COMP250: Artificial Intelligence

7: Procedural Content Generation

What is PCG?

What is procedural content generation (PCG)?

- **Procedural**: by computer program or algorithm, with little or no direct input from designer or user
- **Content**: levels, maps, art, animations, stories, items, quests, music, weapons, vehicles, characters, ...
- **Generation**: creating stuff

Types of PCG

- **Online**
  - Generate content at run-time
  - Part of the game
- **Offline**
  - Generate content at design-time
  - Tool for developers

PCG $\neq$ randomness

- Many PCG systems use random numbers, but randomness in itself is not PCG
- Can have PCG without randomness, e.g. based on fractals or simulations
- Randomness in PCG is generally **constrained** to produce desired content
- Shuffling a deck of cards for a game of Solitaire is **not** PCG!

Why PCG?

- More content for less development effort
- Decrease development costs
- Increase replayability
- Decrease storage requirements
- Allow game mechanics based on unseen content

Further reading

Noor Shaker, Julian Togelius and Mark J. Nelson. *Procedural Content Generation in Games: A textbook and an overview of current research*. Springer, 2016. Available online: `http://pcgbook.com`

The Binding of Isaac (2011)

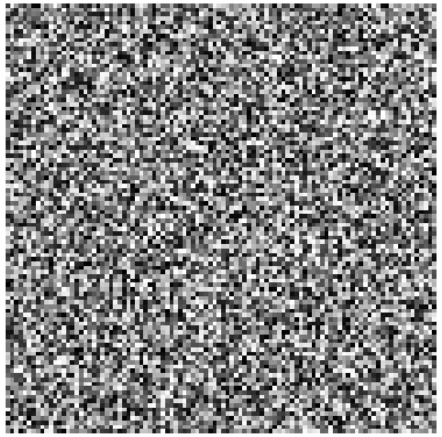
Enter The Gungeon (2016)

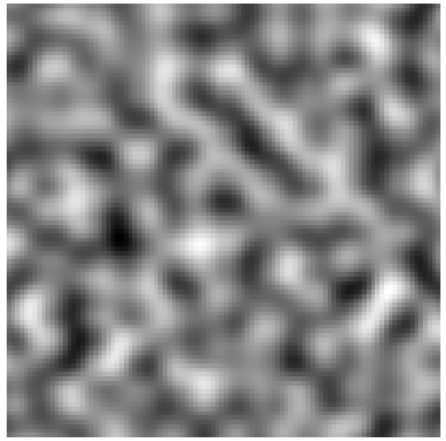
Spelunky (2008)

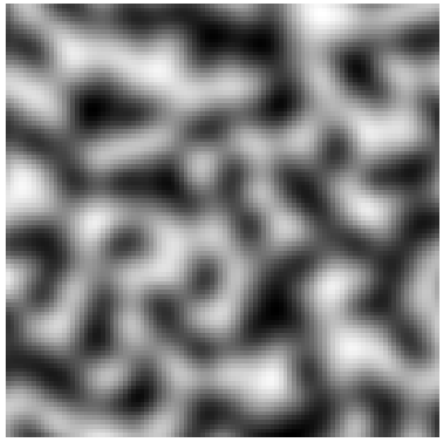
Dwarf Fortress (2006)

No Man's Sky (2016)

NOISE FUNCTIONS







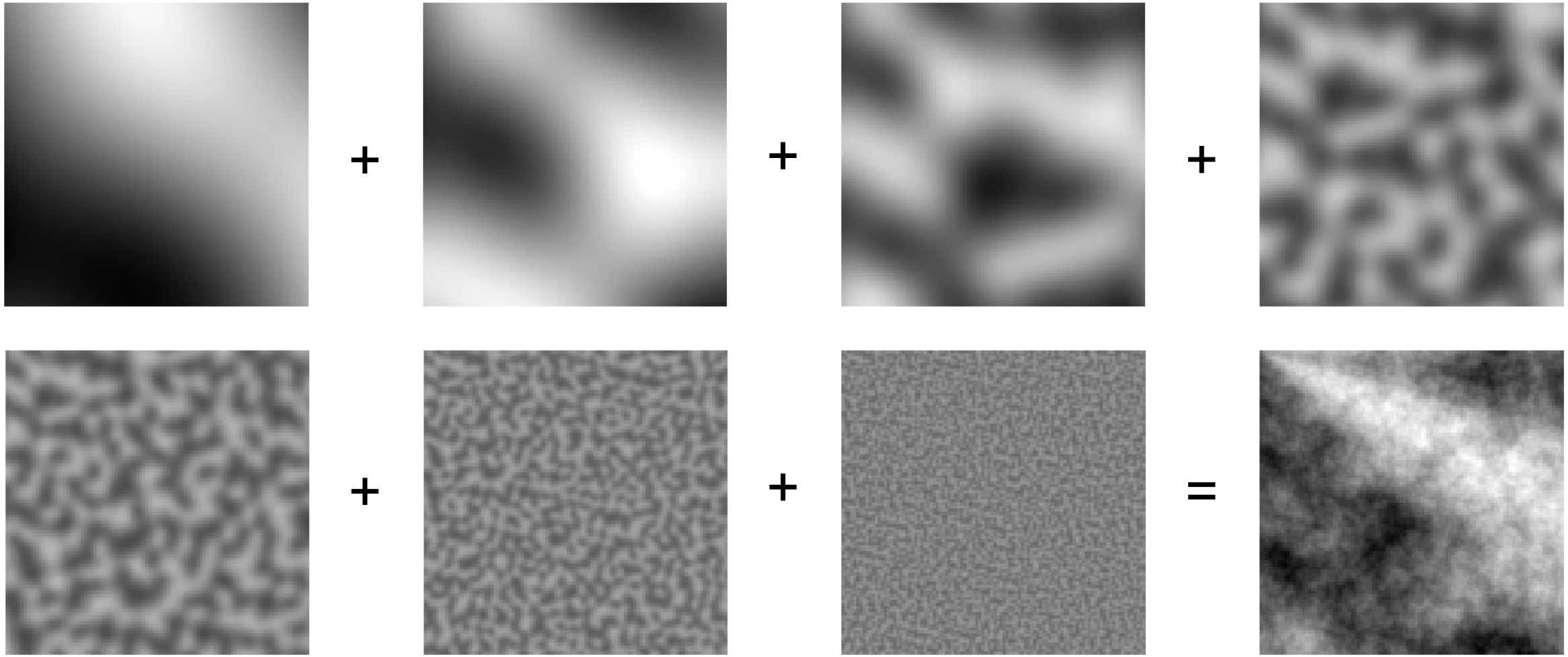
NOISE FUNCTIONS

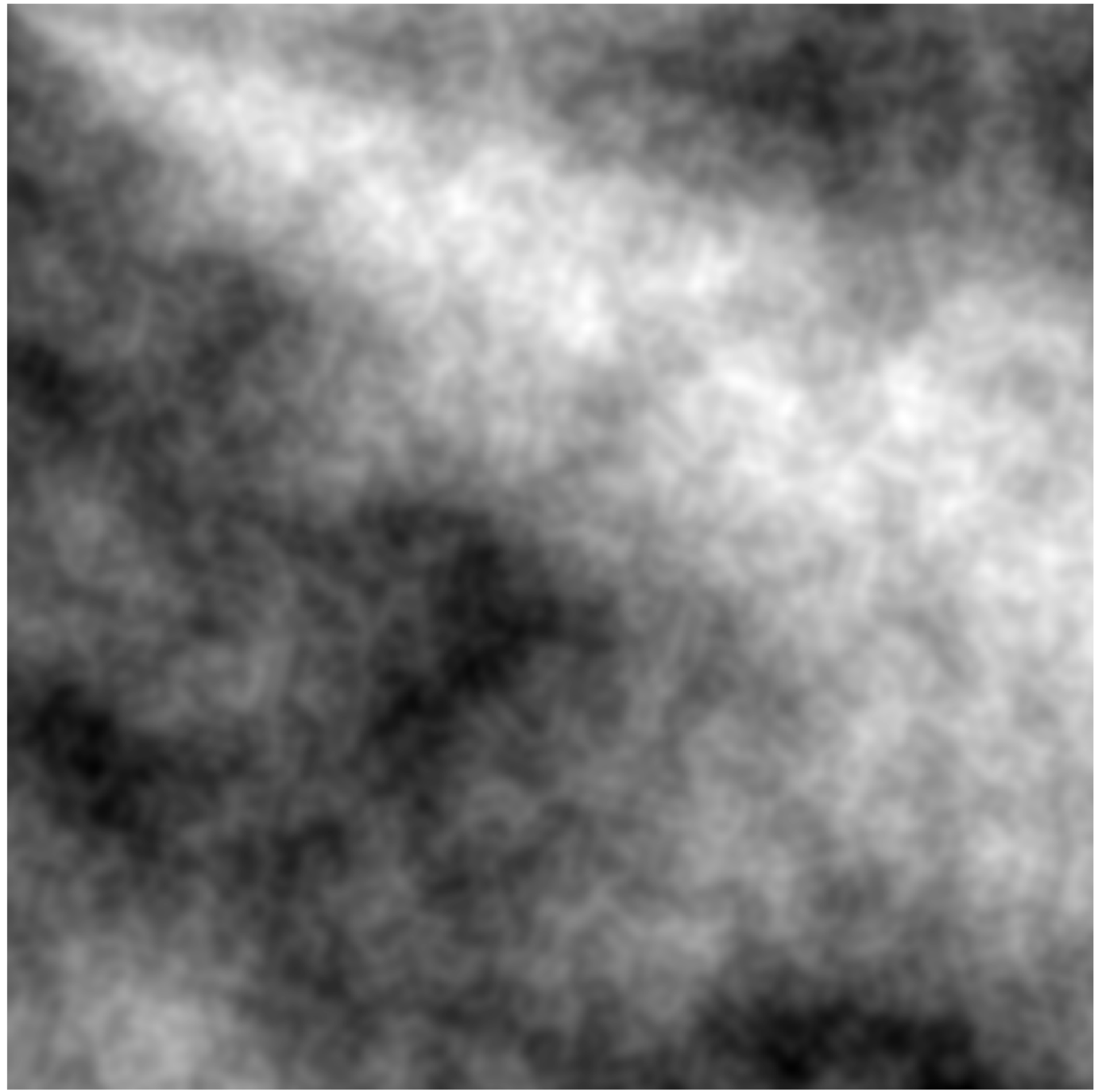
- Functions which map 1D, 2D or 3D points to pseudorandom values
- Input parameter is a `float` or `Vector2` or `Vector3`; output return value is a `float`
- **Pure random noise** is generally not used as it's **too** noisy
- **Perlin noise** has smoother gradients
- **Simplex noise** (also developed by Perlin!) uses a non-rectangular grid – reduces artefacts

FRACTAL NOISE

- Can get higher **frequency** noise by multiplying the x, y, z parameters by a constant
- Can change the **amplitude** of noise by multiplying the output by a constant
- Fractal noise: add together several frequencies of noise – **higher frequency, lower amplitude**
- Low frequency features are big – mountains, valleys
- High frequency features are small – bumpy surfaces

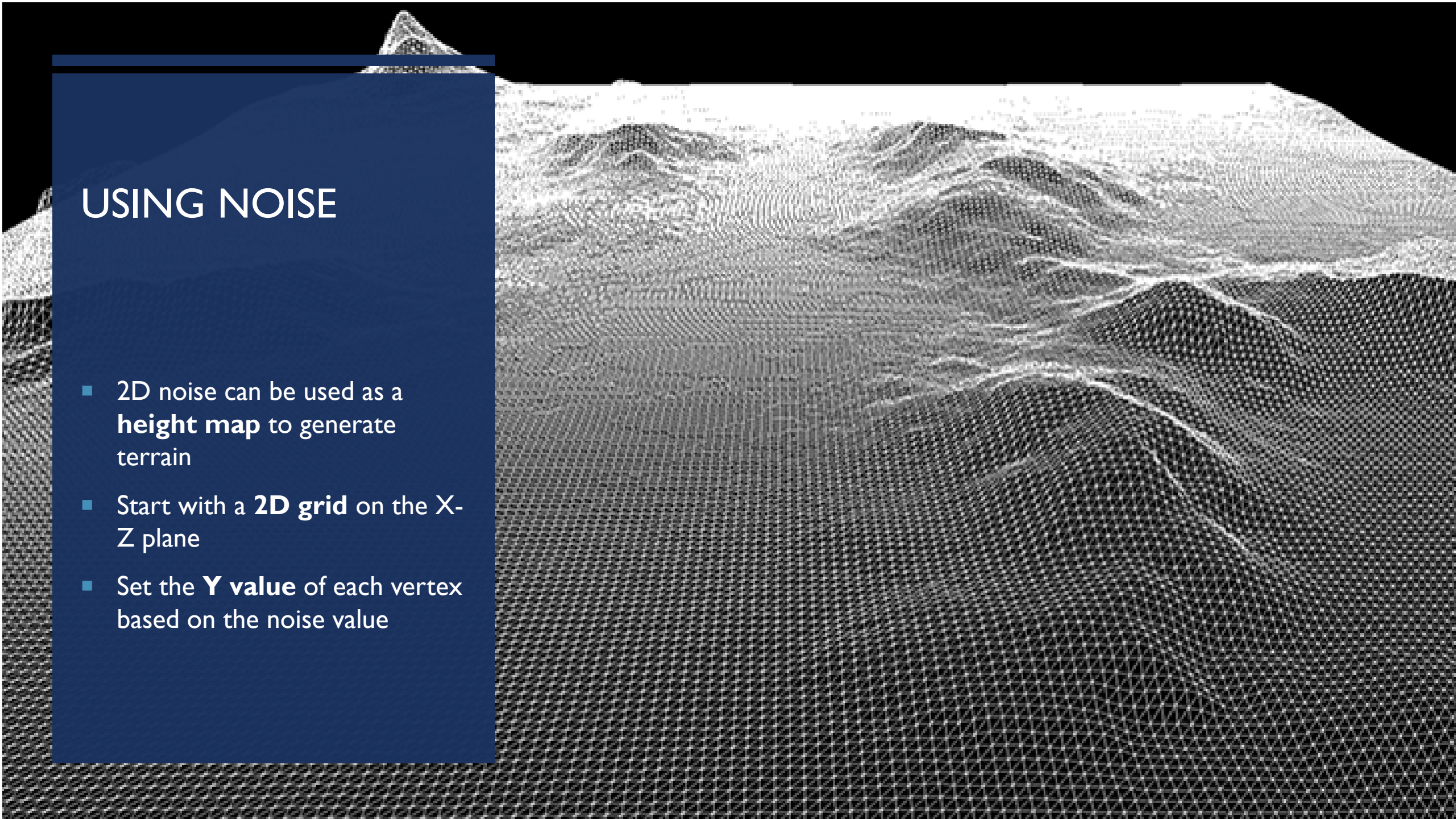
FRACTAL NOISE EXAMPLE





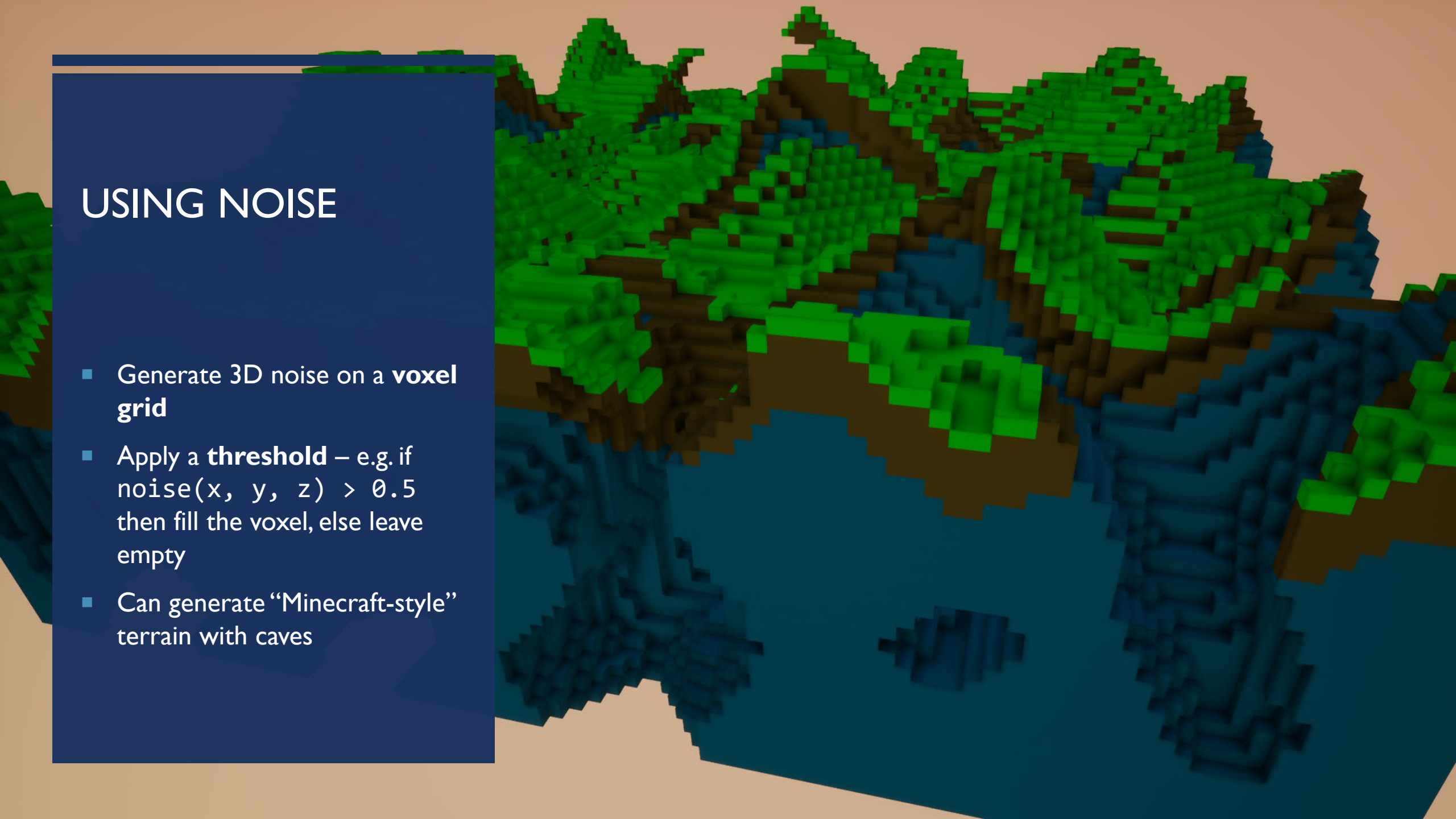
USING NOISE

- 2D noise can be used as a **height map** to generate terrain
- Start with a **2D grid** on the X-Z plane
- Set the **Y value** of each vertex based on the noise value



USING NOISE

- Generate 3D noise on a **voxel grid**
- Apply a **threshold** – e.g. if `noise(x, y, z) > 0.5` then fill the voxel, else leave empty
- Can generate "Minecraft-style" terrain with caves

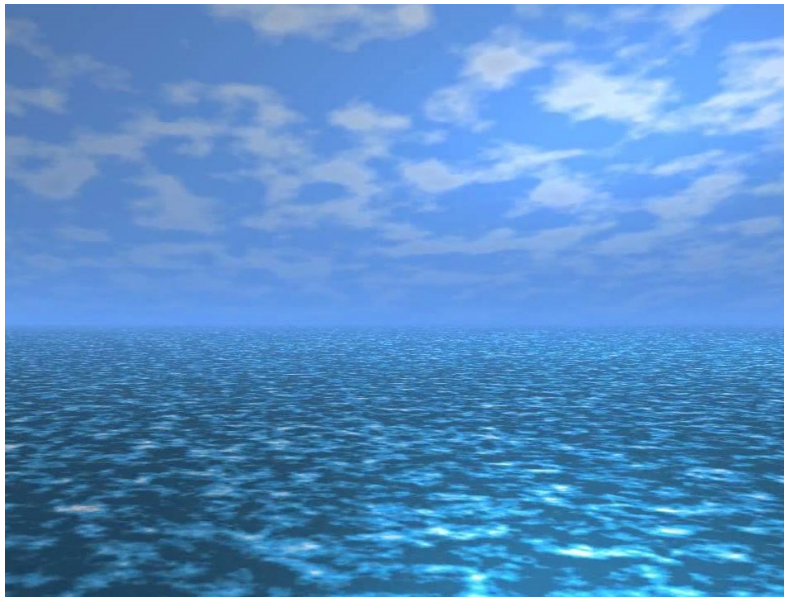


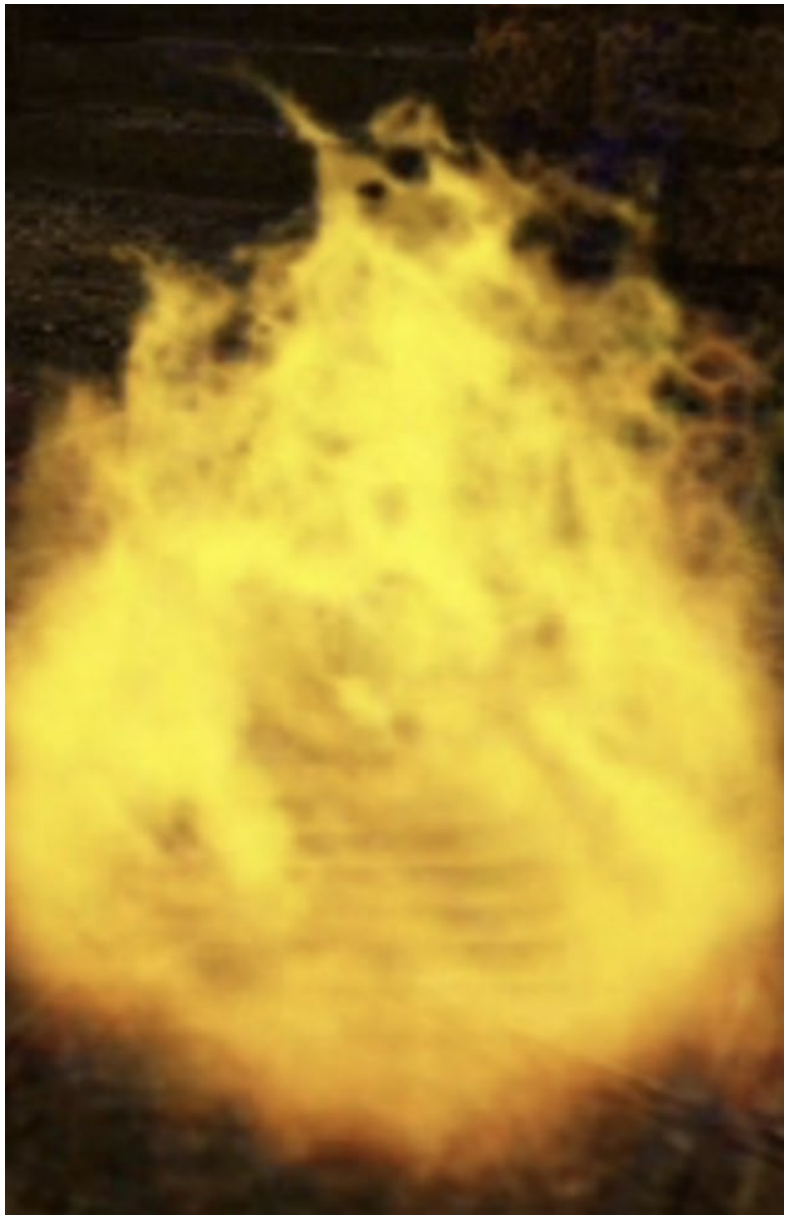
USING NOISE

- Different noise functions can be layered to generate terrain, water, resources, …

USING NOISE

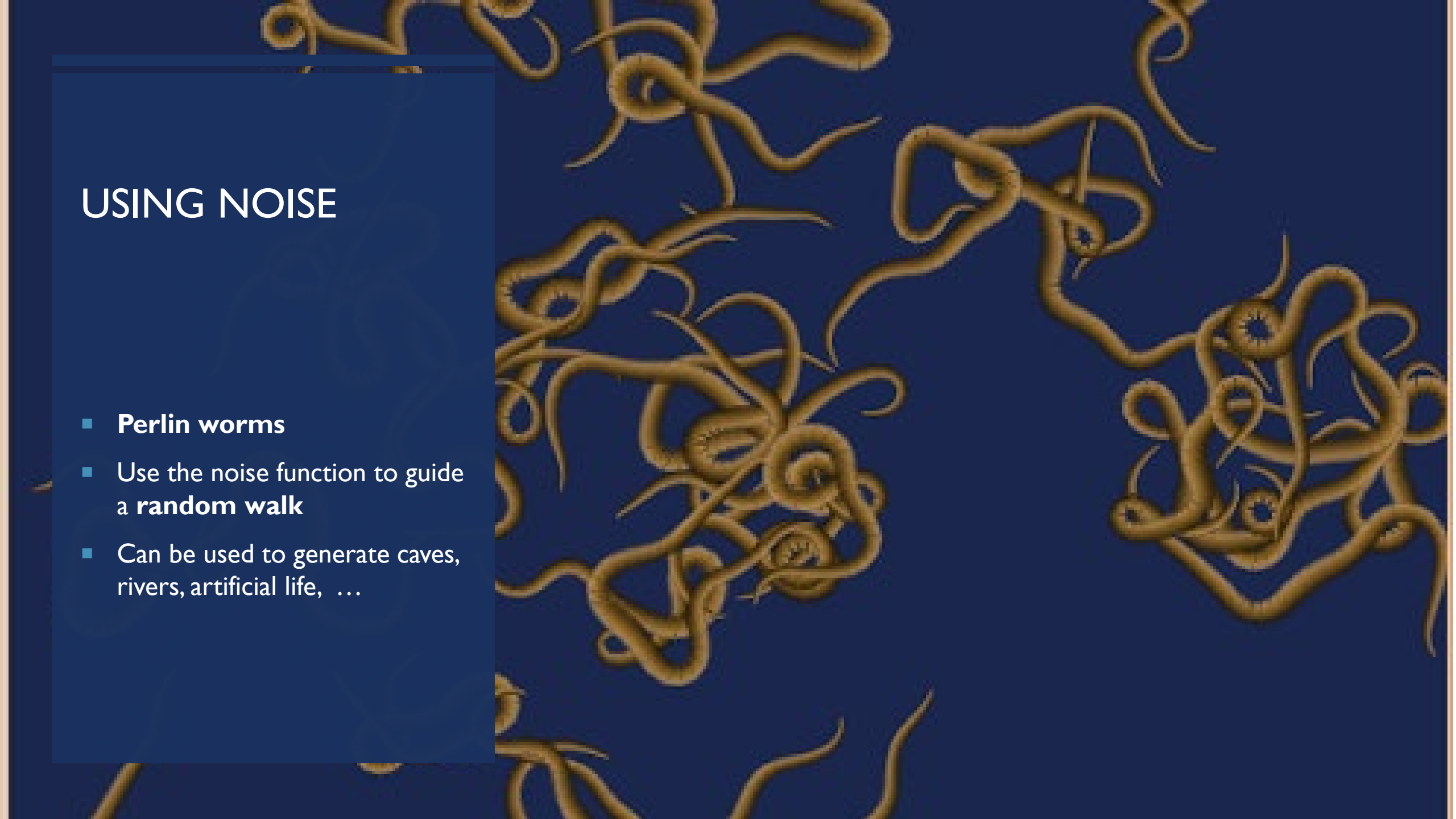
- Many creative uses of noise to generate textures
- Clouds, water, fire, marble, wood, grass, lava, liquid, …





USING NOISE

- **Perlin worms**
- Use the noise function to guide a **random walk**
- Can be used to generate caves, rivers, artificial life, …



N-GRAM MODELS

N-GRAMS

- Consider a **text string**
- An **N-gram** is a sequence of N consecutive characters
- E.g. a 2-gram is a pair of characters, a 3-gram is a triple, etc

I	n	t	e	l	l	i	g	e	n	c	e

2-grams: “In”, “nt”, “te”, “el”, “ll”, “li”, …
3-grams: “Int”, “nte”, “tel”, “ell”, “lli”, …

TRAINING A MODEL

- Given a large set of text, we can count the **frequency** of each possible N-gram
- This is a very basic form of **machine learning**

3-gram	Frequency
ton	156
ham	95
ing	79
ort	57
ord	54
for	53
ley	51
ter	49
on-	41
rth	40
est	39
and	39
sto	38

USING THE MODEL

- Generate a string **iteratively**
- At each step, look at the last N-1 characters
- Frequency table tells us how often each following letter occurs
- Choose next letter at random based on these frequencies

3-gram	Frequency
out	34
oug	29
our	9
ouc	3
ous	2
oul	2
oud	1

ENGLISH TOWNS AND CITIES, N=2

Kile	Daswichin	Dury	Selt Maney	Brerrntomonghone
Bichaxmbyke	Witllesl	Sts	Dan-Fon	Kinhyn
Wan	Soth	Eam	Oshicedbor	Farorsthemetondort Horthers
Cach	Nene	Cale	Telk	Pe

ENGLISH TOWNS AND CITIES, N=3

Gray	Wiveyntinscomyaltongwarighton	Twickham	St Reth Edmandfieleigh	Toth Warle-one
Sandburntword	Amborley	Rowmand	Sough	Mitnabley
Southetford	Whipon	Dary	Ive	Wivey
Bunston Leothet Hareetton	Marthoe	Hykerthes	Easterloughord	Oakeat Ber

ENGLISH TOWNS AND CITIES, N=6

Lichfield	***Medlar with Newton***	Fazeley	***Frinton and Winslow***	Penrith
Malmesbury	Crewkerne	Staines-upon-Thames	Blyth	Alston
Gainsborough	Falmouth	***Burton and Loscoe***	Oakengates	Reading
Wem	Burgh-le-Marsh	Morecambe	Torpoint	Chagford

RPG GAMES, N=4

Under

City

Dunger

Thieveration

Rune

Commission

Fants of the Domin

Fifth Cycle Warrings Alley on Heroughtern

Dangers

Breathworld

Stal Freet Voyage of the 7 Skyrealms of the 23rd Weird RPG

Legave

Rapture Game

Cutthroat: The One Weird is - Time of And Creak: The SpaceTimemastic Role-Playing Game

Fantain

Fearscapes

Mekton's World

Omnighboronicle

Hard of Dark Dunger Suburban Earterning game

Dead

POKEMON, N=3

Shinett	Swagon	Shera	Surk	Miepting
Munid	Raile	Gulayque	Learodur	Whirizior
Fareezormado	Forusharon	Sawsbulbastarcato	Close	Trespra
Woobbuzz	Swakar	Para	Woonfoom	Phime Jr.

“THE ADVENTURES OF SHERLOCK HOLMES”, N=3

“We sons, at ve do way mising,” he tonfeent unithathe ingave whove; I haver at sectes. We to buiether a vould gothe ingust andearematin as larchat a sad I hich so I ingic se-bas wance theiresse thipsell and hat I cout ince.

“THE ADVENTURES OF SHERLOCK HOLMES”, N=10

“You are a benefactor. Are you hungry, Watson, founded upon the table and glanced back at me.” The words of the sill, but I felt a sudden effort, straight into the match, and lashed furiously with his thick red finger planted halfway down Swandam Lane is a vile alley lurking behind us, and send down to the fire. The last straggling houses here. It arrived. I paid the fee was at least a presumption that Colonel Lysander Stark stopped at last.

OTHER USES

- Not limited to generating text – can generate other sequences e.g. music, game levels
- Related technique in 2D/3D: **Wave Function Collapse (WFC)**