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** and 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.
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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Procedural characters

Simple object and texture combine.
Procedural charactersy

Aliens (Spore and No Man Sky)
Procedural characters

How spore like aliens can be made.

**Metaball** - an n-dimensional distance function. Thresholding this value defines a solid volume.

\[ \sum_{i=0}^{m} \text{metaball}_i(x, y, z) \leq \text{threshold} \]

Marching cubes algorithm can be used to define the geometry.
Procedural characters

Many RPG games allow character customizations.

It is often a trade secret!
Procedural characters

But you can’t create unique characters at runtime!

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

My implementation of character creation / customization:
https://drive.google.com/open?id=0B232TQYJs91cbTFSOE1WYk56Qzg
Procedural characters

How it was done
The Sims 4 character generation

Technical talk: https://www.youtube.com/watch?v=s7R_HHxCokU
Procedural level design

Level generation:

- Map
- Puzzle
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_MhZlK8&t=1m0s
Procedural level layout

1. Carcassonne a city building board game
Bad North level generation

Generator example: https://oskarstalberg.com/game/wave/wave.html

https://twitter.com/i/moments/1065556549542846464?fbclid=IwAR3z-JjGHukbomv5Zo7UNYsbF1FEVtEc7OdEexTspTiyWCAEgK_-qll22Is
Bad North level generation

Generator example: [http://oskarstalberg.com/game/wave/wave.html](http://oskarstalberg.com/game/wave/wave.html)
[https://twitter.com/i/moments/1065556549542846464?fbclid=IwAR3z-JjGHukbomv5Zo7UNYsbF1FEVtEc7OdEexTspTiyWCAEgK_-qII22Is](https://twitter.com/i/moments/1065556549542846464?fbclid=IwAR3z-JjGHukbomv5Zo7UNYsbF1FEVtEc7OdEexTspTiyWCAEgK_-qII22Is)
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/
Procedural Galaxies

Multi level procedural generation

Start from large scale and gradually go into details

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

Generating puzzles

Grammar based approach

Cons:
- Some puzzles can be too easy / hard

Pros:
- Can be used in real time
Generating puzzles

Generate and solve 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-gY
Procedural geometry

Making and altering 3D models.
Procedural geometry

1. Generative functions like Superformula (Patented)
Procedural geometry

2. Lindenmayer system (L-system)
Procedural geometry

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

4. Noise - mathematical function -> \( \text{noise}({\text{coordinate}}) = \text{value} \)
Noises

1. White Noise
Noises

1. Value noise
Noises

1. Perlin noise

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

1. **Voronoï noise** - uses voronoï 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

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

This is how it’s done

\[ \text{billow} \]

\[ \text{ridged} \]

\[ \text{abs}(\text{simplex}(p)) \]

\[ 1 - (\text{abs}(\text{simplex}(p))) \]
Working with noises

This is how it’s done

\[
\begin{array}{c}
\text{Image 1} \\
+ \\
\text{Image 2} \\
= \\
\text{Result Image}
\end{array}
\]
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

Substance-designer: https://www.allegorithmic.com/products/substance-designer
Procedural textures

Which one of these is procedurally generated?
Procedural textures

They both are!

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