Lecture 14

Procedural Content Generation
In the Beginning, There Was Rogue

0: You (dark) You now have chain mail <13> (g).
                    You dispatched the kobold, catching it unaware.
     Health       You now have a scroll entitled "herba pus flem nidge" (h).
     Nutrition
Str: 12 Armor: 27
Stealth range: 4

!: A blue potion
*: 99 gold pieces

-- Depth: 1 --
          Explore  Rest (z)  Search (s)  Menu  Inventory
In the Beginning, There Was *Rogue*

**Roguelike Genre**
- Classic RPG style
- Procedural dungeons
- *Permadeath*
# A Brief History of Roguelikes

<table>
<thead>
<tr>
<th>Precursors (1978)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Beneath Apple Manor</td>
</tr>
<tr>
<td>- Dungeon (unfamous one)</td>
</tr>
<tr>
<td>Like Rogue, but less famous</td>
</tr>
<tr>
<td>Limited content generation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rogue (1980)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplatform launch</td>
</tr>
<tr>
<td>All very close in playstyle</td>
</tr>
<tr>
<td>Open source development</td>
</tr>
<tr>
<td>Middle Earth themed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Immediate Copycats</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Hack ('82), NetHack ('87)</td>
</tr>
<tr>
<td>- Moria ('83), Angband ('90)</td>
</tr>
<tr>
<td>Massively (~80) multiplayer</td>
</tr>
<tr>
<td>But content less procedural</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Island of Kesmai (1985)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Legends of Kesmai (1996)</td>
</tr>
<tr>
<td>Relaxing RPG requirement</td>
</tr>
</tbody>
</table>

| The Modern Revival |
# Changing Perspectives on Permadeath

## Advantages
- Greater challenge
  - Used as a badge of honor
- Higher emotional stakes
  - Easy to instill fear & horror

## Disadvantages
- Greater discouragement
  - Seen as a personal failure
- Missed game content
  - Cannot progress in story

---

**Permanent Death**
You have but one life, eager hero. If you should die, though your deeds will be remembered, you shall not return again.
Advantages

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Make dying expected & inevitable

Make each session a complete experience
Changing Perspectives on Permadeath

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Content Generation

Permanent Death
You have but one life, eager hero. If you should die, though your deeds will be remembered, you shall not return again.
Issues with Roguelikes

- Design is often **horizontal**
  - Many verbs, game elements
  - Little coupled behavior

- Each play is a **slice**
  - Access to limited elements
  - Work with what you get

- “Expensive” to create
  - Requires a lot of content
  - But historically just text

- Difficult to balance

### Procedural Content

<table>
<thead>
<tr>
<th>WEAPON (Table 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dagger</td>
</tr>
<tr>
<td>orcish dagger</td>
</tr>
<tr>
<td>dagger</td>
</tr>
<tr>
<td>silver dagger</td>
</tr>
<tr>
<td>athame</td>
</tr>
<tr>
<td>elven dagger</td>
</tr>
<tr>
<td>Knife</td>
</tr>
<tr>
<td>worm tooth</td>
</tr>
<tr>
<td>knife (shito)</td>
</tr>
<tr>
<td>stiletto</td>
</tr>
<tr>
<td>scalpel</td>
</tr>
<tr>
<td>crysknife</td>
</tr>
<tr>
<td>Axe</td>
</tr>
<tr>
<td>axe</td>
</tr>
<tr>
<td>battle-axe</td>
</tr>
<tr>
<td>Pick-axe</td>
</tr>
<tr>
<td>pick-axe</td>
</tr>
<tr>
<td>dwarvish mattock</td>
</tr>
<tr>
<td>Short sword</td>
</tr>
<tr>
<td>orcish short sword</td>
</tr>
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**Procedural Content for Modern Games?**

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<tr>
<td><strong>COST</strong></td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>orcish dagger</td>
</tr>
<tr>
<td>dagger</td>
</tr>
<tr>
<td>silver dagger</td>
</tr>
<tr>
<td>athame</td>
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Main Types of Procedural Content

- Simulation
- World Generation
- Puzzle Generation
- Story Generation
- Dynamic Challenges
- Adaptive Difficulty

Procedural Content Wiki: http://pcg.wikidot.com
Simulation

- Complexity appears random
- Often a physical process
  - Fires, Fluids, Weather
  - Terrain generation
  - Artificial life
- **Teleological**
  - Run the full simulation
  - Accurate; hard to control
- **Ontological**
  - Create reasonable output
  - Inaccurate; easy to control
Simulation

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Scientific Computing

Ad Hoc Algorithms
Simulation

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Scientific Computing

Ad Hoc Algorithms

- Minimal effect on gameplay
  - Often largely aesthetic
  - Hard to control difficulty
- Lot of work for little payoff
World Generation

• Often thought of as map generation
  • But really generation of game *geography*
  • Particularly broad category of PCG

• **Basic Format**
  • Start with basic geography building blocks
  • Include combination rules for blocks
  • Build until reach a stopping point

• Algorithms vary widely
Example: NetHack

Izchak the Curator

St:18/11 Dx:16 Co:17 In:18 Wi:18 Ch:17 Lawful
Dlvl:8 $:94041 HP:217(234) Pw:190(195) AC:7 Exp:30
Example: NetHack

Procedural Content
Example: NetHack

Procedural Content
Example: NetHack
Example: Vertical Drop Heroes

- **Movement**
  - Can move left-right
  - Down arrow to stomp/fall
  - Cannot jump at all!

- **Combat**
  - Space to fire weapon
  - Weapon depends on class
  - Free cage to switch class

- **Goal**
  - Collect treasure
  - Reach (a possible) exit
Example: Vertical Drop Heroes
Example: Vertical Drop Heroes

What if a platform were here?
The Reachability Problem

- Levels are effectively graphs
  - Edges are player choices
  - Choices are discretized
  - Fully **connected** (why?)
- PCG might make a graph
  - with a lot of dead ends
  - with a lot of backtracking
  - that is **unconnected**
- Need to remember goal
  - Should always be reachable
  - Else, reset must be painless

Reachability is not just a spatial issue.
Example: Spelunky
Ensuring Reachability

Two Options:

- Limit generation to reachable game states
- Verify goal is reachable or regenerate
Ensuring Reachability

Two Options:

- Limit generation to **possibly** reachable states
- Verify goal is reachable or regenerate
Grammars: A Formal Approach

- **Notation**
  - Set $\mathcal{N}$ of nonterminals
  - Set $\Sigma$ of terminal symbols
  - Set $\mathcal{P}$ of production rules
    - Have the form $A \Rightarrow B$
    - $A$, $B$ are words of symbols
  - To generate a value
    - Start with word $XAY$
    - Pick any rule $A \Rightarrow B$
    - Replace with $XBY$
    - Repeat until only terminals

- **Example**
  - $\mathcal{N} = \{ S, B \}$
  - $\Sigma = \{ a, b, c \}$
  - $\mathcal{P}$ is the list of rules
    - $S \Rightarrow aBSc$
    - $S \Rightarrow abc$
    - $Ba \Rightarrow aB$
    - $Bb \Rightarrow bb$
  - Possible outputs
    - $abc$, $aabbcc$, $aaabbbcccc$, …
Grammars on Graphs

- Symbols are colored nodes
  - Either terminal or not
  - Edges replace word order
- Words are now graphs
  - Productions on subgraphs
  - LHS is node+boundary
  - RHS alters the node
- Output built as before
  - But rule matching harder
  - Graph equivalency
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**Game Geography is a graph**

- LHS is node + boundary
- RHS alters the node

- Output built as before
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  - Graph equivalency
Puzzle Generation

- Basic puzzle structure
  - Discrete actions/moves
  - Moves applied in sequence
  - **Goal**: get correct sequence

- Identify move sequences
  - Could be a loose category
  - Represent specific strategies

- Build up from sequences
  - Start from solved state
  - Invert moves (scrambling)

- Will require verification
Example: Lyne
Example: Lyne

Backtrack Pattern
Story Generation

- **Narrative** is tightly crafted
  - Must have emotional arc
  - Very hard to generate

- But **backstory** is looser
  - Collection of tales/subplots
  - Combine to form a story
  - Often displayed in a codex
  - Much easier to generate

- **Idea**: Create list of subplots
  - Pick some subset at a time
  - Mix with NLG techniques
Example: Dwarf Fortress
Natural Language Generation

• Function that outputs language
  • **Given**: complex set of data
  • **Outcome**: comment on data
  • Major area of CS research

• Comment requirements
  • Must be **simpler** than data
  • Should also be **natural**

• **Examples**
  • Sports commentary
  • Party combat chatter
  • Intelligent townsfolk
Often a set of “canned” text
- React to specific events
- NPC picks text as appropriate

Text is \textit{parameterized}
- “What do we do, <name>?”
- “Someone killed <monster>!”
- “That was <numb> days ago.”

Choosing text to say
- Favor important events?
- Favor recent events?
- Random (pull-toy)?
Skyrim’s Radiant Quest System

- Geography includes NPCs
  - Mobile, removable location
  - Dialogue is also a space
- System “randomly” chooses
  - Quest giver
  - Quest location
  - Location’s challenges
  - Quest redeemer
- Randomness is limited
  - Lists appropriate to quest
  - Depends on earlier actions

- Goals:
  - Send to unexplored areas
  - Adjust challenges to level
  - Can never be missed
- Largely a success
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Guarantees
- reachability
- unexplored areas
- Adjust challenges to level
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Dynamic Challenges

- Challenges that can change
  - Become easier or harder
  - Just be different

- **Example**: Autoleveling
  - NPCs have statistics
  - Adjust to character level
  - Difficulty always reasonable
  - Allows true “open” world

- Not always popular
  - Can lead to design recycling
  - Sense of risk is lost

---

<table>
<thead>
<tr>
<th>ATK</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFN</td>
<td>0</td>
</tr>
<tr>
<td>HP</td>
<td>5</td>
</tr>
</tbody>
</table>

**Rat: Level 1**

<table>
<thead>
<tr>
<th>ATK</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFN</td>
<td>1</td>
</tr>
<tr>
<td>HP</td>
<td>9</td>
</tr>
</tbody>
</table>

**Rat: Level 50**
Other Types of Dynamic Challenges

- **Composite Challenges**
  - Encounter is a collection of NPCs, obstacles
  - Add or remove individuals from encounter

- **Dynamic NPC AI**
  - NPCs have a choice of AI scripts
  - Choose one that matches the player

- **Player Boosting**
  - Change result of player actions, interactions
  - Modifications make challenges easier/harder
Assigning Dynamic Challenges

Player

Challenge

Extract feature vector from play history

Match the challenge to the play style

Parameterize challenge difficulty

Procedural Content

$$(a_1, a_2, a_3, \ldots, a_n)$$

$$(b_1, b_2, b_3, \ldots, b_k)$$
Assigning Dynamic Challenges

Player

Challenge

Extract feature vector from play history

Match the challenge to the play style

Parameterize challenge difficulty

Matching Function is hardest to balance

(a₁, a₂, a₃,…, aₙ) → (b₁, b₂, b₃,…, bₖ)

Procedural Content
Adaptive Difficulty

Player

Challenge

Extract feature vector from play history

Match via machine learning

Parameterize challenge difficulty

\((a_1, a_2, a_3, \ldots, a_n)\) \rightarrow \text{Match via machine learning} \rightarrow \text{Parameterize challenge difficulty} \rightarrow \((b_1, b_2, b_3, \ldots, b_k)\)
Adaptive Difficulty

• Manually define the **gameplay model**
  - Metrics that identify player behavior
  - Parameters that define challenge behavior
  - Also metrics to evaluate player success or failure

• **Goal**: Use learning to find player-challenge match-up
  - Use playtesting/beta to get a large training set
  - Create an initial model from these results
  - Adjust in the game according to current player

• Still largely an academic exercise
Summary

- Procedural content started with Rogue(likes)
  - Tightly coupled with permadeath, horizontal design
  - Becoming fashionable once again

- Many applications to modern game design
  - World Generation
  - Puzzle Generation
  - Story Generation
  - Dynamic Challenges