Think of a game that has randomly generated content? Does it add to or detract from the game?
Minecraft
No Man’s Sky
PCG Use

Random Numbers → Asset Generation

Asset Model → Asset Generation

Pre-defined Assets → Asset Generation

New Game Asset
PCG

Advantages
• Smaller teams
• Storage of assets
• Scaling
• Loading Assets
• Reuse of a few assets
• Human in the loop

Disadvantages
• Repetitive/Boring
• “Computer Generated”
Randomness in Game Assets

- Terrain
- Map, Level, Dungeon etc.
- Items/Weapons
- Dialog
- History
- Difficulty
- Puzzles
Pseudo-Random Number Generators

What does it mean for a process to generate random numbers?

What properties would we like our random numbers to have?
Lehmer RNG

private final int MULT = 28;
private final int MOD = 1013;

private double current;
private int seed;

public double nextDouble(){
    seed = ( MULT * seed ) % MOD;
    return current = ((double)seed)/MOD;
}

public int nextInt(int min, int max){
    int range = max - min;
    return (int)(nextDouble() * range + min);
}
L(28, 1013)
L(30, 1023)
Linear Congruential Generator

\[ X_{n+1} = (a \times X_n + c) \mod m \]

Java’s Random class:

- \( m = 2^{48} \)
- \( a = 25214903917 \)
- \( c = 11 \)

- Output bits: 47..16
“Real” Randomness

DataInputStream in = new DataInputStream(new FileInputStream("/dev/random"));

for(int i = 0; i < 1000; i++){
    System.out.println(in.readByte());
}
Terrain – Height maps

1 1 2 1
1 3 3 1
1 2 2 1
1 1 1 1
Terrain - Random
Terrain – Circular Hills
Terrain – Fault Lines
Particle Deposition
Terrain – Perlin Noise
Terrain - Volumetric

[Dey et al]
Modular Dungeon Generation
BSP Dungeon Generation

[Shaker et al.]
Rooms and Mazes Demo

http://journal.stuffwithstuff.com/2014/12/21/rooms-and-mazes/
No Man’s Sky’s Creatures

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      </Property>
    </Property>
  </Property>
</Data>

[Greg]
No Man’s Sky Creatures
History – Dwarf Fortress

Simulates History: civilizations, wars, religion etc.
History – Caves of Qud

The shrine depicts a significant event from the life of the ancient sultan Uumasp II:

While leading a small army in Forum Province Alep, Uumasp II assassinated the sultan of Qud over an ordinance prohibiting the practice of staining glass. She won and ascended to the crown. She was 6 years old.

Perfect

[Grinblat and Bucklew]
History - Caves of Qud

[Grinblat and Bucklew]
Caves of Qud - Substitution

Acting against #injustice#, #sultanName# led an army to the gates of #location#.⁴

Acting against the prohibition on the practice of taking a spiritual trek through the tundra, Antixerpur led an army to the gates of Minekesh. She sacked Minekesh and persecuted its citizens, forcing them to change its name to Antixerpurplatz.

After treating with cats, Antixerpur convinced them to help her found a dig site in the Philosophers’ Quarter of Shaneruk for the purpose of excavating ancient blocks of ice. They named it the Freezing Dig Site.

At the Battle of Old Teggash, Antixerpur fought to liberate cats. She wielded a frosty hammer with such prowess, that it became forever known as Frosticus Catsfriend.
Generating Dialog for NPCs

Dialog Rules in Ceptre:

\[
\text{change_topic} : \\
\text{turns } (N + 1) * \text{current_topic } T * \text{relevant } T T' \\
* \text{ }$\text{thinks Character (opinion } T' \text{ Sentiment)} \\
-0 \\
\text{current_topic } T' * \text{turns } N.
\]

If there exist terms $N$, $T$, $T'$, and $C$ such that the following constraints are satisfied:
- There are $N + 1$ turns remaining
- The current topic is $T$
- Character $C$ is currently speaking
- $C$ has an opinion about topic $T'$
- $T$ and $T'$ are related

Then the simulation state changes as follows:
- There are $N$ turns remaining (instead of $N + 1$)
- The current topic is $T'$ (instead of $T$)
Generating Dialog for NPC’s

begin_speaking :
    current_topic T * $listening C C' *
    finished_speaking C' * thinks C Statement *
    on_topic Statement T * turns (N+1)
-o
    is_speaking C * hears C' C Statement * turns N.

interrupt :
    turns (N+1) * $is C Type *
    interruptive Type * is_speaking C' *
    $listening C C'
-o
    interrupts C C' * is_speaking C *
    feels C' miffed * turns N.

upset_from_interruption :
    feels C miffed * feels C miffed
-o
    feels C angry.
### Generating Dialog for NPC’s

<table>
<thead>
<tr>
<th>Interpreted Utterance</th>
<th>Ceptre Rule</th>
<th>State Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daphne:</strong> Let’s talk about this house.</td>
<td>initiate</td>
<td>set topic: house; Daphne speaking</td>
</tr>
<tr>
<td><strong>Daphne:</strong> I think it looks nice.</td>
<td>finish speaking with opinion</td>
<td>Daphne finished speaking</td>
</tr>
<tr>
<td><strong>Velma:</strong> It’s decrepit. I—</td>
<td>begin speaking with opinion</td>
<td>Velma speaking</td>
</tr>
<tr>
<td><strong>Fred:</strong> Well, I think—</td>
<td>interrupt</td>
<td>Fred speaking; Velma is miffed</td>
</tr>
<tr>
<td><strong>Velma:</strong> I think it looks awful.</td>
<td>interrupt</td>
<td>Velma speaking; Fred is miffed</td>
</tr>
<tr>
<td><strong>Velma:</strong> And people are saying it’s haunted.</td>
<td>finish speaking with fact</td>
<td>Velma finished speaking</td>
</tr>
<tr>
<td><strong>Fred:</strong> It’s very old.</td>
<td>begin speaking with fact</td>
<td>Fred speaking</td>
</tr>
<tr>
<td><em>(Daphne thinks to herself: I guess it’s not as nice as I thought it was.)</em></td>
<td>positive to neutral opinion</td>
<td>Daphne’s opinion of the house declines</td>
</tr>
<tr>
<td><strong>Fred:</strong> It’s 20 years old.</td>
<td>finish speaking with fact</td>
<td>Fred finished speaking</td>
</tr>
<tr>
<td><strong>Velma:</strong> Fred, is the house old? It shouldn’t look so worn down after such a short time.</td>
<td>question fact</td>
<td>Velma speaking</td>
</tr>
<tr>
<td><strong>Velma:</strong> That’s probably why people are saying it’s haunted—but we all know it isn’t.</td>
<td>question fact</td>
<td></td>
</tr>
<tr>
<td><em>(Fred thinks to himself: maybe Velma is right about the house.)</em></td>
<td>positive to neutral opinion</td>
<td>Fred’s opinion of the house declines</td>
</tr>
</tbody>
</table>
References

1. Minecraft: http://minecraft.wikia.com
2. No Man’s Sky: https://www.nomanssky.com/
Conclusion

• PCG provides tools for creating all sorts of game assets, but be careful.
• Resources are available from scholarly articles to videos to blog posts.
Thank You!