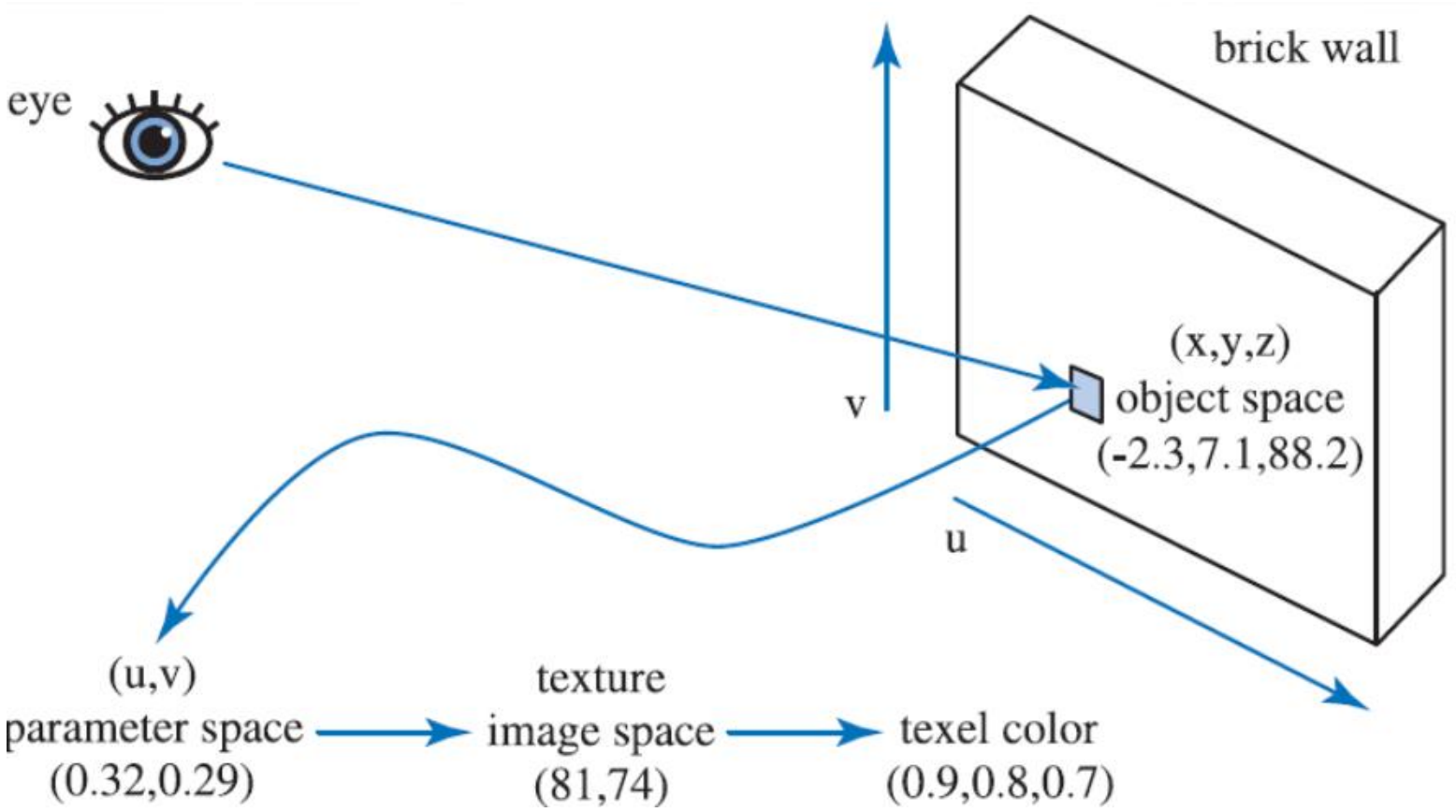
Advanced Shading II: Procedural Texture and Noise

Recall: Texture Mapping



Procedural Texture

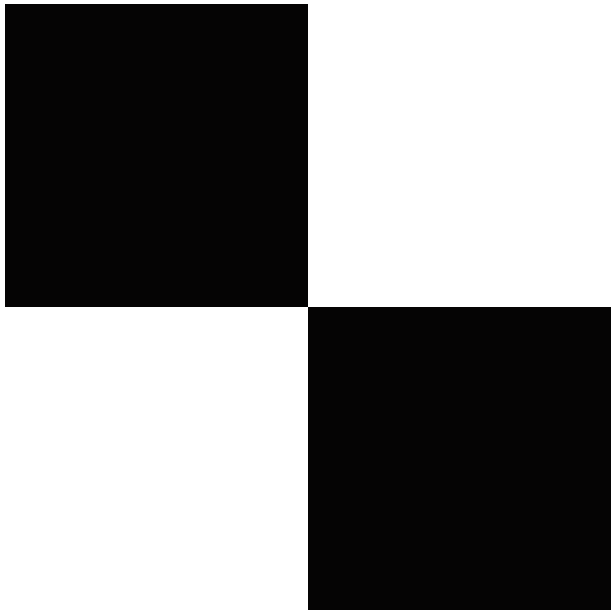
Main idea: determine color at (u,v) using **mathematical function**

Procedural Texture

Main idea: determine color at (u,v) using **mathematical function**

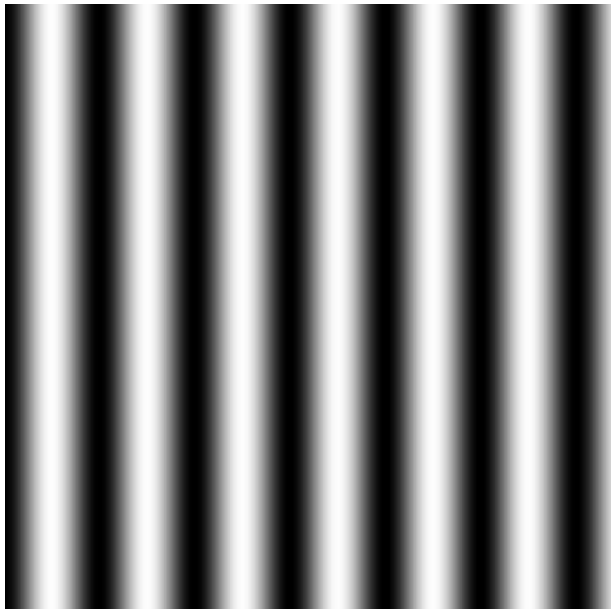
- no need for art assets
- computed on the fly: no memory cost
- can generate infinite amounts of data

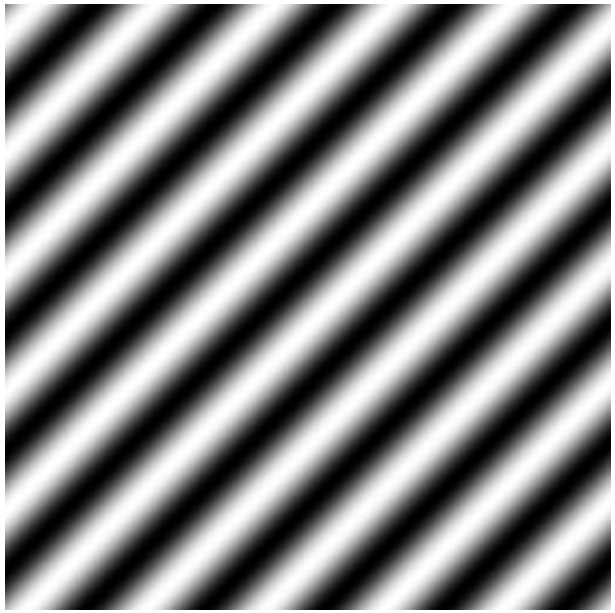
Checkerboard



$$I(u,v) = (\lfloor 2u \rfloor + \lfloor 2v \rfloor) \mod 2$$

Stripes





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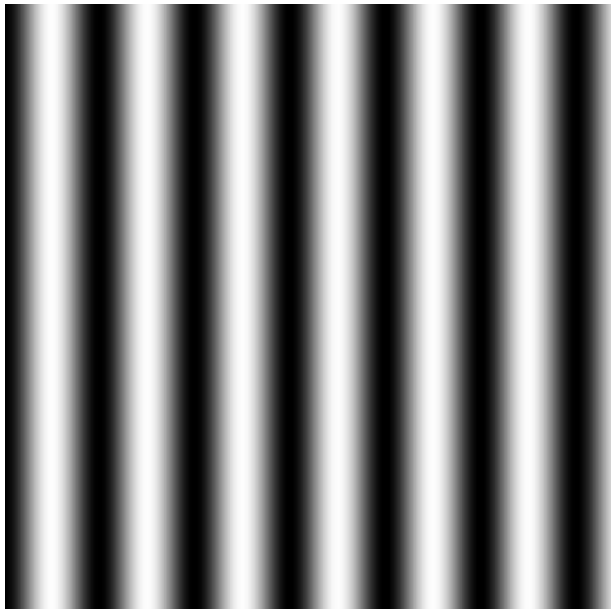
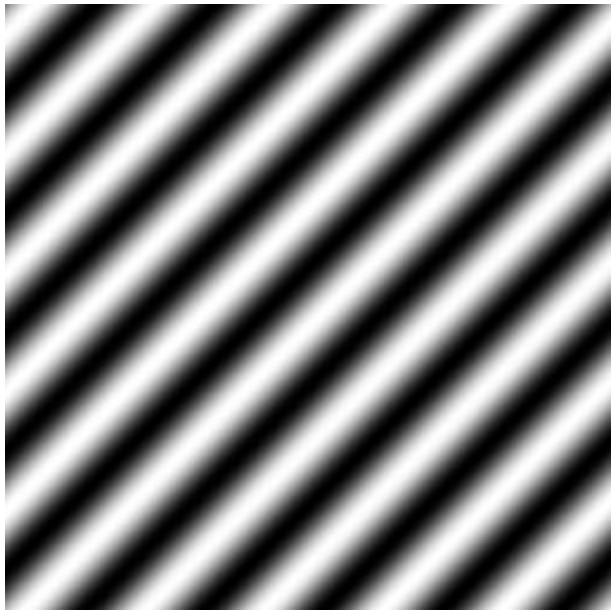
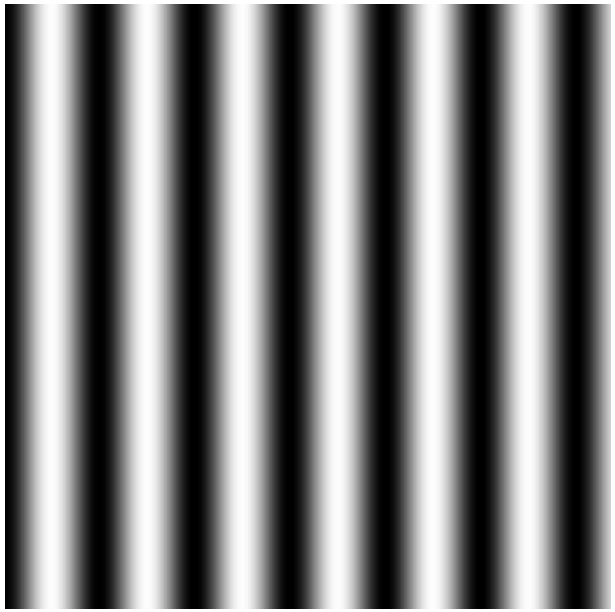




$$I(u, v) = \sin u$$

Stripes



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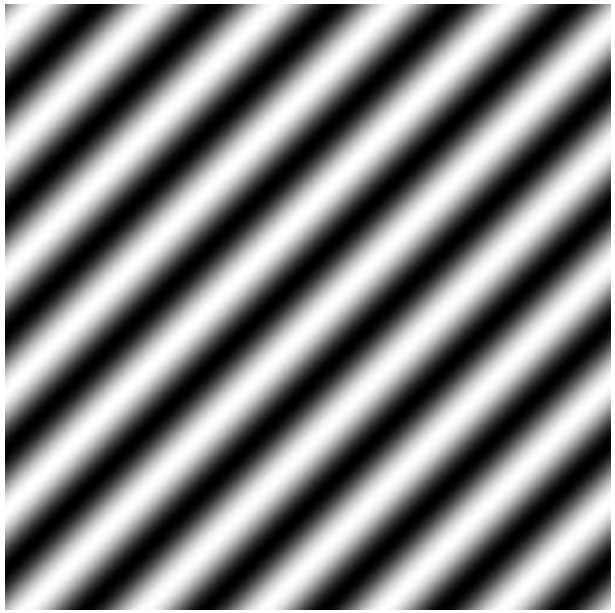
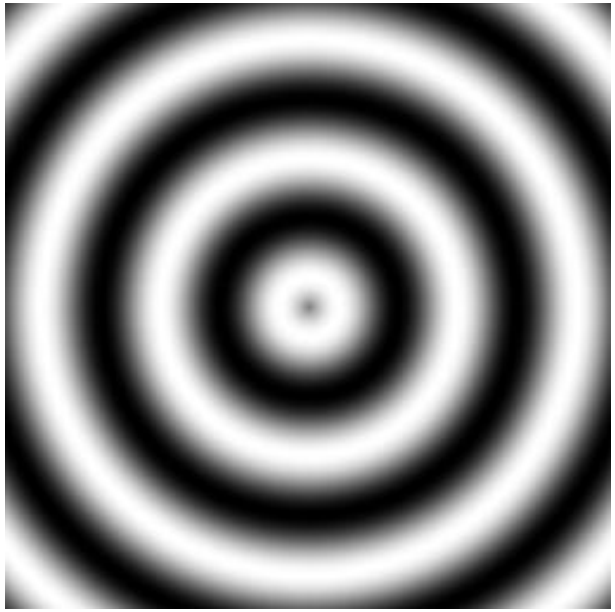


$$I(u, v) = \sin(u + v)$$

Stripes

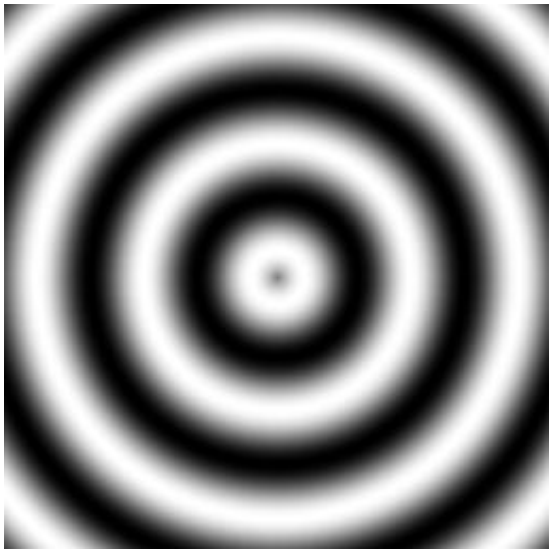


Stripes

$$I(u,v) = \sin \sqrt{(u-0.5)^2 + (v-0.5)^2}$$

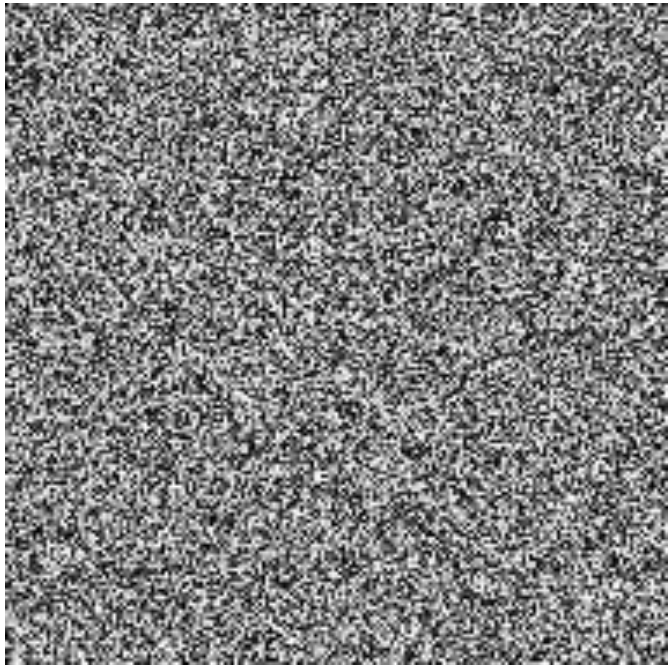
Problem with Procedural Noise

"Looks fake" – too regular



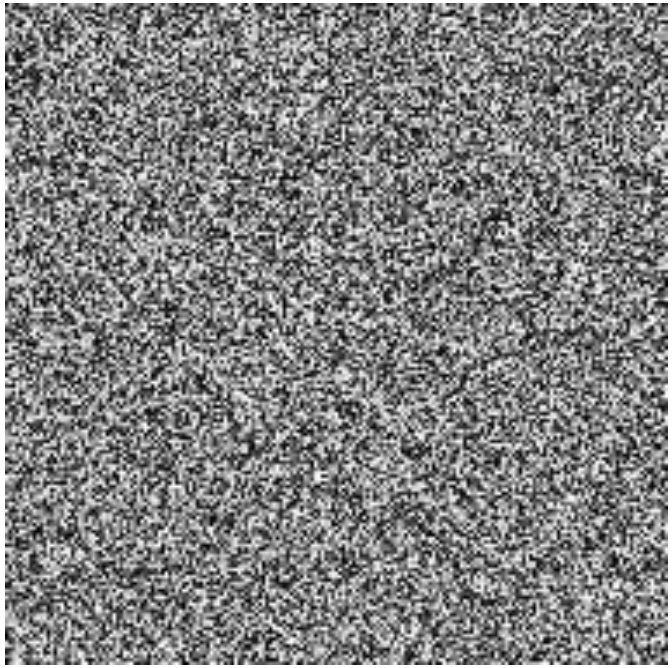
Real texture has **noise**

White Noise



$$I(u, v) = \text{rand}()$$

White Noise



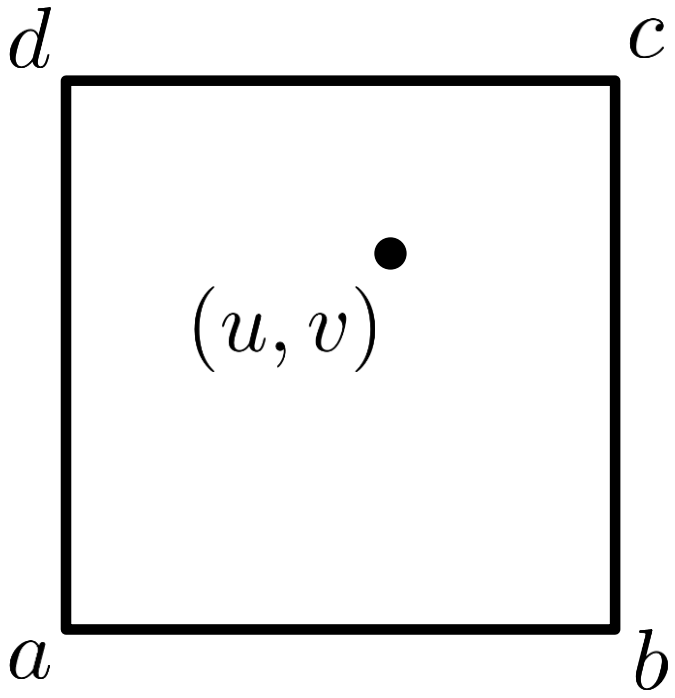
$$I(u, v) = \text{rand}()$$

White noise problems:

- isn't smooth
- isn't correlated

Upsampling Noise

Bilinear interpolation



Upsampling Noise

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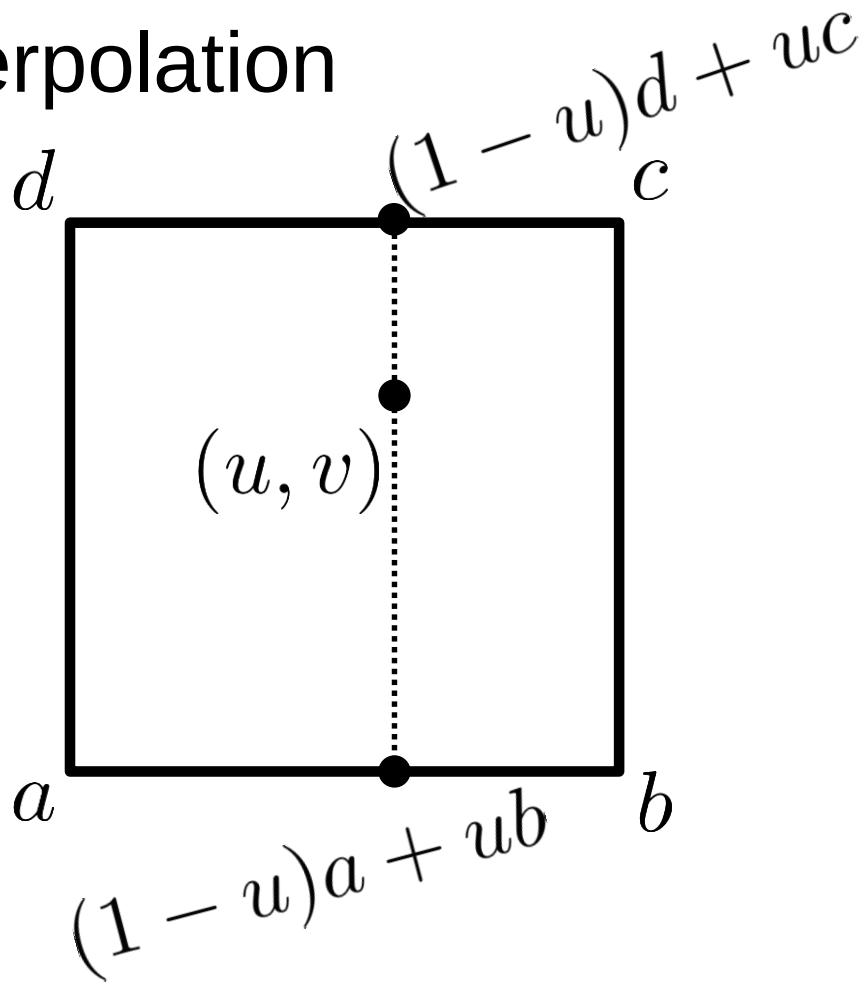

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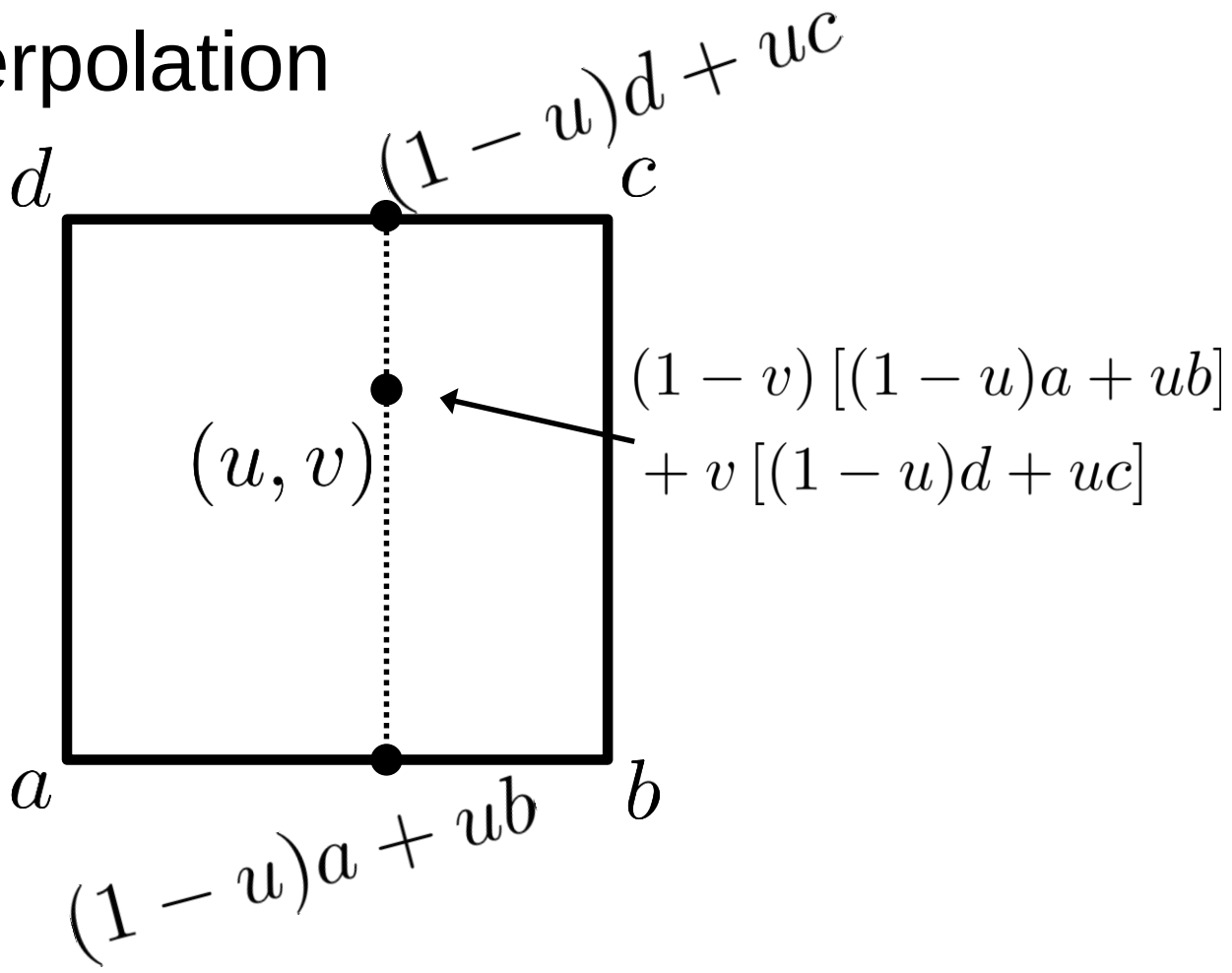

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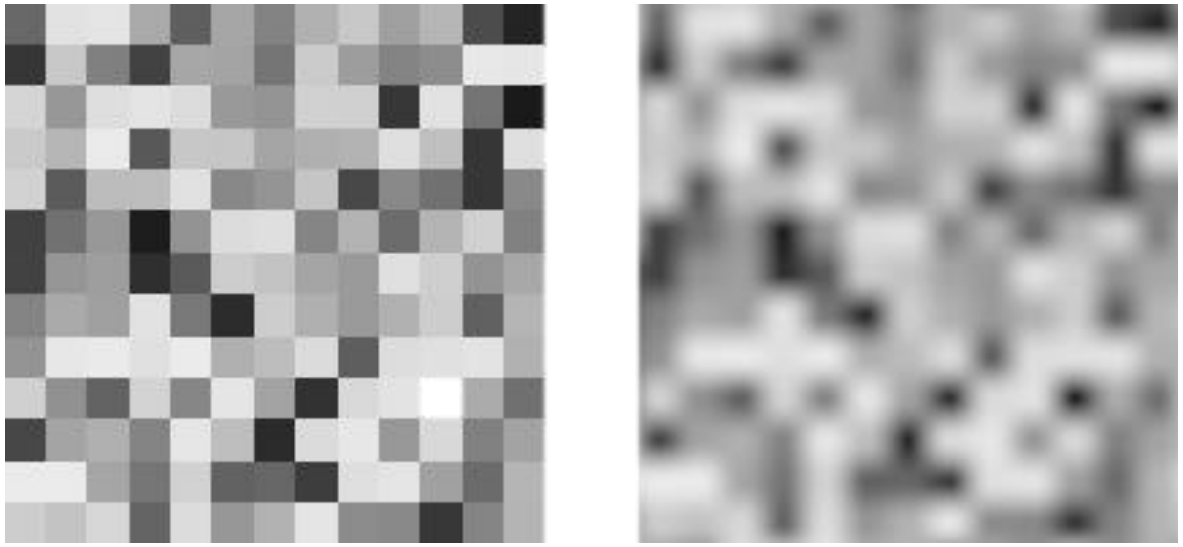
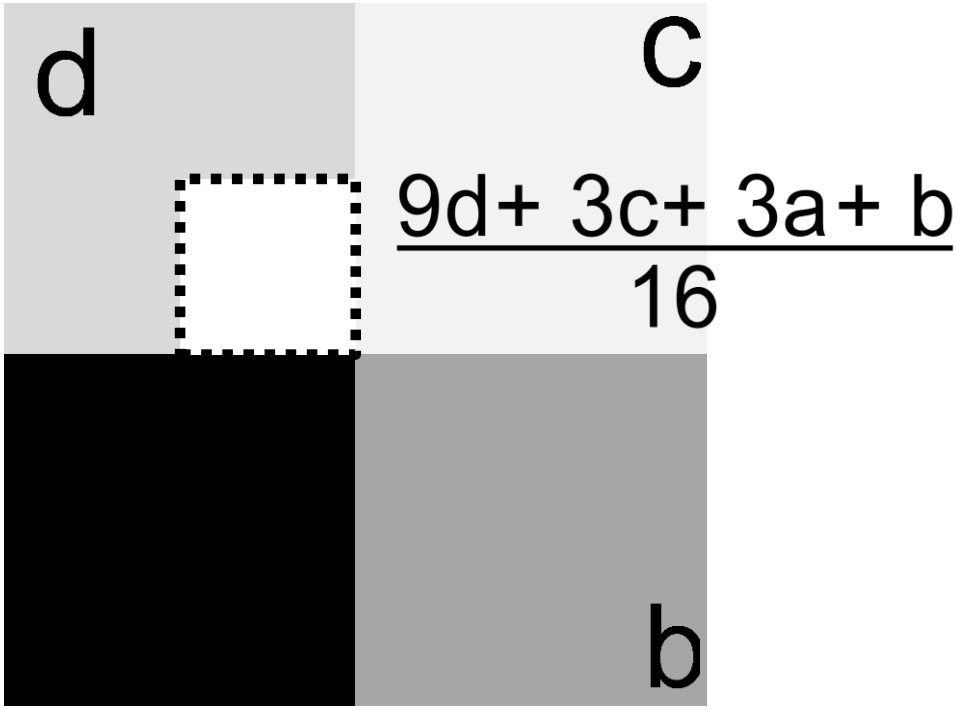


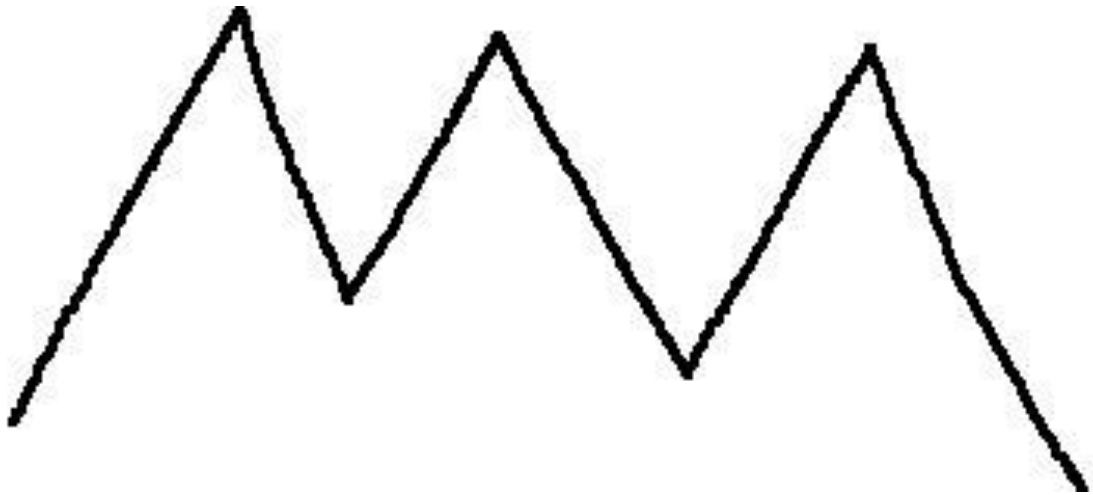
Upsampling Noise

Special case: power of 2 grid



Mountain Analogy

At coarse scale, has sparse peaks



Mountain Analogy

At coarse scale, has sparse peaks

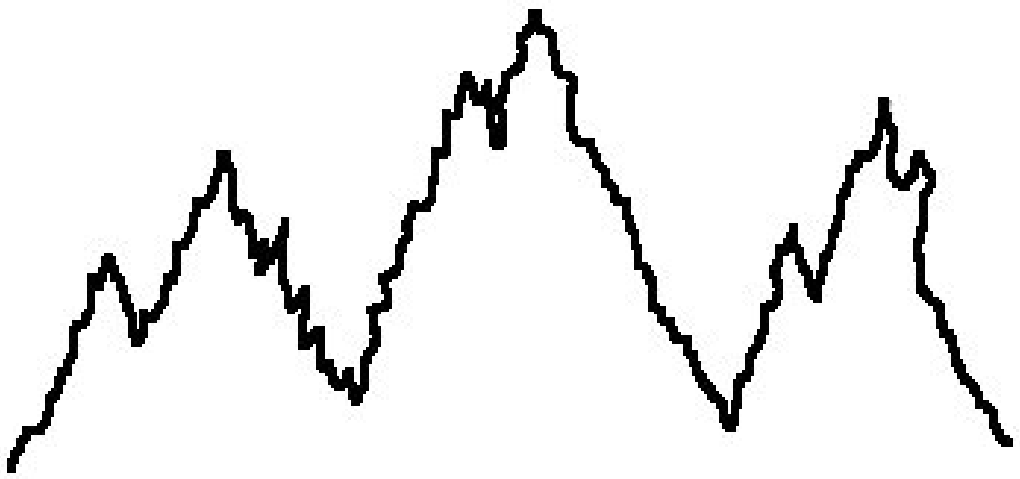
Look closer, see false peaks

Mountain Analogy

At coarse scale, has sparse peaks

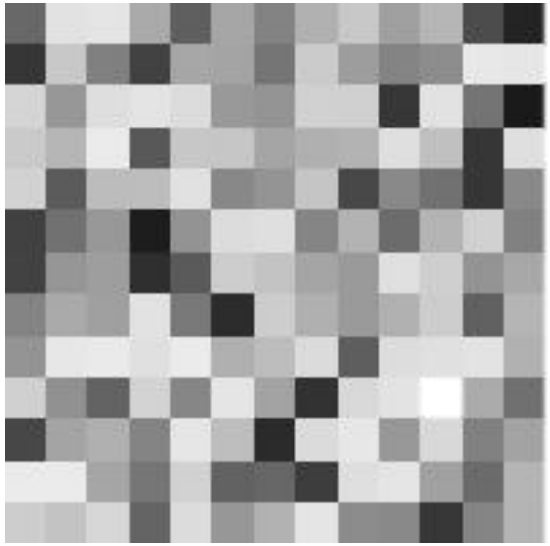
Look closer, see false peaks

Look even closer, see boulders, etc…



Procedural Noise

Pick random values on a **coarse grid**



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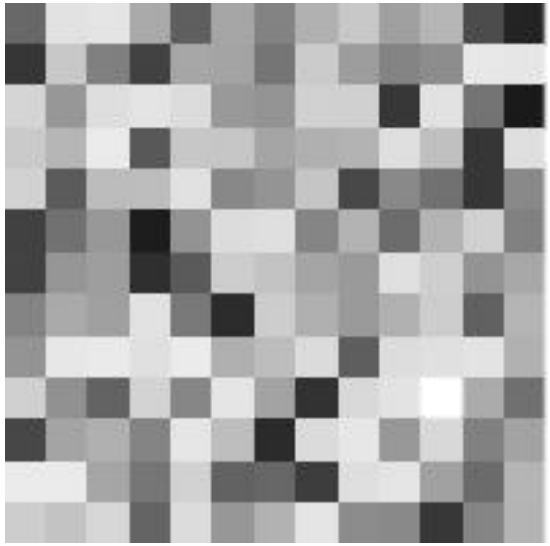
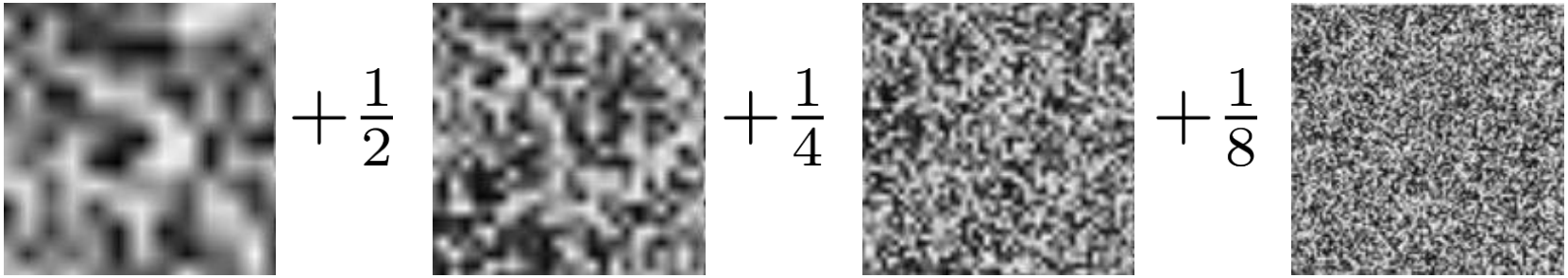


Interpolate to get coarse smooth texture

Procedural Noise

Apply mountain analogy to grid size:

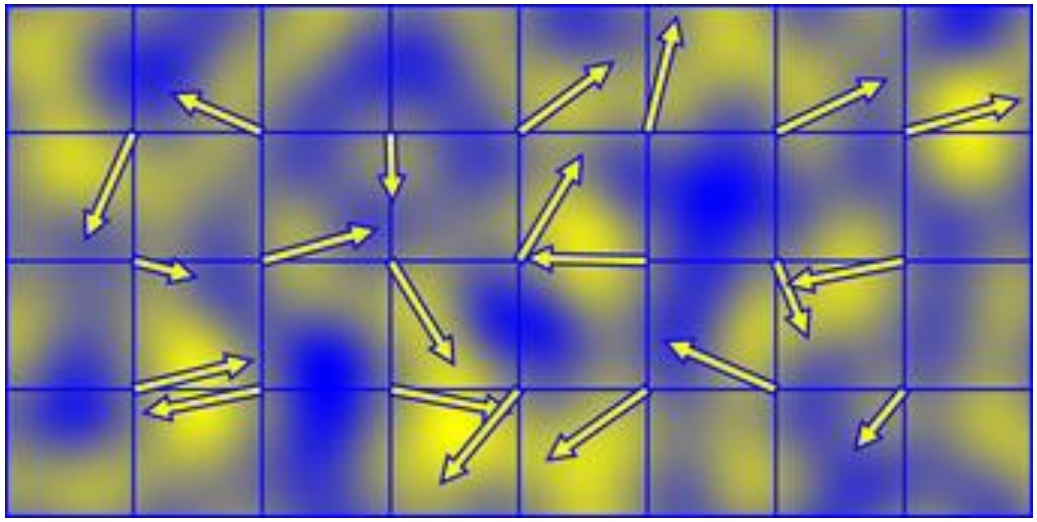


$$= \qquad n(u,v)$$

Procedural Noise

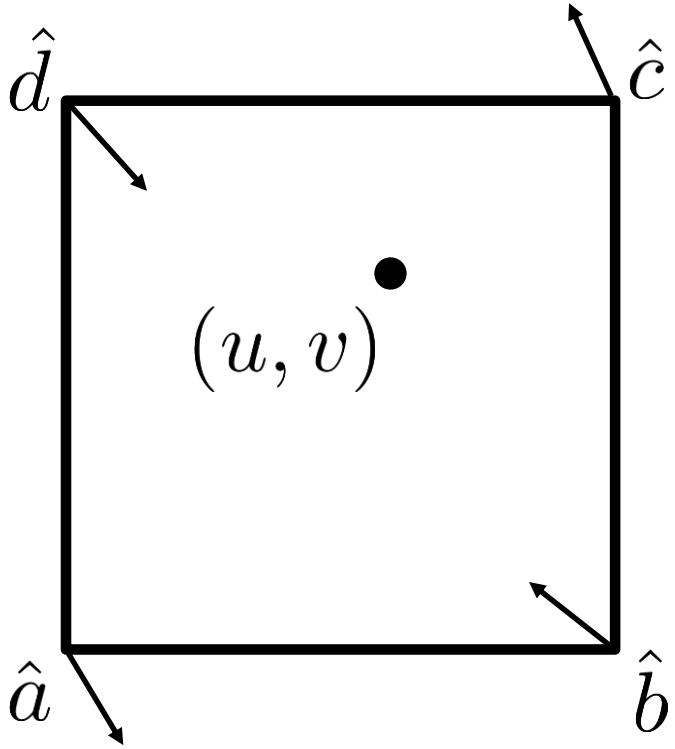
Previous scheme called **value noise**

Popular alternative: gradient (Perlin) noise



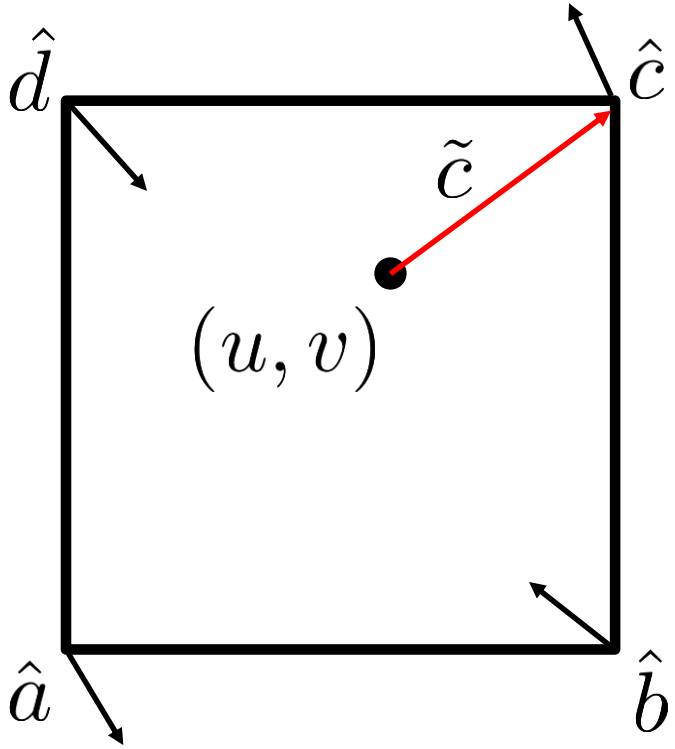
Perlin Noise

Sample unit vectors instead of values



Perlin Noise

Interpolate dot product with vec to corners



Perlin Noise

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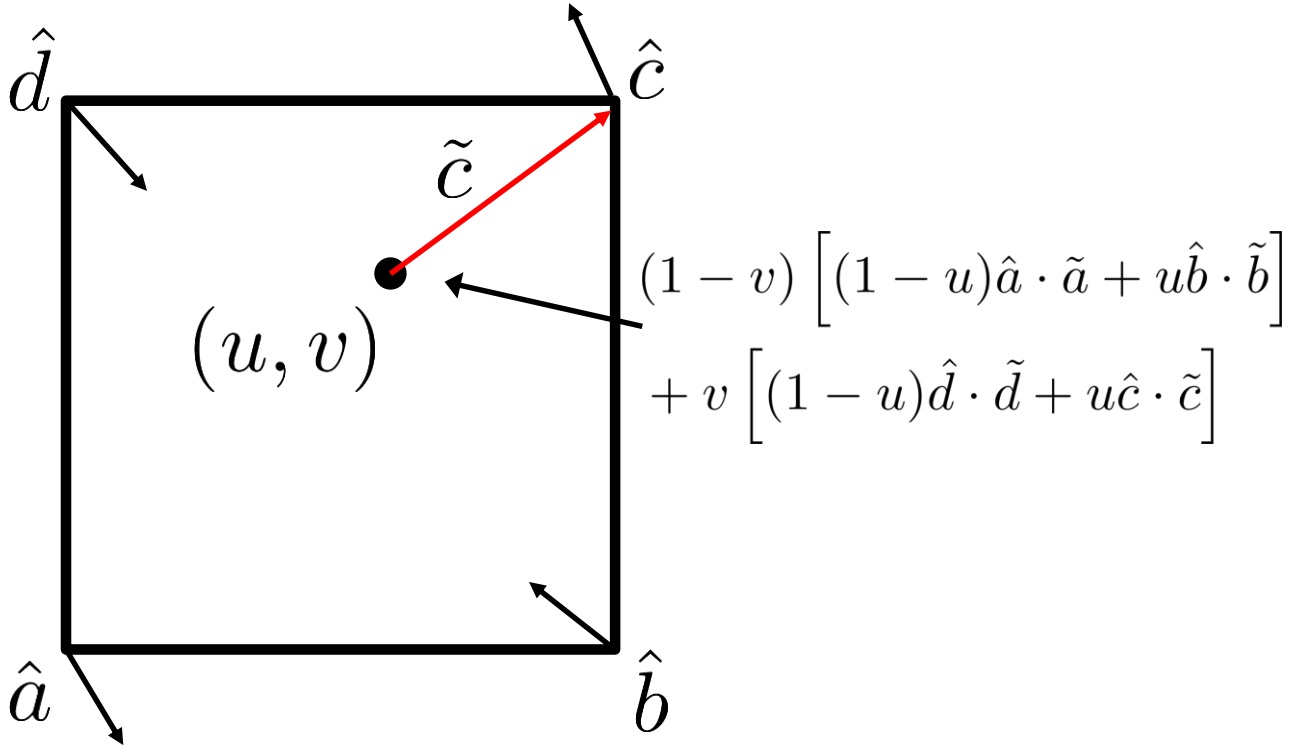
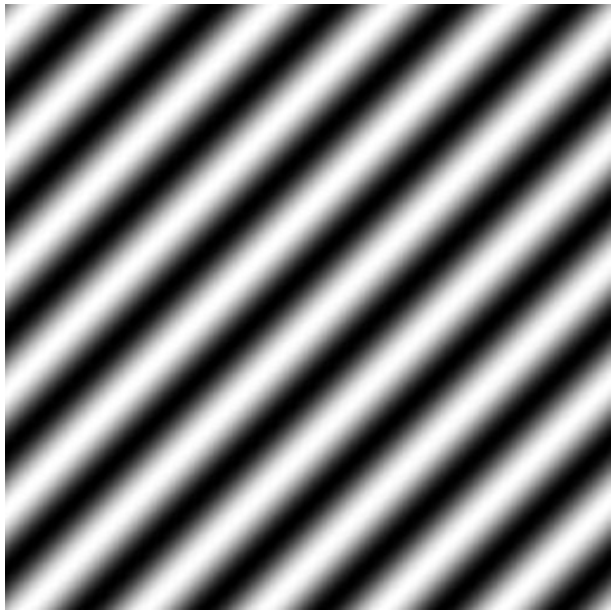
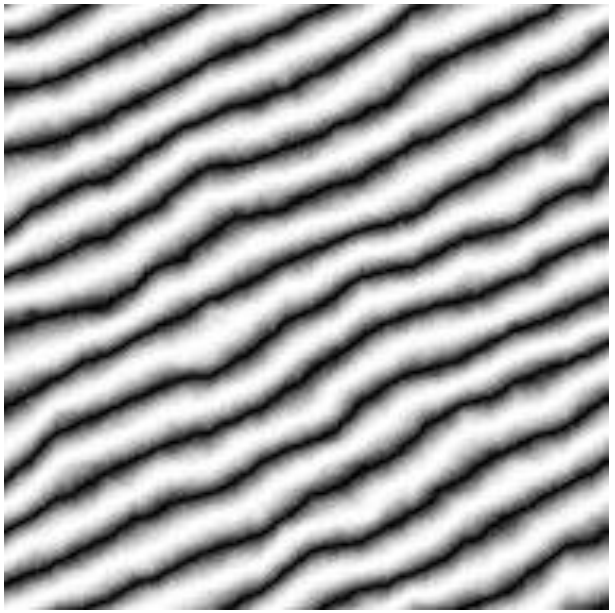


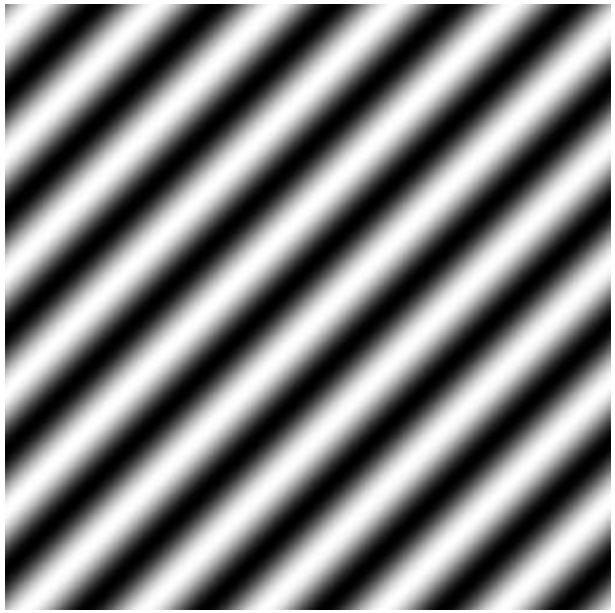
Procedural Noise Applications



$$I(u, v) = \sin(u + v)$$



Procedural Noise Applications



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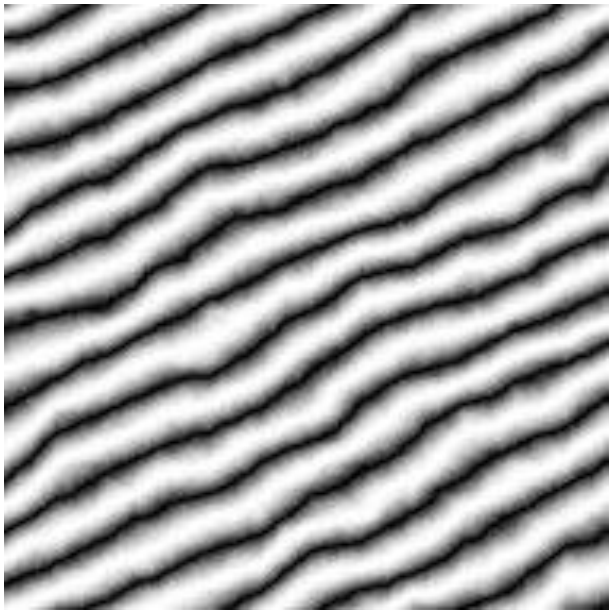
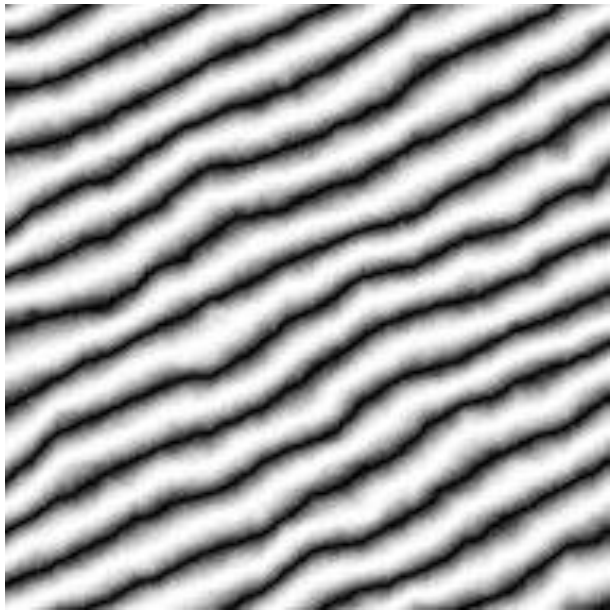
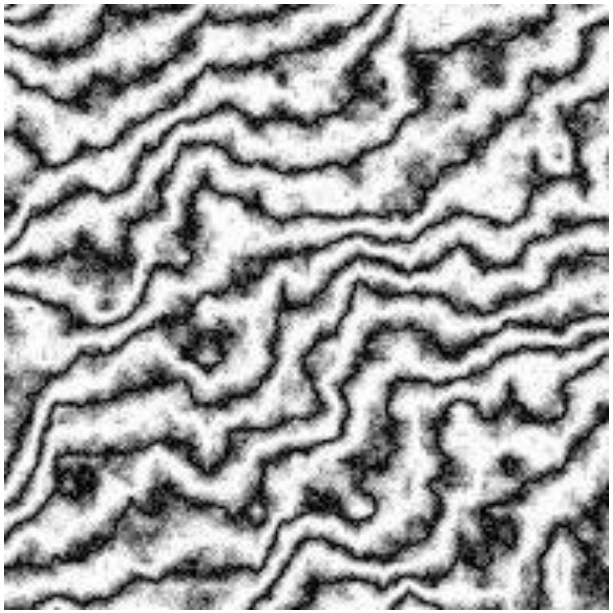


$$I(u, v) = \sin[u + v + \alpha n(\beta u, \beta v)]$$

Procedural Noise Applications

higher α





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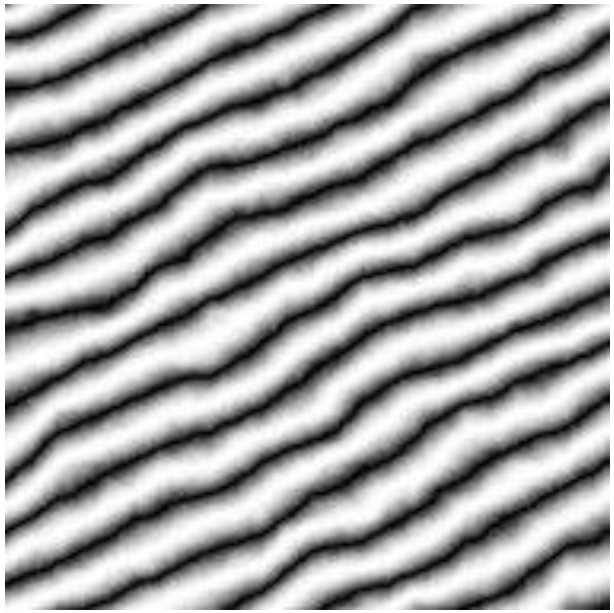
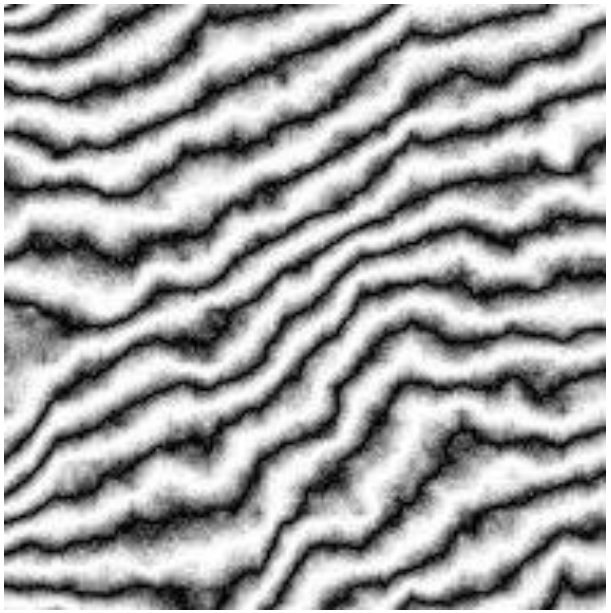
Procedural Noise Applications

higher β





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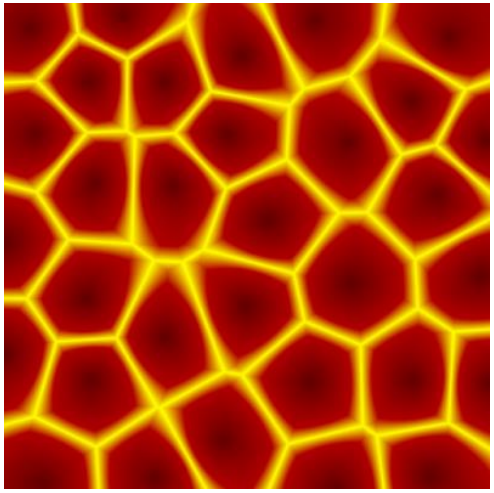
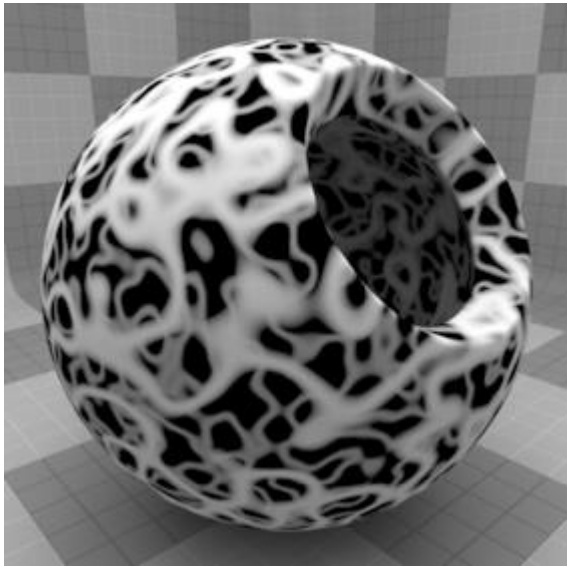
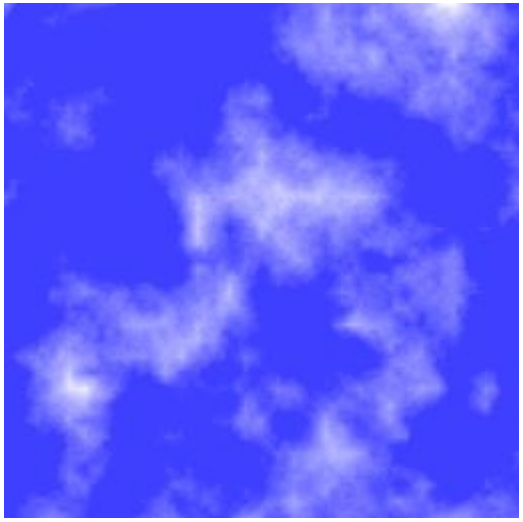
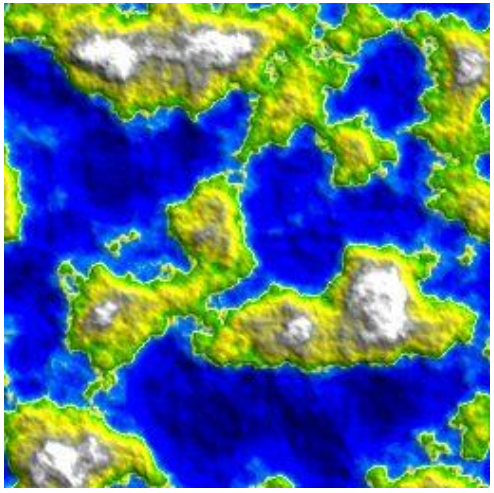
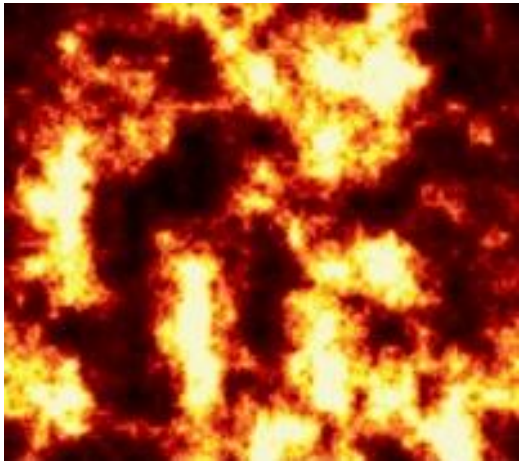
Procedural Noise Examples












Minecraft Landscape

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Key features:

- discrete (made of blocks / **voxels**)
- random – no repeated features
- extends indefinitely
- persistent

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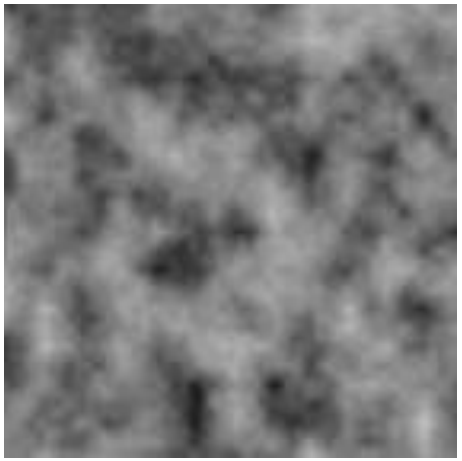
- discrete (made of blocks / **voxels**)
- random – no repeated features
- extends indefinitely
- persistent
  - walk 5 miles north, then 5 miles south, should see the same landscape features

Minecraft Landscape

Making a small piece of landscape easy:

1. Generate procedural noise patch
   - one pixel per block in xy directions

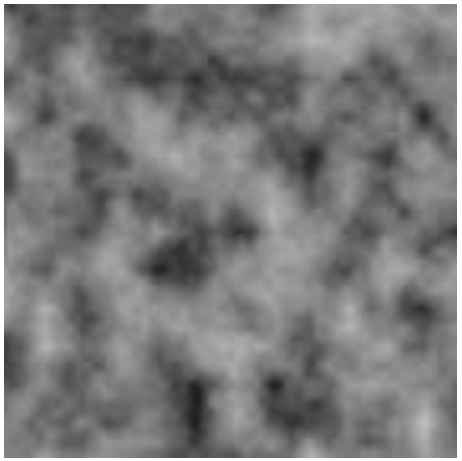


Minecraft Landscape

Making a small piece of landscape easy:

1. Generate procedural noise patch
   - one pixel per block in xy directions

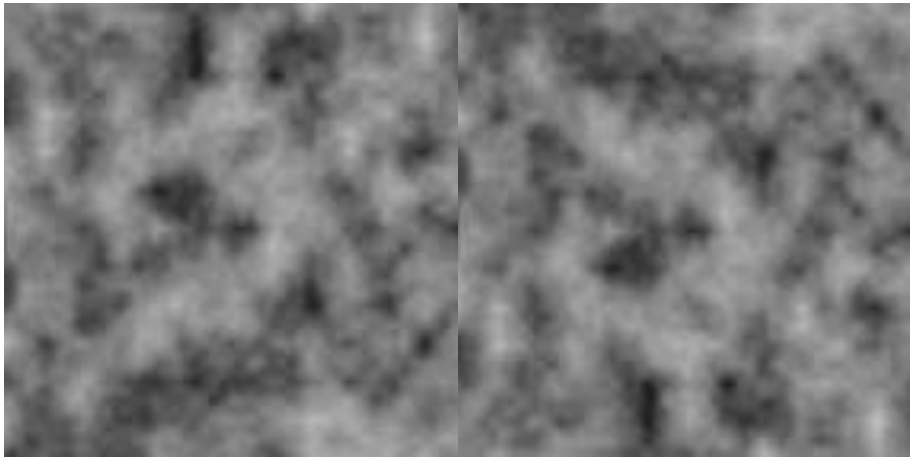
2. Clamp heights to discrete steps



Minecraft Landscape

Problems

1. not persistent
2. has seams between patches



Guaranteeing Persistence

Could precompute entire world…

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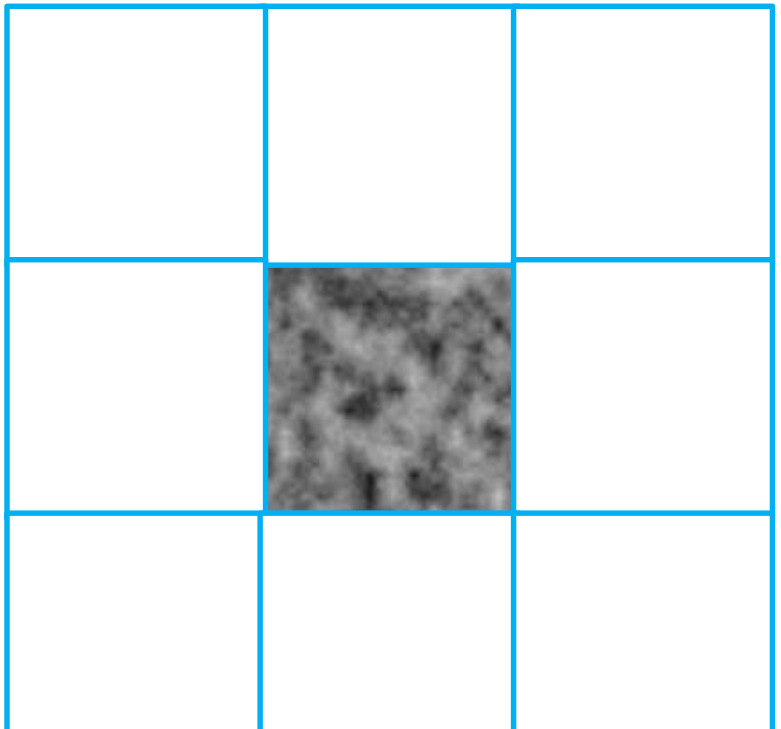
…intractable and unnecessary

Cut up world into **tiles**



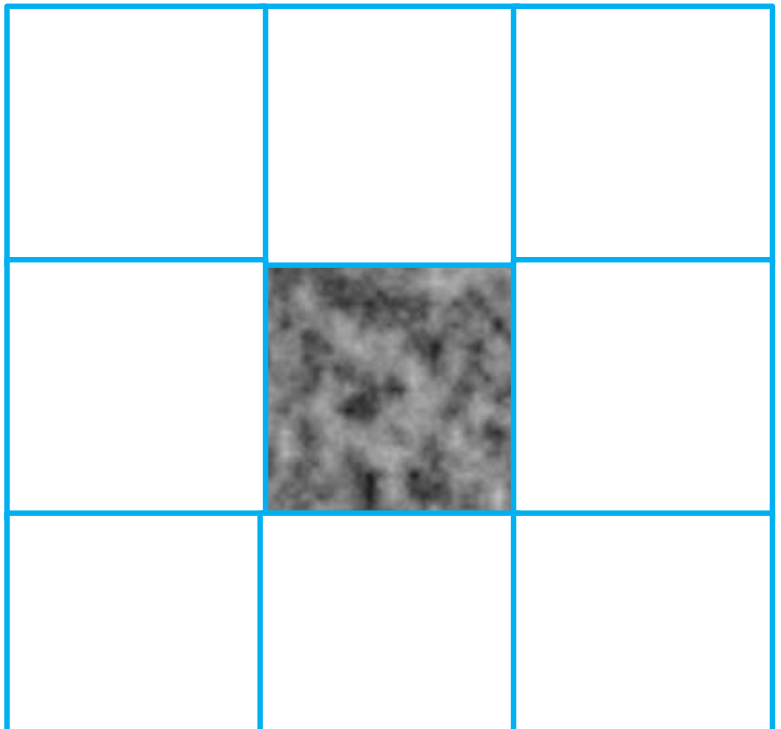
Guaranteeing Persistence

Could precompute entire world…

…intractable and unnecessary

Cut up world into **tiles**

Use deterministic seed for each tile



Building World on the Fly

Swap tiles in and out as needed

Keep **n** x **n** buffer of tiles loaded around the player

- "Zelda Algorithm"

Will still have some popping…

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Swap tiles in and out as needed

Keep **n** x **n** buffer of tiles loaded around the player

- "Zelda Algorithm"

Will still have some popping…

…could show only coarse levels far away

Eliminating Seams

Interpolate with neighbor tiles at each level