Procedural Generation

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What is procedural generation?

**Procedural generation** is a method of creating data (content) algorithmically as opposed to manually. **Deterministic** -> same inputs = same output.

The input of deterministic system is **seed**
Early games

Pitfall 1982 - initially released for Atari 2600

128 Bytes of RAM
4K Byte ROM cartridge

More info: https://www.youtube.com/watch?v=tfAnxaWiSeE
Early games

Pitfall 1982

More info: https://www.youtube.com/watch?v=tfAnxaWiSeE
Early games

Rogue 1980
What can be generated procedurally?

1. Game map
2. ...


We will cover following things:

1. **Content** - items, weapons, characters, animals
2. **Maps** - puzzles,
3. **Procedural geometry**
4. **Noises**
Procedural game content

Typical procedural generation system is made of:
1. **Randomizer** - modifies values using some random input
2. **Constraint system** - sets constraints to the randomizer to make the output logically correct or visually appealing.
Common things to be made procedurally

**Procedural Items** - usually combinations of pre-made objects

Borderlands and Fallout 4 both create weapons procedurally

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<th>Shotguns combat/assault</th>
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Common things to be made procedurally

Procedural characters - Mostly known by Spore and No Man Sky aliens.
Common things to be made procedurally

Procedural characters - Many RPG games allow character customizations.

Often business secret!
Common things to be made procedurally

Procedural characters - https://www.mixamo.com/

But you can’t create unique characters at runtime!
Common things to be made procedurally

Procedural characters
Common things to be made procedurally

Procedural characters -
https://drive.google.com/open?id=0B232TQYJs91cbTFSOE1WYk56Qzg
Common things to be made procedurally

Procedural characters - how it was done
The Sims 4 character generation

Talk: https://www.youtube.com/watch?v=s7R_HHxCokU
Common things to be made procedurally

Procedural color palettes - alter the look of the whole game!
Common things to be made procedurally

Procedural color palettes - How it’s made?

Some theories of color harmony in use!
Common things to be made procedurally

Procedural color palettes - *How it’s made?*

Transform the color space using a lookup texture made procedurally.
Procedural Galaxies

Procedural level design

Level generation:

- Puzzle
- Map
Generating puzzles

Pregenerated puzzle approach:
- **Generator** - generates random rooms
- **Solver** - evaluates the puzzle

**Cons:**
- Doesn’t work in real time
- Needs manual verification in the end

**Pros:**
- Can be applied to any kind of puzzle
- Might create more interesting puzzles than humans do

https://www.youtube.com/watch?v=RLcMvCS4-qY
Generating puzzles

Grammar based approach

Cons:
- Some puzzles can be too easy or hard

Pros:
- Can be used in real time
Procedural level layout

Number of techniques is unlimited!

http://www.nullpointer.co.uk/content/research-info-in-ruins/
Drunkard walk algorithm

http://www.youtube.com/watch?v=I74I_MhZIK8&t=1m0s
Procedural level layout

1. Carcassonne a city building board game
Procedural level layout

Procedural level layout

2. [World Remade](#) - my own game :) -> [Connect the dots puzzle](#)
Procedural level layout

2. World Remade - my own game :) -> Connect the dots puzzle
Procedural map generation

https://watabou.itch.io/medieval-fantasy-city-generator
Procedural map generation

https://azgaar.github.io/Fantasy-Map-Generator/
Multi Level procedural generation

Start from large scale and gradually go into details

https://www.youtube.com/watch?v=GJWuVwZO98s
Procedural geometry

2. Either for altering models or making new models from ground up
Procedural geometry

1. Superformula - nature like structures
Procedural geometry

2. Lindmayer system (L-system)
Procedural geometry

3. **Voronoi diagram** - cut 3D meshes or create artistic structures
Noise

2. Noise - mathematical function -> noise(coordinate) = value
Noises

1. White Noise
Noises

1. **Value noise** - lower frequency
Noises

1. Perlin noise

Simplex noise produces very similar results but is a little bit faster to calculate.
Noises

1. **Voronoi noise** - uses voronoi pattern, cell points are scattered uniformly

   The real knowledge is how to combine and modify those noises.
Working with noises

Example of heightmap generated in GPU using noises:
Working with noises

Another example:
Working with noises

This is how it’s done

\[ \text{simplex}(p) \quad \text{Turbulence} \rightarrow \text{abs}(\text{simplex}(p)) \]
Working with noises

This is how it’s done

\[ \text{billow} \]

\[ \text{ridged} \]

\[ \left| \text{simplex}(p) \right| \]

\[ \Rightarrow \]

\[ 1 - \left| \text{simplex}(p) \right| \]
Working with noises

This is how it’s done

\[ + = \]
Working with noises

This is how it’s done

Another simplex noise to distort

->
Working with noises

This is how it’s done

Or use ridged noise instead
Working with noises

This is how it’s done

Or don’t go rigged, use billow
Working with noises

What about Voronoi?
Procedural tools

Procedural textures

Which one of these is procedurally generated?
Procedural textures

They both are!

https://i.pinimg.com/originals/09/b7/01/09b701daa24f5193086da0ecd52c7a0a.jpg

Many steps forward

https://i.pinimg.com/originals/09/b7/01/09b701daa24f5193086da0ecd52c7a0a.jpg
Advanced landscapes

Sometimes noise is not enough! - thermal, hydraulic, wind erosion?

Procedural generation

What else can you do?
Procedural generation

You have to find it out! Yourself