CS/INFO 4154: Analytics-driven Game Design

Class 13: Procedural Content Generation
Procedural Content Generation

- Interesting for both programming and design

Source: Mojang
Today you will learn

- Two bread-and-butter techniques
  - Perlin Noise
  - Grammars
- How Minecraft’s terrain generation works*

*to the extent that has been discussed publicly
Outline

- History
- Techniques for Aesthetics
- Techniques for Structure
Outline

• History

• Techniques for Aesthetics

• Techniques for Structure
Rogue (1980)
1980 – 1996

- A bunch of games I’ve never played

*Nethack* (1987)

Source: www.dlcompare.com
Spore (2008)

Source: spore.wikia.com
Spore (2008)

Source: spore.wikia.com
Spore (2008)
Spelunky (2008)
Elder Scrolls V: Skyrim (2011)

After successfully locating the Ragged Flagon, Brynjolf has given me a new assignment. Three business owners in Riften are proving to be a thorn in his side and I'm supposed to teach them the error of their ways. I should speak to Brynjolf about these townspeople in the event that they prove to be as stubborn as I'm expecting them to be.

**OBJECTIVES**

- (Optional) Steal Haelga's Statue of Dibella
- (Optional) Smash Bersi's prized Dwarven Urn
- Collect Haelga's debt
- Collect Bersi Honey-Hand's debt
- Collect Keerava's debt
FTL (2012)
Clicker Heroes (2014)
Infinite Mario (2008)

Markus Persson
Minecraft (2009)
Challenges

“You’ve just taken a really hard problem and made it harder”
Kate Compton, who worked on *Spore*
Challenges

- Good?
- Fun?
- Beatable?
- Consistent? Is it *always* acceptable?
- Interesting?
- As good as human-designed content?
Outline

- History
- Techniques for Aesthetics
- Techniques for Structure
Pair discussion: Aesthetics

- Describe this scene
  - What is in it?
  - How is it organized?
Idea: Random mountains

- Ugly
- Unstructured
Actual surface of the earth

Source: Google maps
Management of Randomness

more random

Random numbers

more structured
Management of Randomness

more random

Random numbers

Perlin Noise

more structured
Perlin Noise
Perlin Noise Mountains

Source: Giliam de Carpentier
2D mountains
How to make 3D mountains?

Source: Mojang
How to make 3D mountains?
Idea: do this on a grid
Step 1: Random gradients
Step 2: Slopes as vectors
Step 3: Pick a target point
Step 4: Isolate local vectors
Step 5: Get vectors to target point
Step 5: Vectors to target point
Step 5: Vectors to target point
Step 6: Dot products
Step 7: Interpolate

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>.6</td>
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<td>.3</td>
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Minecraft with pure Perlin Noise

Comparison?
Other problem: periodicity
Solution: Octaves
Octaves

https://www.redblobgames.com/maps/terrain-from-noise/
Outline

- History
- Techniques for Aesthetics
- Techniques for Structure
Returning to *Spelunky*
Review: design patterns
Pair activity: what makes a maze valid?
Constraints

- must have an entrance
- must have an exit
- must have a path to get to the exit
- cells have four walls
- walls can be open or closed
- exterior walls (except entrance/exit) must be closed
- can get from cell to adjacent cell if wall is open
Management of Randomness

more random

Random numbers
Perlin Noise
Grammars

more structured
Grammars

S → a

a a
Grammars

\[ S \rightarrow a \mid b \]
Grammars

S → Sb | a

S
Sb
Sbb
abb

S → Sb
S → Sb
S → Sa
Grammars

\[
S \rightarrow Sb \mid a
\]
Grammars

S → aSc
S → b

abc
aabcc
aaabcccc
Individual Check

\[
\begin{align*}
S & \rightarrow X \mid Y \\
X & \rightarrow XX \mid ab \\
Y & \rightarrow YY \mid bc
\end{align*}
\]

\[
\begin{align*}
ab \\
ababab \\
bcbc \\
bcbcbbcbbc
\end{align*}
\]

NOT: ababbbc
Shape Grammar
Shape Grammar
Shape Grammar
Spelunky Level Generation

Source: Derek Yu
Spelunky Level Generation
Spelunky Level Generation

Source: Derek Yu
Spelunky Level Generation

Source: Derek Yu
Spelunky Level Generation

Source: Derek Yu
Spelunky Level Generation

Source: Derek Yu
Problem with grammars

- Individual cells don’t really know about each other
Zelda: Twilight Princess

Source: ZorZelda Youtube
Missions
Graph Grammars
Task → Key → Door

Dormans et al. FDG 2010
How to get this into a space?

Dormans et al. FDG 2010
Idea: combine with shape grammar

Dormans et al. FDG 2010
Returning to *Infinite Mario*
Describe this scene
Management of Randomnessness

more random

Random numbers
Perlin Noise
Grammars
Constraint satisfaction

more structured
LaunchPad

Rhythm

A

B

C

D

Smith et al. TCIAIG 2011
Management of Randomness

more random

Random numbers
Perlin Noise
Grammars
Constraint satisfaction

more structured
Summary

- Procedural content generation
  - enhances design power
  - enables some games (Minecraft)
  - combines programming and design

- Key techniques
  - Perlin Noise
  - Grammars