Procedural Terrain Generation

Generating a beautiful world at runtime

Brothers of Destruction
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How does an endless scroller become endless?

Why Learn This?

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3D Voxel terrain in Minecraft

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2D terrain of Terraria

- How do your favourite games create these **beautiful** endless terrains?

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- Create a single terrain by hand and store it somewhere, repeat when it ends.

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- How do we ensure nothing repeats without having infinite memory and infinite time?

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- Analytic terrains ($y = sin(x)$) are boring and not realistic

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- How do your favourite games create these **beautiful** endless terrains?
- Create a single terrain by hand and store it somewhere, repeat when it ends.
- Have a set of terrains and choose one at random at start.
- How do we ensure nothing repeats without having infinite memory and infinite time?
- Analytic terrains ($y = sin(x)$) are boring and not realistic
- We need to somehow accommodate the randomness of nature.

Generation Algorithms

Cellullar automata

Steps of algorithm

Step 1: Start with random grid with 1 as wall and 0 as passage.

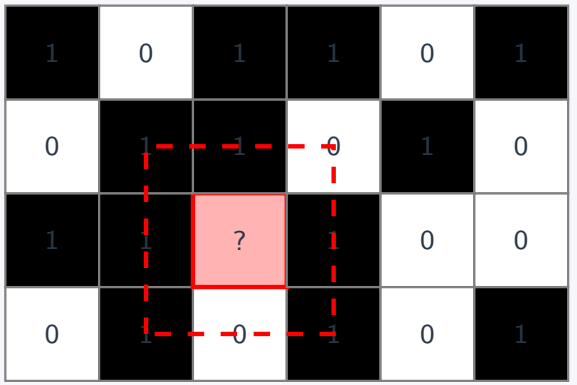
0	0	0	0	0	0
1	0	0	0	0	1
1	1	1	0	1	0
0	1	0	1	1	1
1	1	0	1	0	1
1	1	0	0	0	1

Random Initial Grid

Cellullar automata

Steps of algorithm

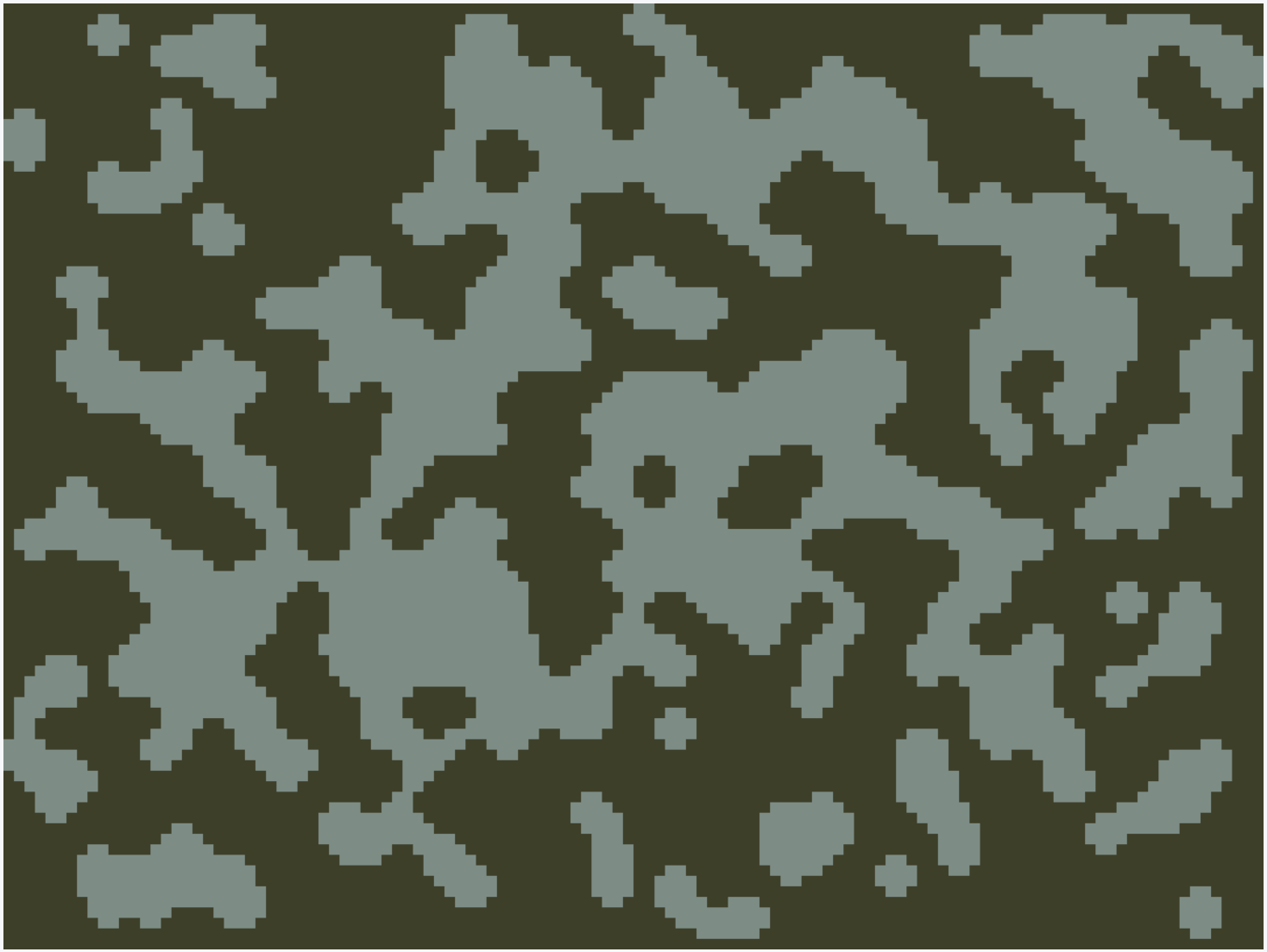
Step 2: Each next iteration, change a cells value according to the following rule.
A cell becomes a wall, if in it's Moore neighborhood (including itself), majority of cell is wall.
Otherwise it becomes a passage.



Moore Neighborhood Rule

Cellullar automata: Demonstration

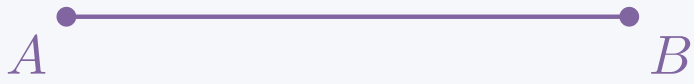
Cellullar automata: Demonstration



Midpoint Displacement Algorithm

Steps of algorithm

Step 1: Begin with a straight line segment AB.



Midpoint Displacement Algorithm

Steps of algorithm

Step 2: Compute the midpoint C of AB

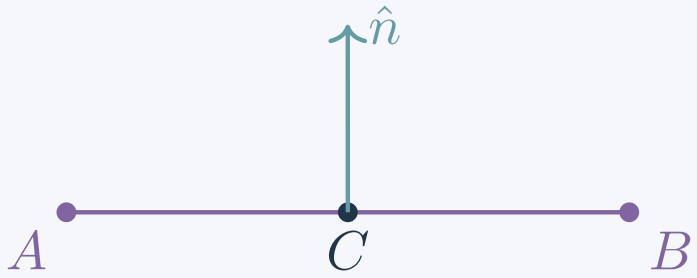
$$C = \frac{A + B}{2}$$

Midpoint Displacement Algorithm

Steps of algorithm

Step 3: Compute unit normal $\hat{n}$ of segment AB

$$\hat{n} = \frac{B - A}{|B - A|} \times \hat{k}$$

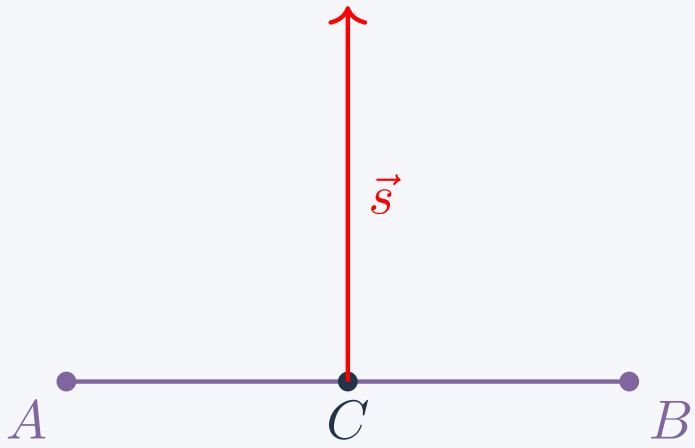


Midpoint Displacement Algorithm

Steps of algorithm

Step 4: Multiply with `random(-h, h)` to find displacement

$$\vec{s} = \hat{n} \times \texttt{random(-h, h)}$$

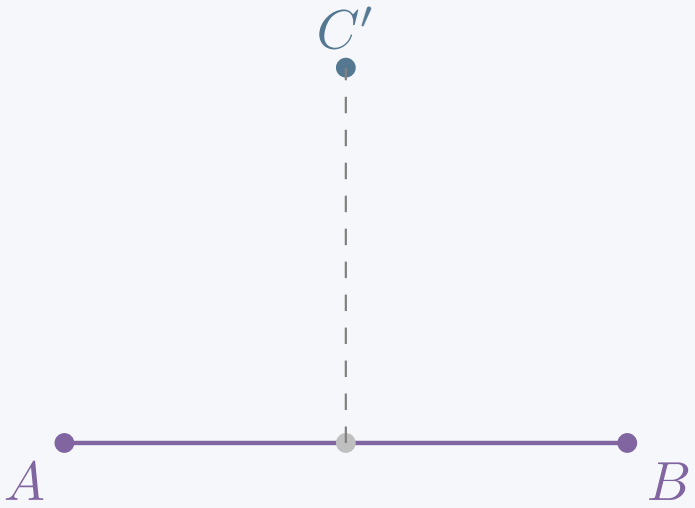


Midpoint Displacement Algorithm

Steps of algorithm

Step 5: Displace midpoint

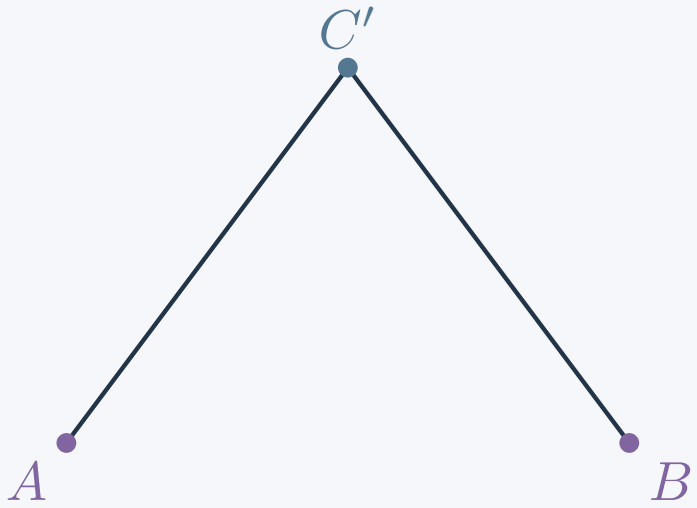
$$C' = C + \vec{s}$$



Midpoint Displacement Algorithm

Steps of algorithm

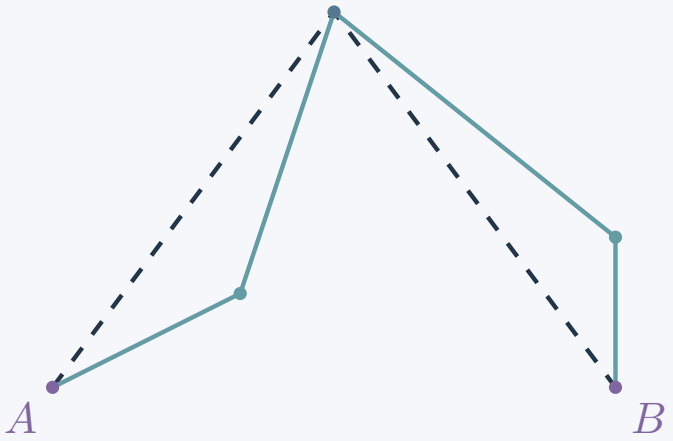
Step 6: Remove old line segment (AB) and add new segments (AC', BC')



Midpoint Displacement Algorithm

Steps of algorithm

Step 7: Repeat the process (with geometrically reduced h) n times to create a terrain with $2^n + 1$ points



Terrain after 2 iterations

Midpoint Displacement Algorithm

Steps of algorithm

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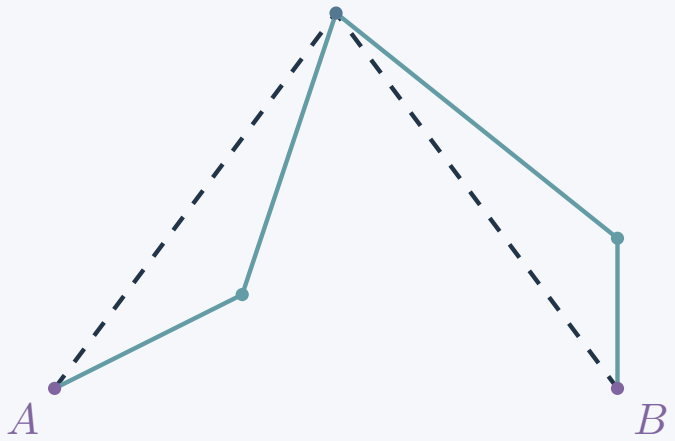


Terrain after 2 iterations

Making it endless

- **Two terrains** Create two overlapping terrains
- **Swap and create** When the first terrain goes out of screen swap the terrains and replace the later terrain with a new one.

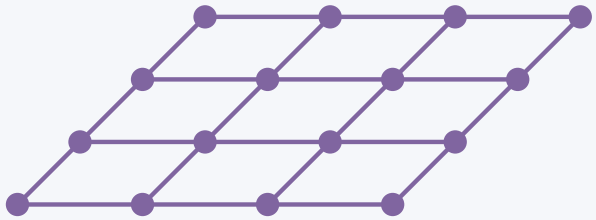
Midpoint Displacement Algorithm: Demonstration

Midpoint Displacement Algorithm: Demonstration

Terrain with Perlin Noise

Steps of algorithm

Step 1: Begin with a tessellation of a region in xy plane.
Store the tessellation as a list of lattice points.



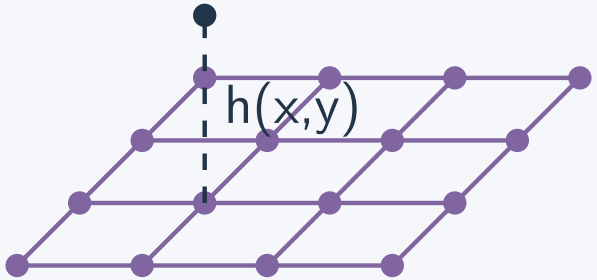
Connected Grid

Terrain with Perlin Noise

Steps of algorithm

Step 2: For each lattice points use Perlin noise to compute the terrain height.

$$h(x, y) = \texttt{height} \times \texttt{perlin(x,y)}$$

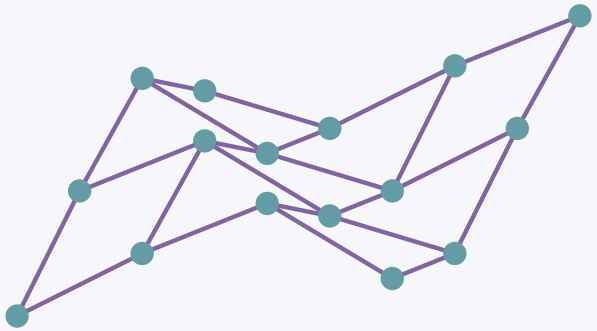


Terrain with Perlin Noise

Steps of algorithm

Step 3: Extrude each lattice point in tessellation

$$C' = C + h(x, y) \times \hat{k}$$



3D Terrain

Terrain with Perlin Noise

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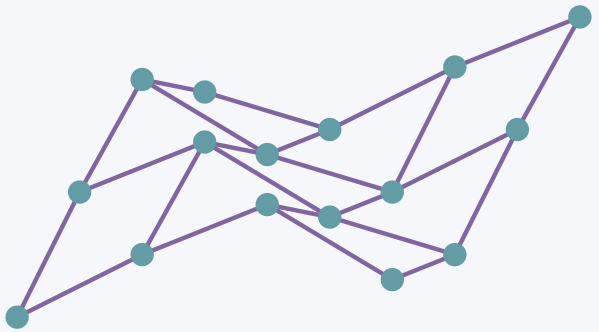


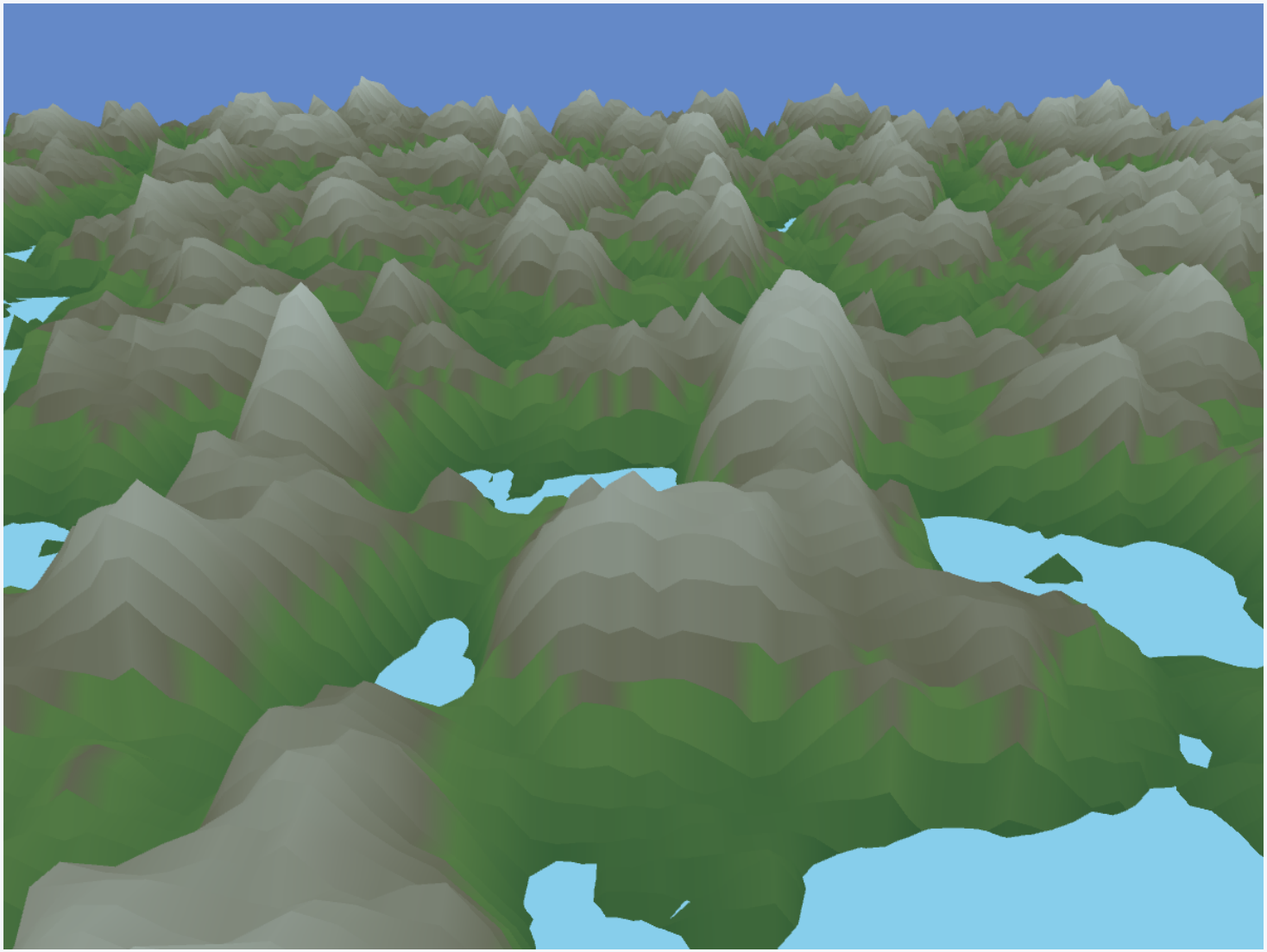
3D Terrain

N.B.:

- **Fixed world** World grows in one side and shrink in another to make it feel endless
- **Noise heightmap** Other noises like **Worley noise** or **Simplex noise** can also be used in a similar way to generate heightmap.

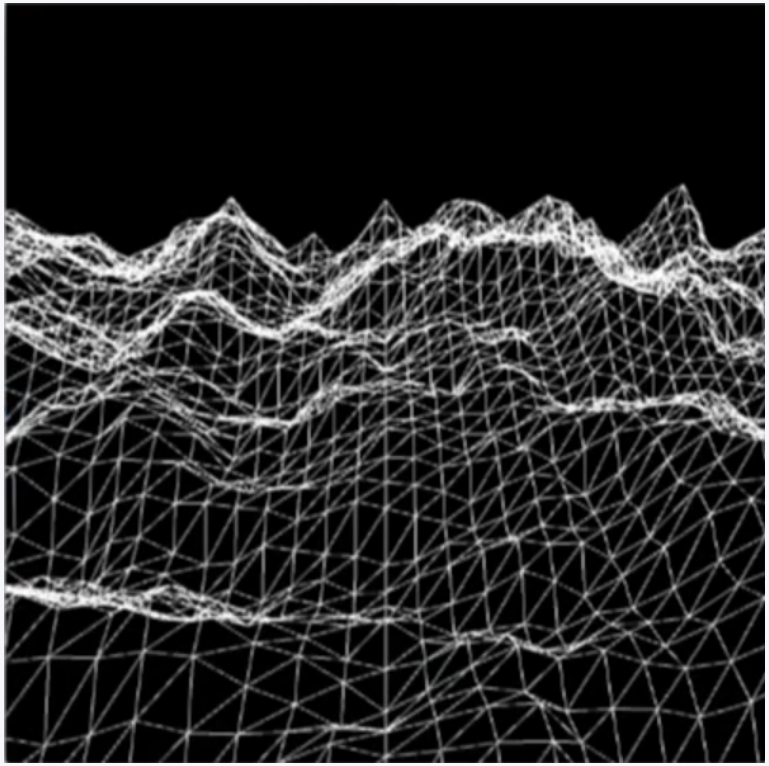
Terrain with Perlin Noise: Demonstration

Terrain with Perlin Noise: Demonstration



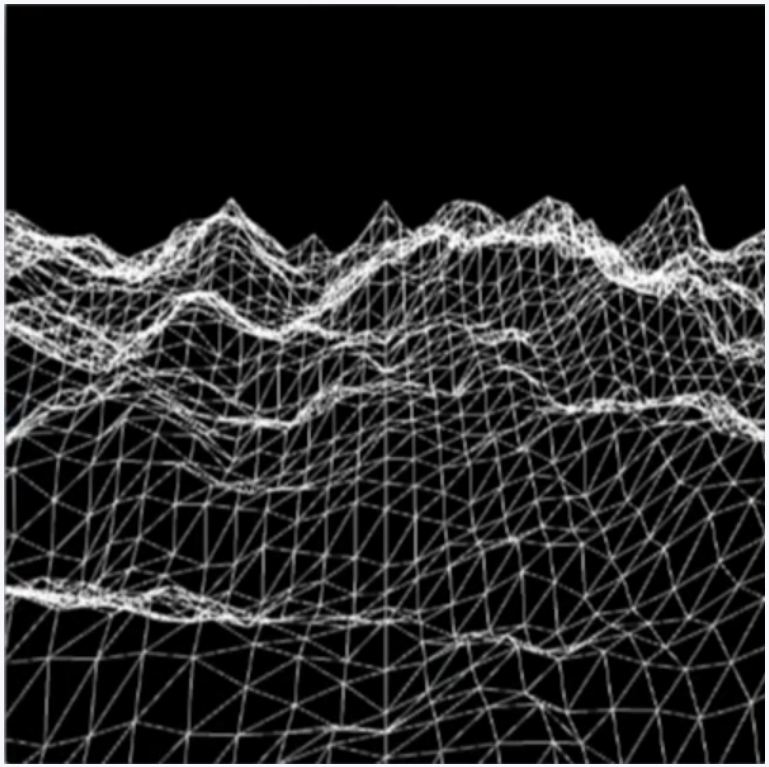
Making it realistic

Realistic terrains



Your ugly wireframe terrain

Realistic terrains



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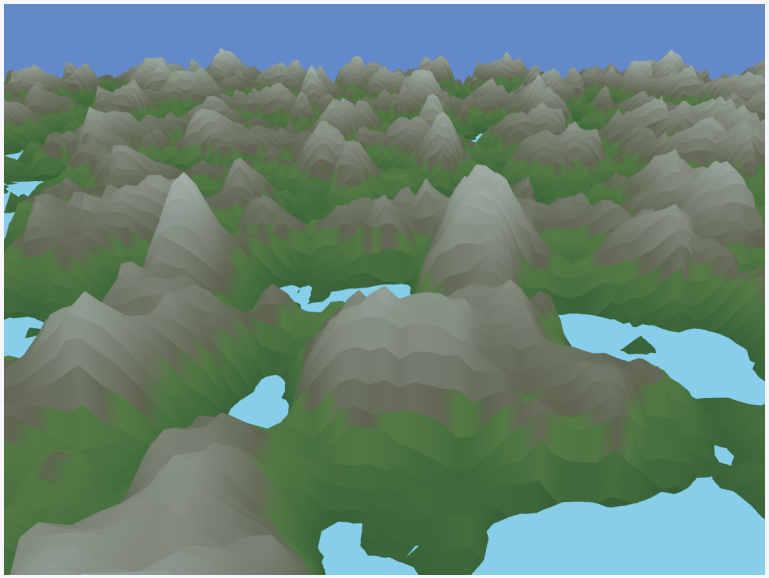
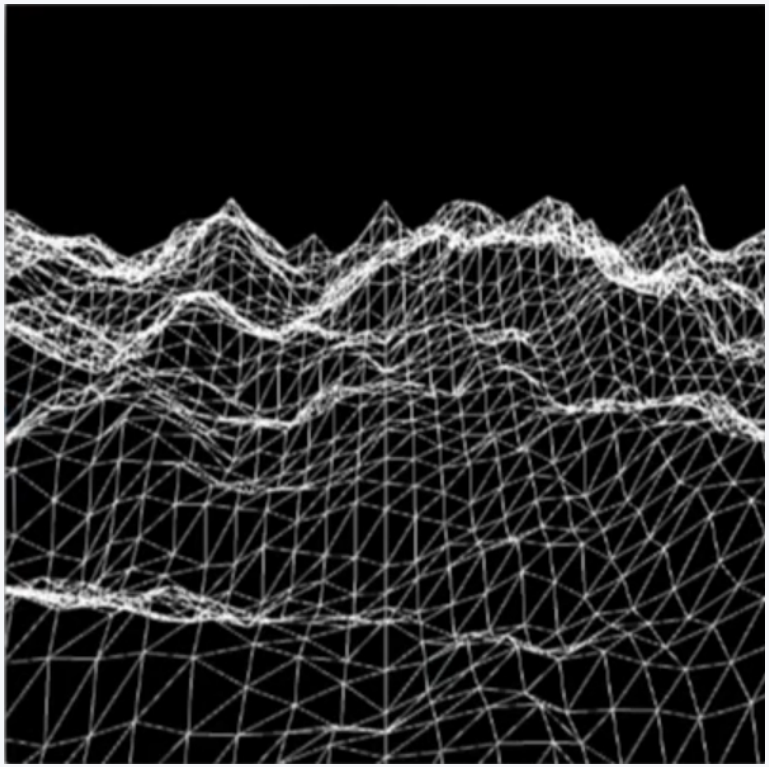


Beautifully rendered terrain

Realistic terrains



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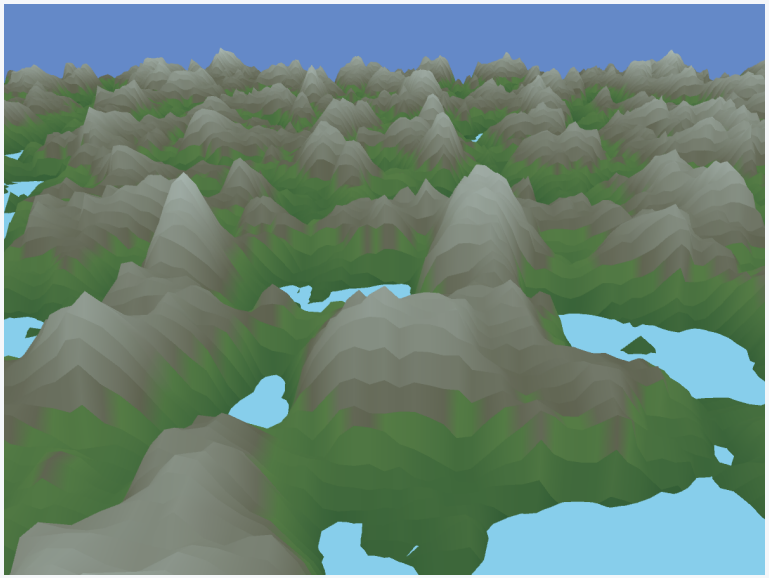
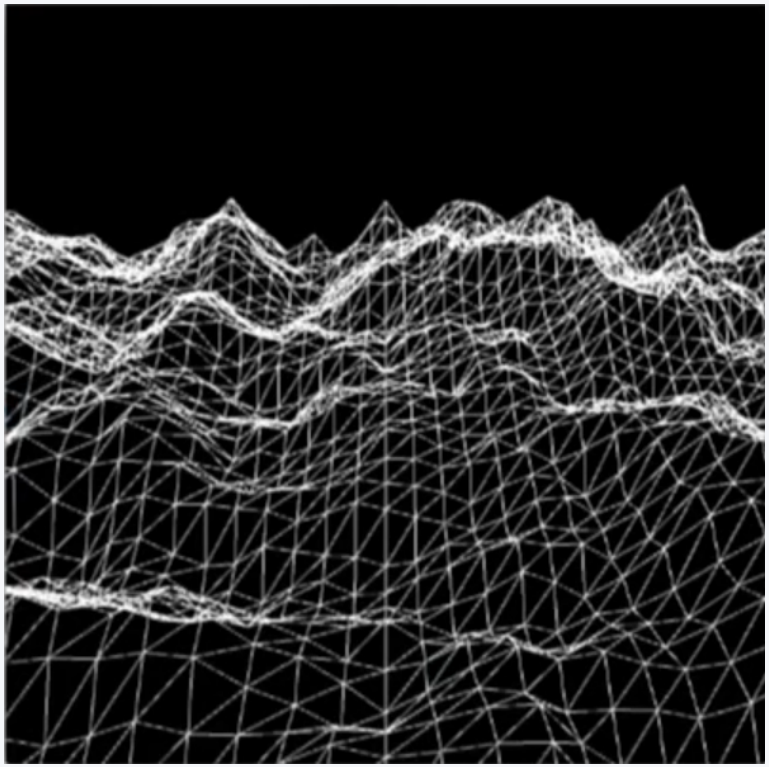


Beautifully rendered terrain

- Choose color based on height.

Realistic terrains



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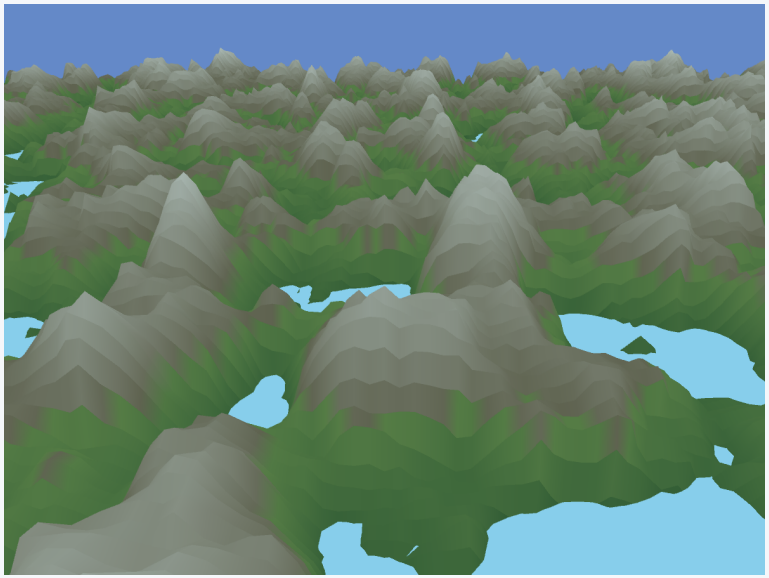

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- Choose color based on height.
- $z > z_{thresh}$ can be colored with the color of mountains

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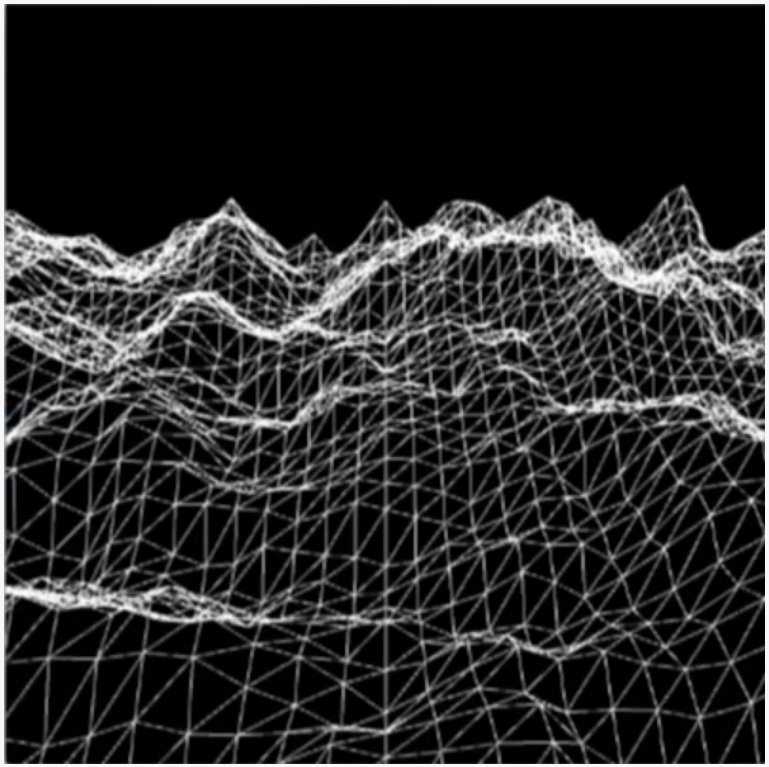

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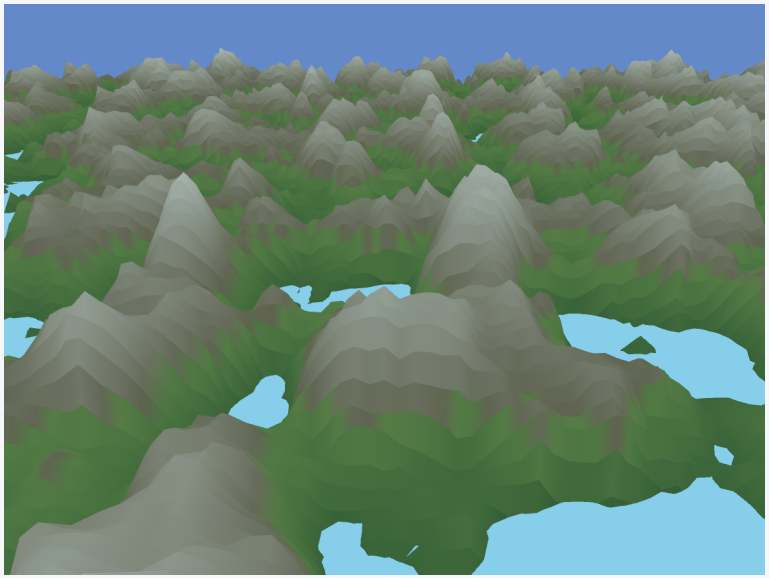

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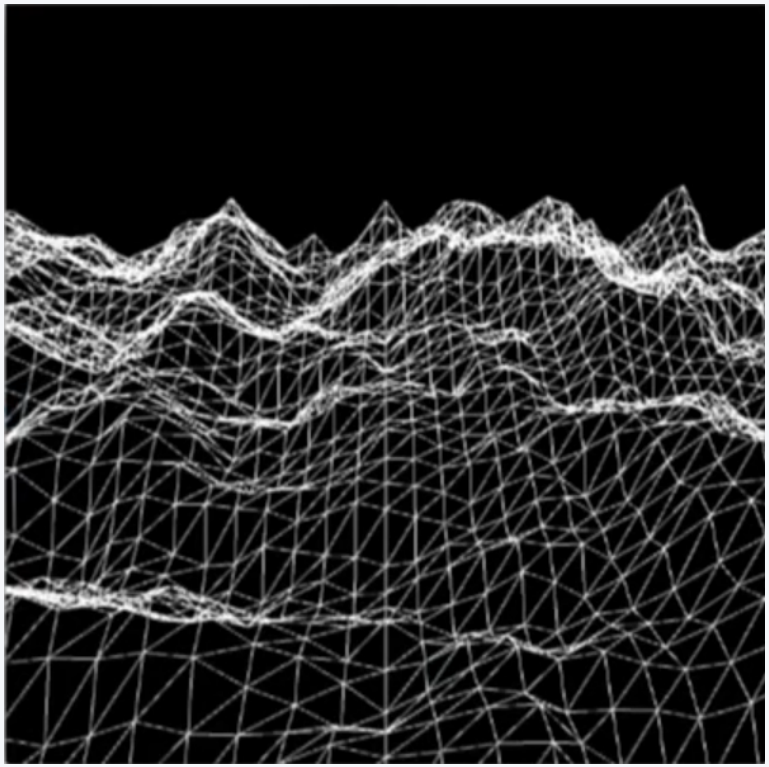

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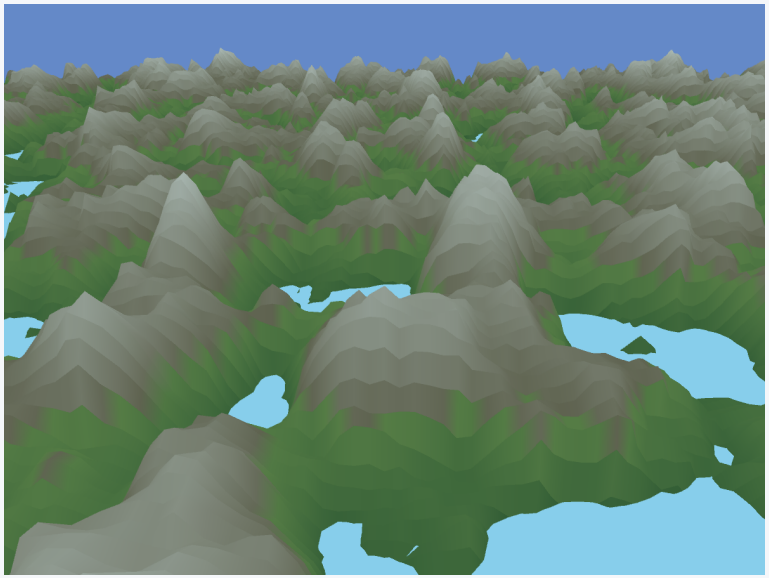
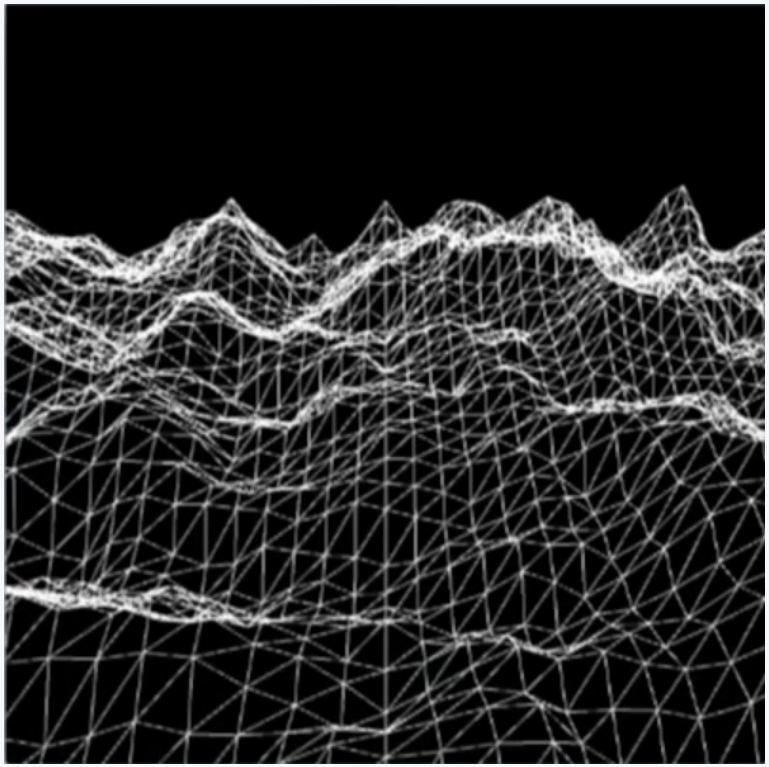


Beautifully rendered terrain

- Choose color based on height.
- $z > z_{thresh}$ can be colored with the color of mountains
- $z \leq z_{thresh}$ can be colored with the color of ground.
- Create more levels of z_{thresh} to create more interesting scenes

Realistic terrains



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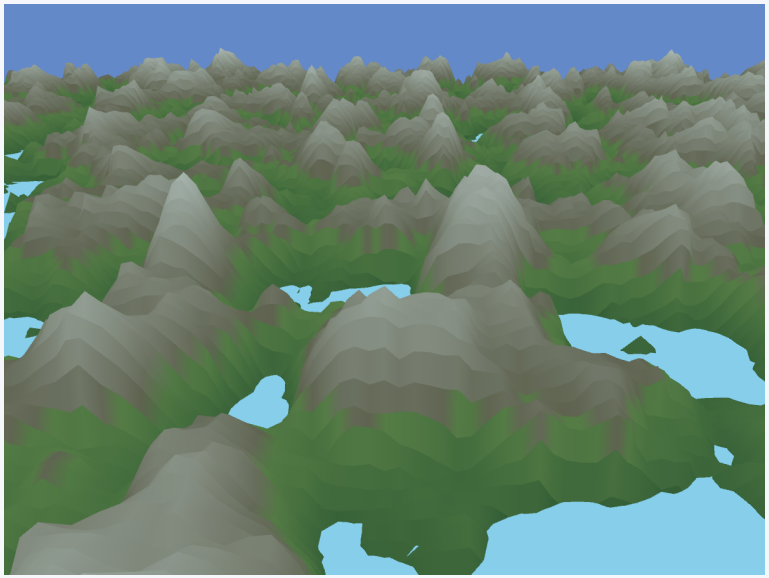

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- Create more levels of z_{thresh} to create more interesting scenes
- Apply texture for extra pizazz

References & Further Reading

- *Kabir Brothers guide to terrains for dummy dum dums* Slide code
- *Fundamentals of Terrain Generation*. Available as PDF
- *Landscape generation with midpoint displacement algorithm*. Availabe online
- Daniel Shiffman *3D Terrain Generation with Perlin Noise in Processing*. Available as video