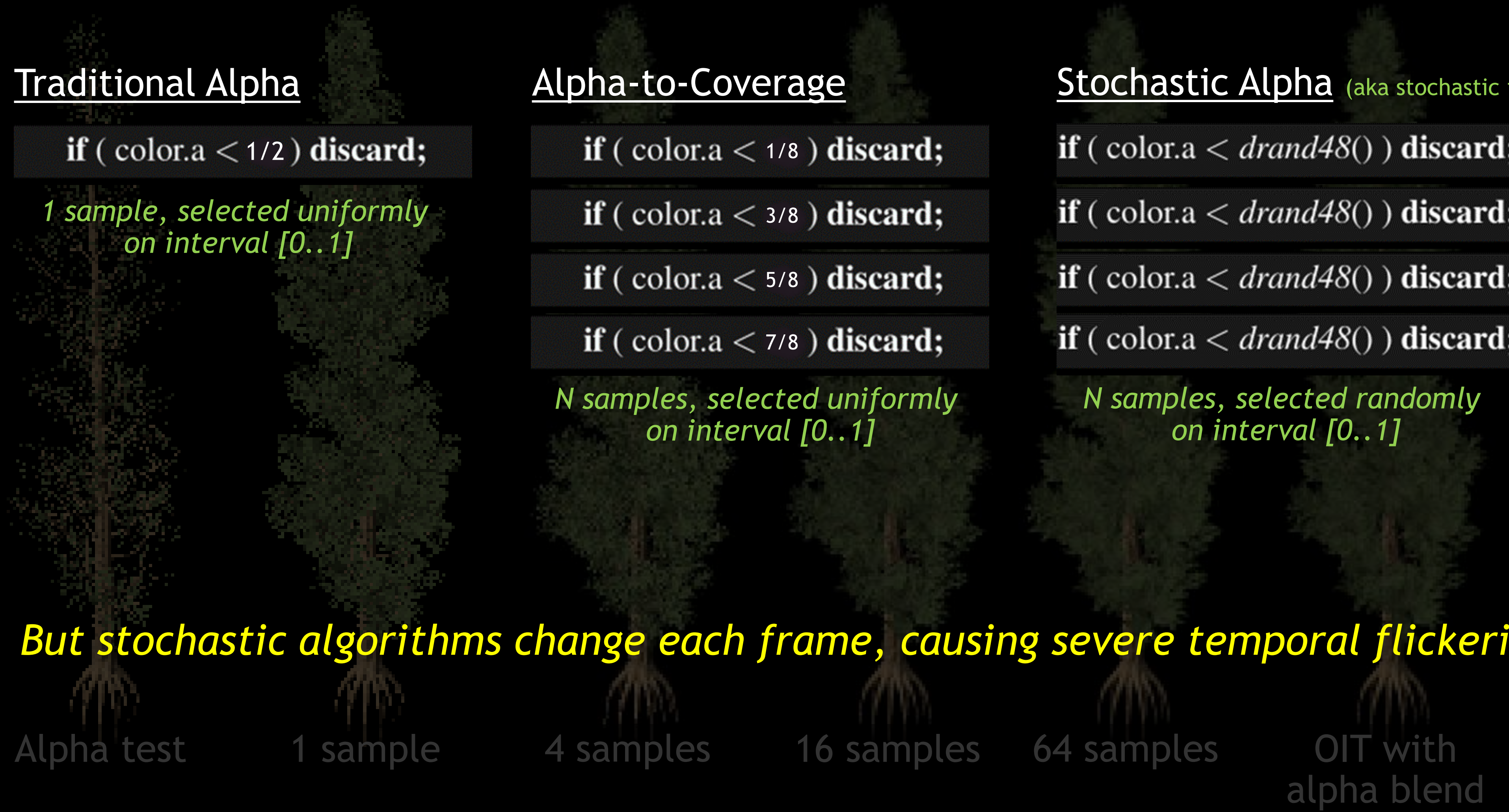
But stochastic algorithms change each frame, causing severe temporal flickering!



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  - See *“Numerical Recipes”* for an example PRNG using DES encryption

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

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

```
hash( myPosition ) ≠ hash( myPosition + Δ )
```

- 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?

1x1 pixel scale

3x3 pixel scale

9x9 pixel scale

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

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	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

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Clear choices:

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We selected object coordinates; can discuss why, offline

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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)),
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// Factor to interpolate lerp with
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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)),
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// Find our final, uniformly distributed alpha threshold
float ατ = (x < (1-a)) ?
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This math corrects for this non-uniformity

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Clamp; alpha threshold of 0 makes no sense

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```

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 ) );
}
```

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```

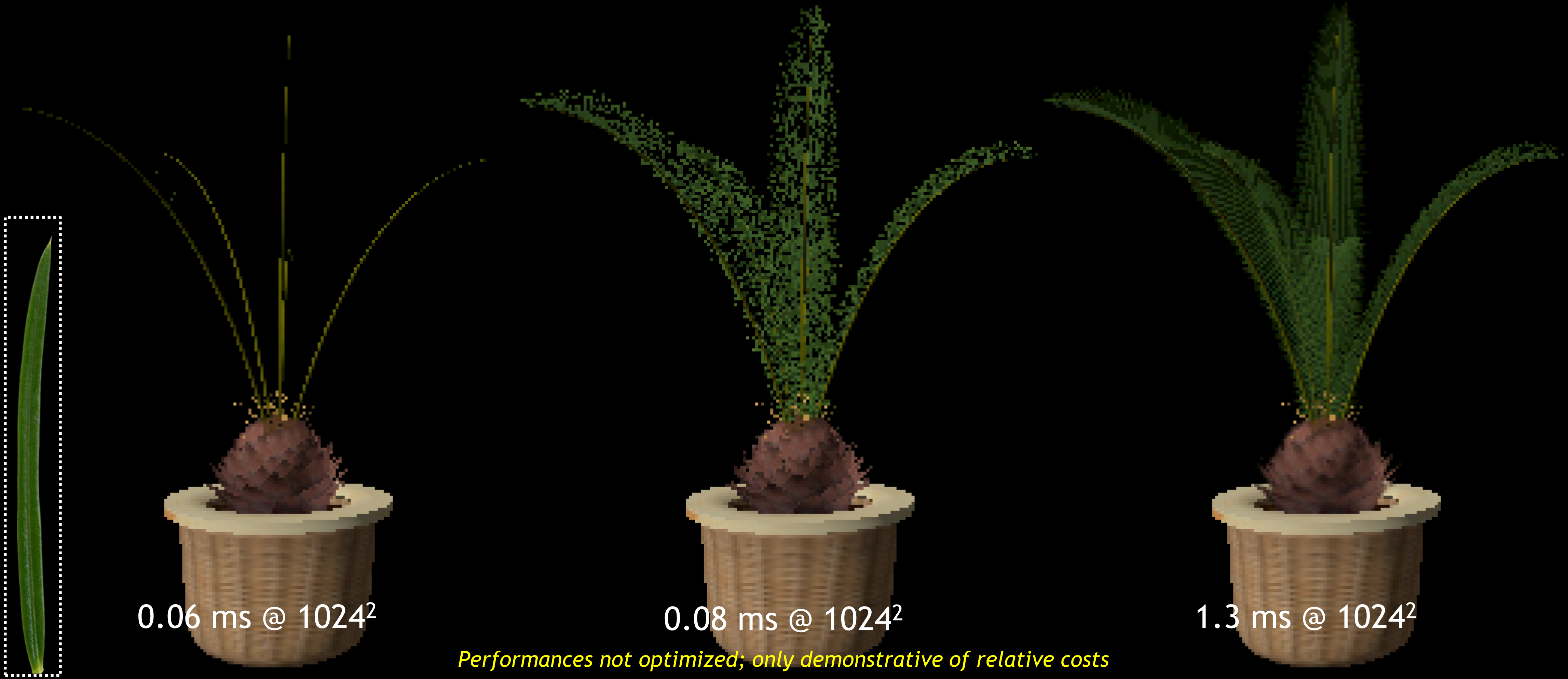
User parameter to control size of noise:

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



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

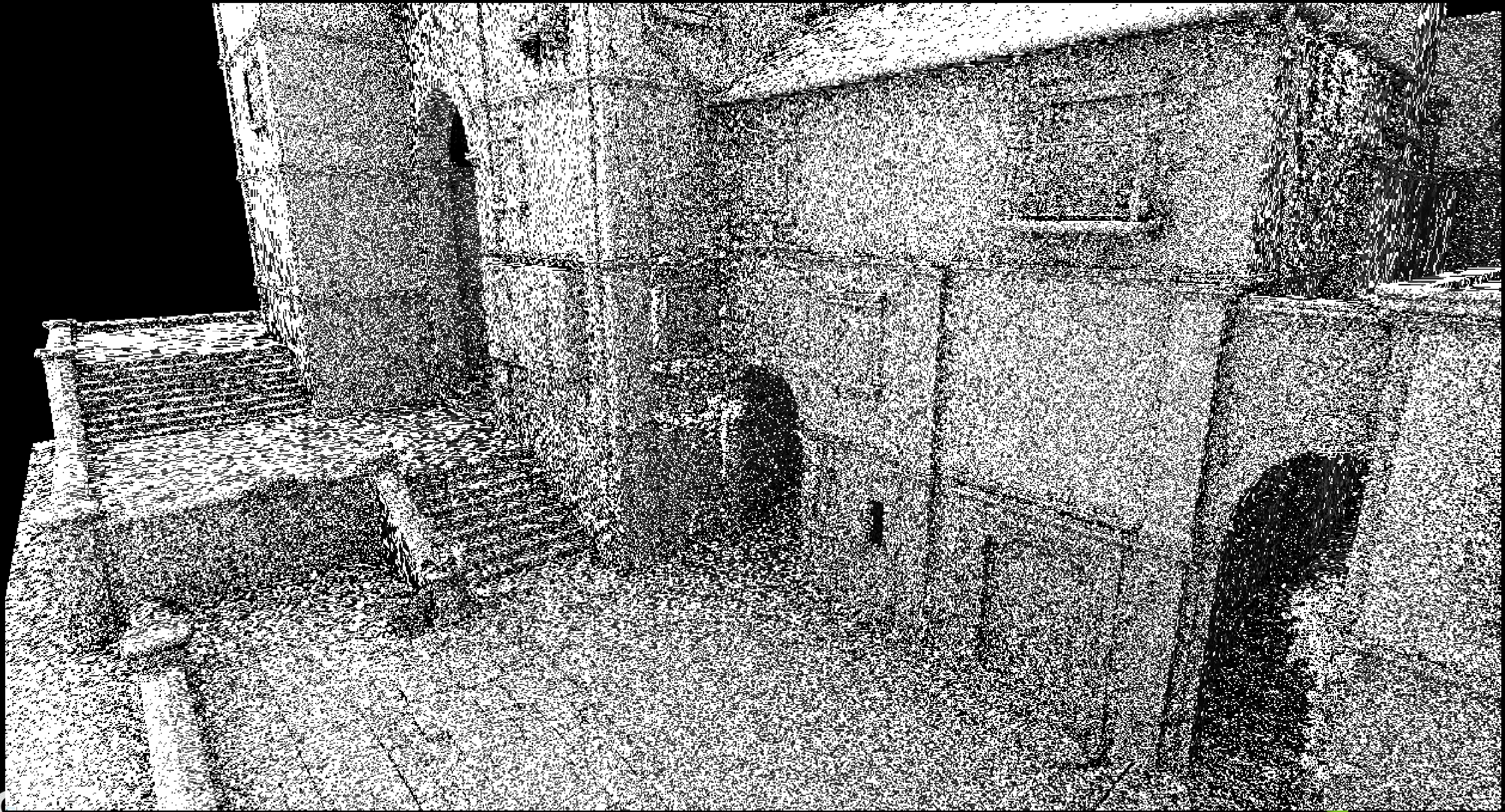
Ground truth OIT

1.3 ms @ 1024^2

Performances not optimized; only demonstrative of relative costs

But Not Just Alpha!

Hashed Sampling Has Other Uses



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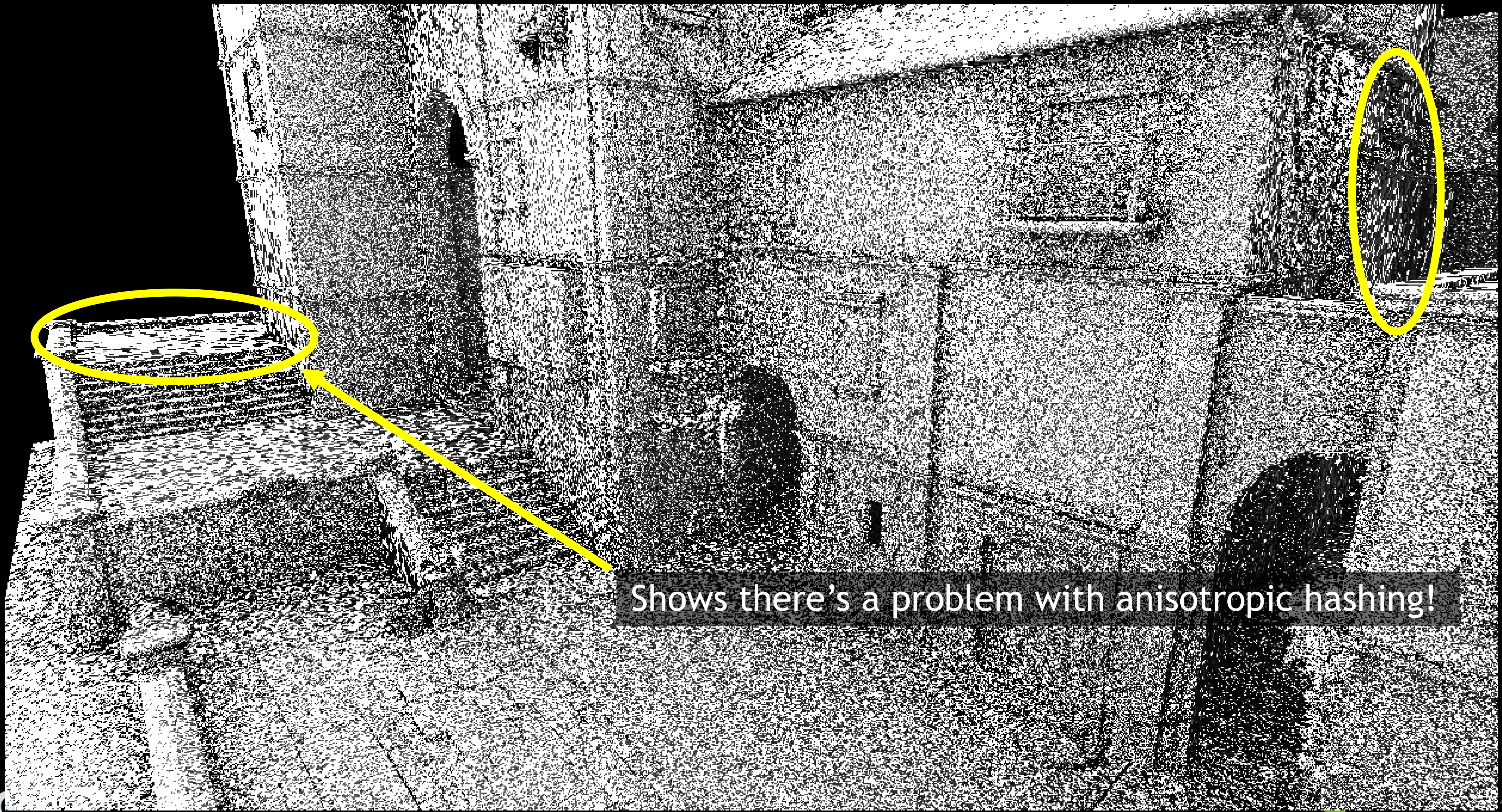

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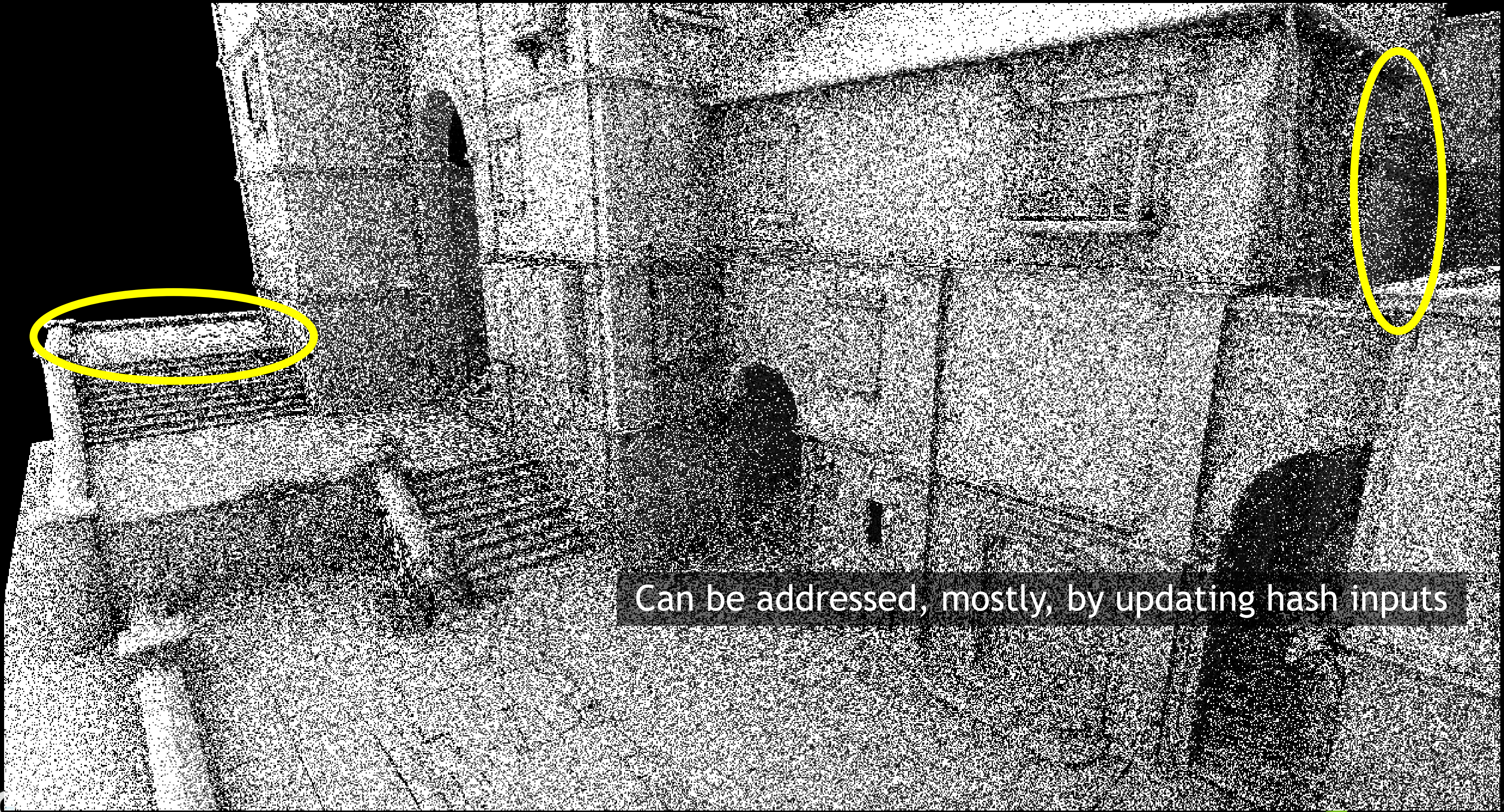
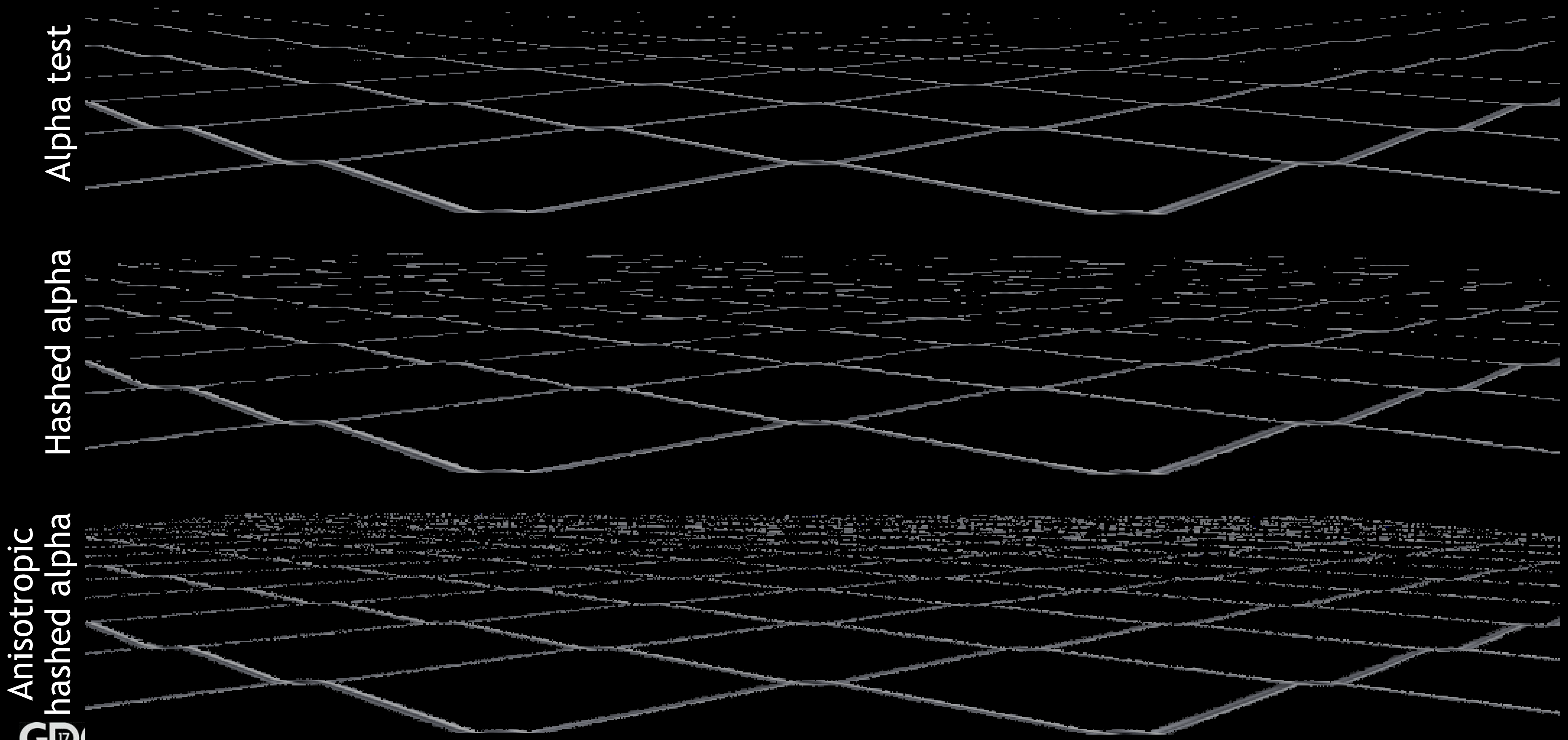


Hashing At Grazing Angles



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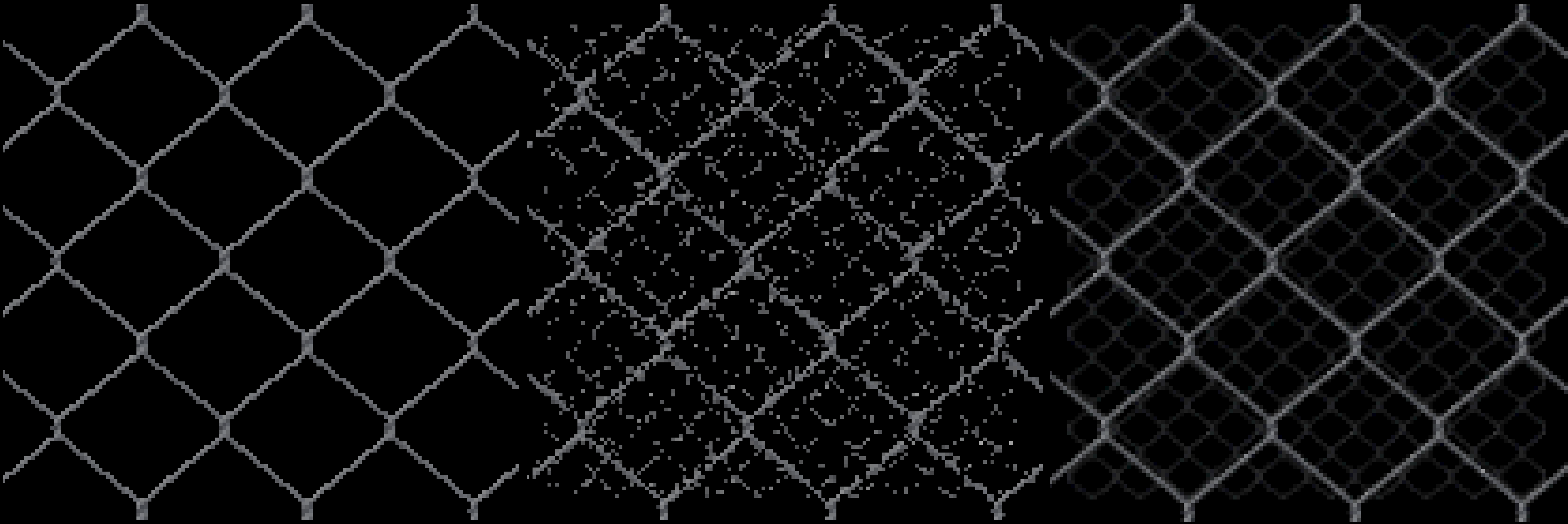
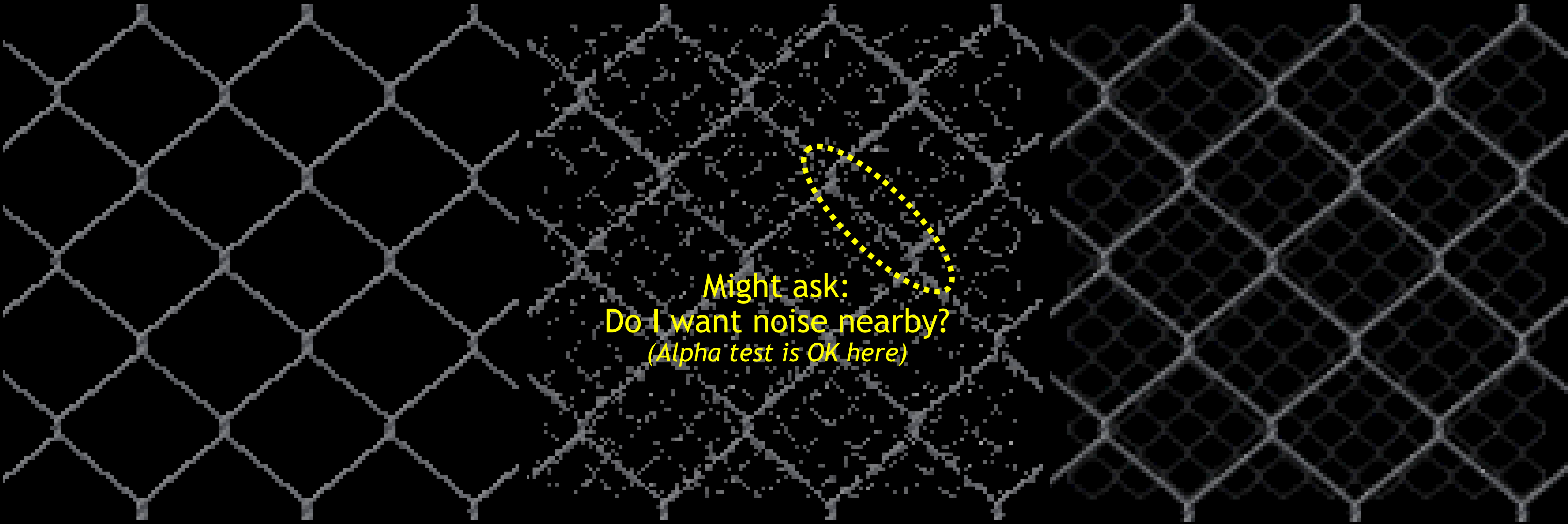


Results

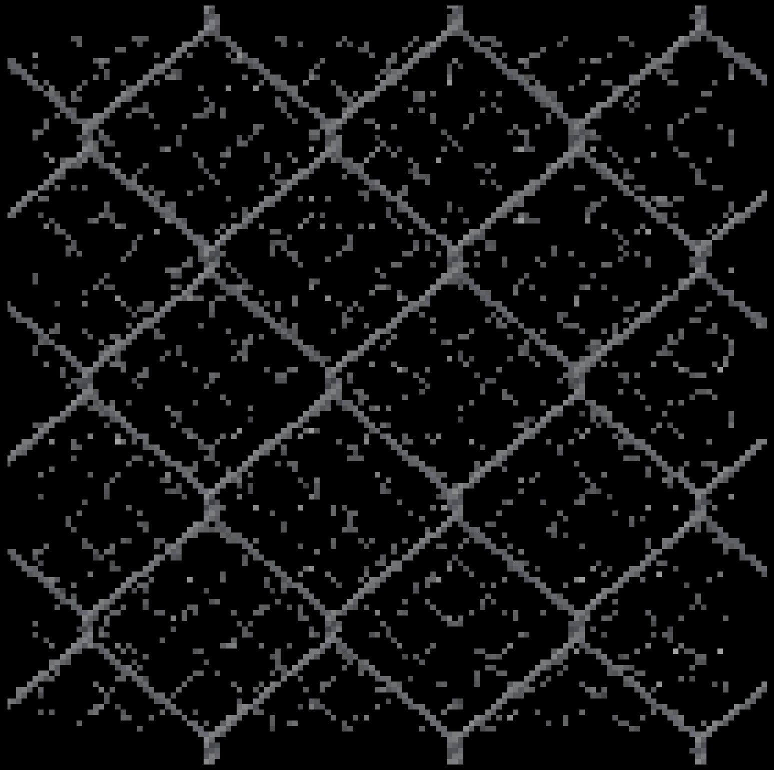
Alpha test α_t = 0.5 | Hashed alpha test | Ground truth OIT



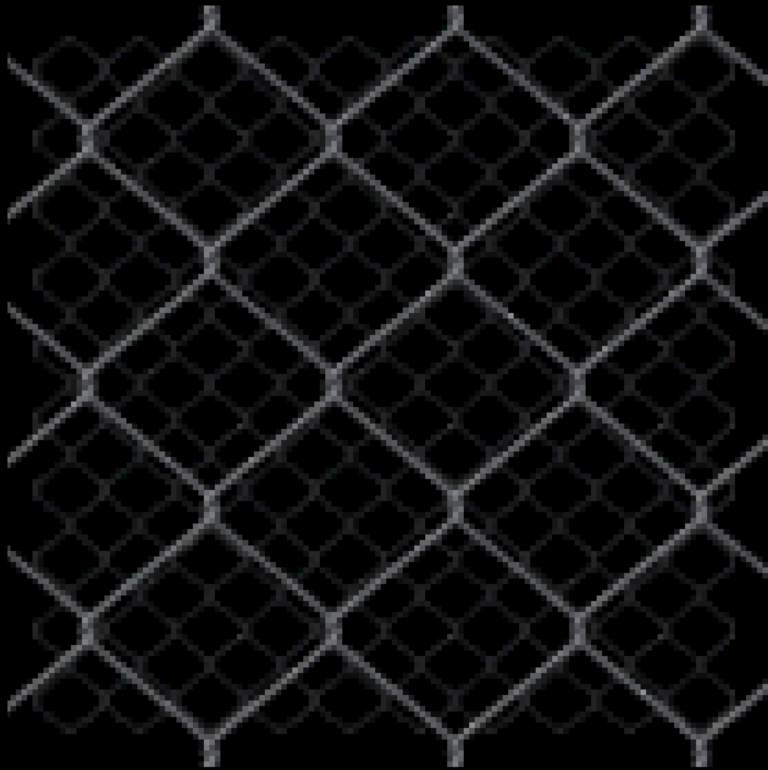
Results

Adjust alpha [Castaño 2010]

Hashed alpha test
(Faded in with LOD)



Ground truth OIT

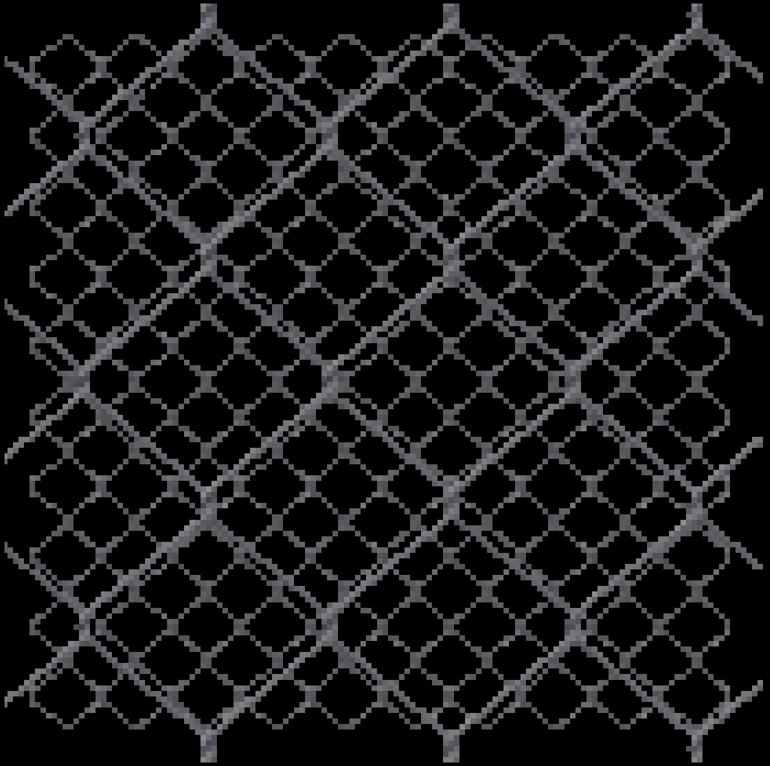


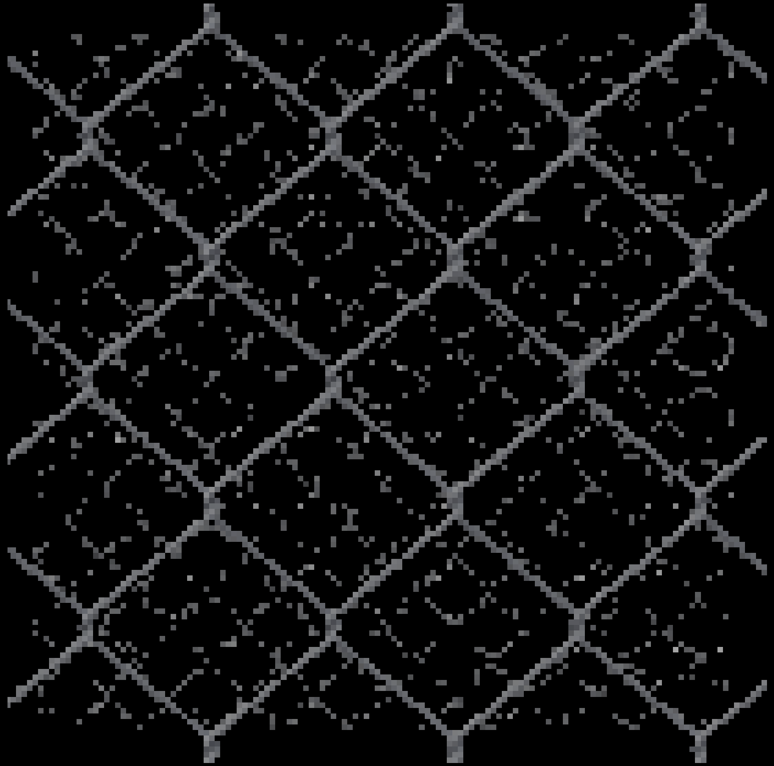
Results

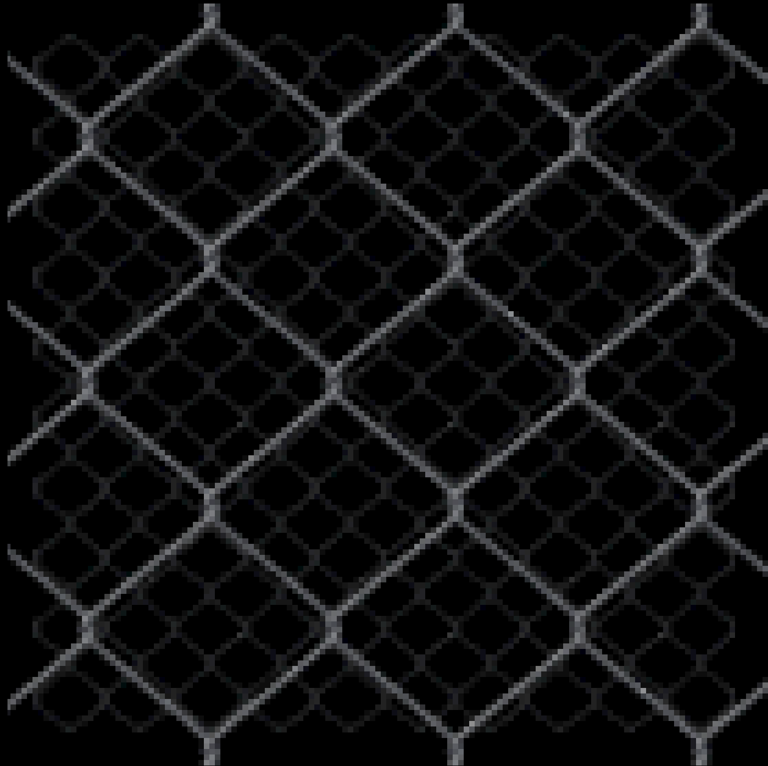
Per-LOD threshold adjust
(Manual, "artist" driven)

Hashed alpha test
(Faded in with LOD)

Ground truth OIT







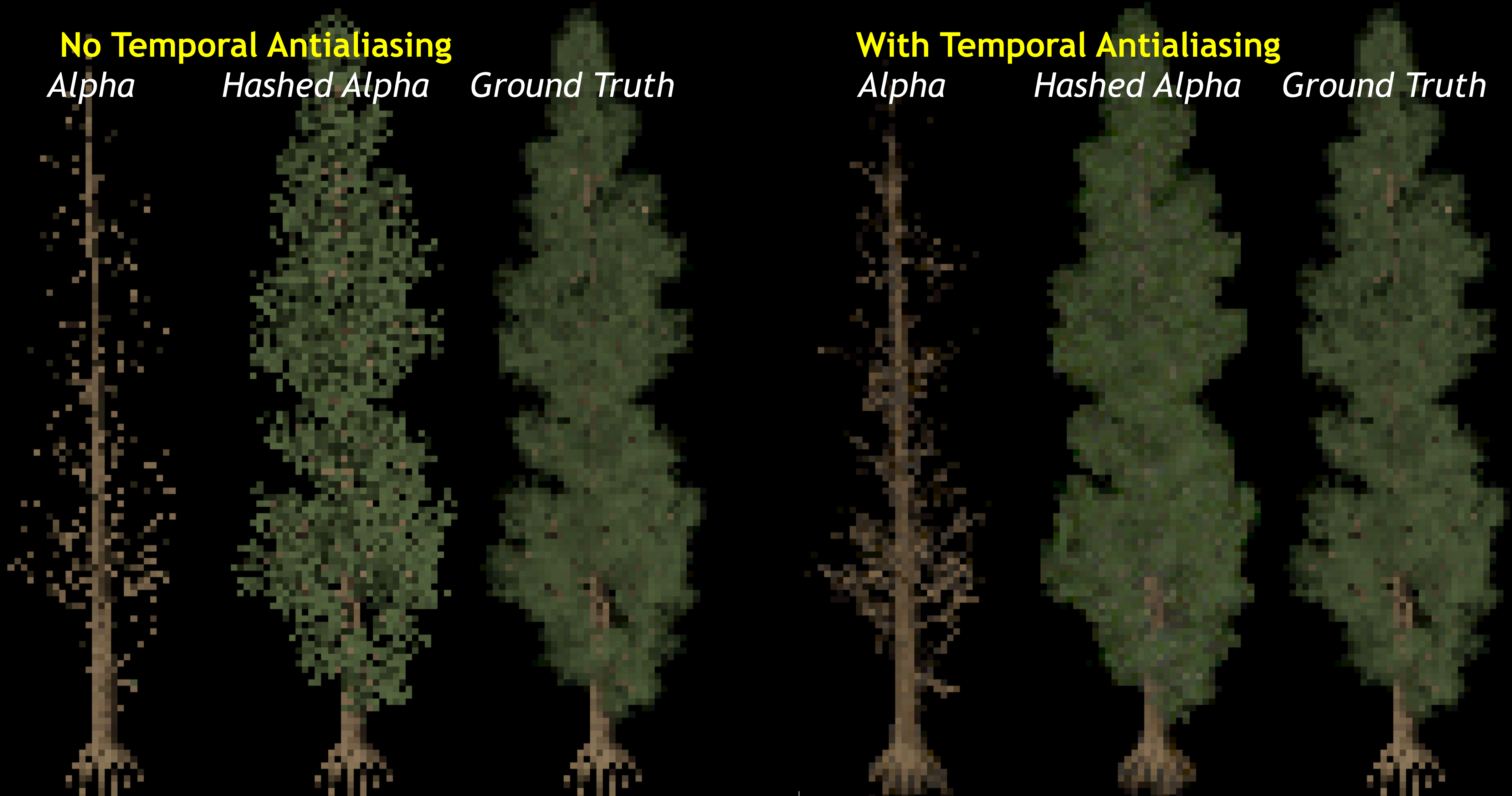
Helps With MSAA and A2C

8x alpha-to-coverage

8x hashed alpha-to-coverage

Ground truth OIT

Temporal Antialiasing



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

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- 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:
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- 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:

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

Thanks!