Lecture 6

Uncertainty & Risk
Uncertainty and Risk

- **Risk**: outcome of action is uncertain
  - Perhaps action has random results
  - May depend upon opponent’s actions
    - Need to know what opponent will do

- Two primary means of risk in a game
  - Chance and *randomness*
  - Imperfect *information*
Uncertainty ≠ Skill

• Outcomes may depend on player skill
  • Hand-eye coordination challenges
  • Reaction-time/twitch challenges
  • Knowledge of optimal strategies

• Varying skill level → uncertain outcomes
  • But challenges themselves are predictable
  • Player can train at challenge over time
  • Not the subject of this lecture
Randomness in Games

• Pure randomness is not a good game
  • Remember coin flipping
  • Player has no *meaningful choice*

• But many games *are* random
  • *Candyland, Snakes & Ladders*
  • Poker, other forms of gambling
  • Tetris and other matching, stacking games
Randomness: Candy Land
Randomness with Choice

- Tetris pieces are random, but
  - Have a choice in how to position them
  - “Hedge your bets” to prepare for bad drops

- RPG combat is die roll influenced by
  - Armor the defender wears
  - Weapons the attack uses
  - Combat maneuvers employed
Randomness with Choice

Uncertainty & Risk
Pig: A Random Game

- Play progresses clockwise
- On your turn, throw the die:
  - If roll 1: lose turn, score zero
  - Anything else: add it to score
    - Can also roll again (and lose)
    - If stop, score is “banked”
- First person to 100 wins.
Strategic Randomness

- Pig has meaningful choice
  - Player can choose to bank
  - Risk nothing for a higher score

- How is the choice meaningful?
  - Certain decisions are better than others
  - Certain decisions are more fun than others
  - Psychological effect on other players
Expected Value

- Outcome of actions is never the same
  - But the sum averages out over many tries
  - Strategy: compare average outcomes

- **Expected Value** = outcome $\times$ % success
  - If many outcomes, sum them together
  - Example: Average die roll is 3.5
    \[1\times\frac{1}{6} + 2\times\frac{1}{6} + 3\times\frac{1}{6} + 4\times\frac{1}{6} + 5\times\frac{1}{6} + 6\times\frac{1}{6} = 3.5\]

- Only applies if can do action *repeatedly*
## Expected Value of Pig

<table>
<thead>
<tr>
<th># Throws</th>
<th>Survival</th>
<th>Expected Gain</th>
<th>Expected Value</th>
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<tbody>
<tr>
<td>1</td>
<td>83%</td>
<td>3.33</td>
<td>3.33</td>
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<tr>
<td>2</td>
<td>69%</td>
<td>2.78</td>
<td>6.11</td>
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<tr>
<td>3</td>
<td>58%</td>
<td>2.32</td>
<td>8.43</td>
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<tr>
<td>4</td>
<td>48%</td>
<td>1.92</td>
<td>10.35</td>
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<tr>
<td>5</td>
<td>40%</td>
<td>1.61</td>
<td>11.96</td>
</tr>
<tr>
<td>6</td>
<td>33%</td>
<td>1.34</td>
<td>13.30</td>
</tr>
<tr>
<td>7</td>
<td>28%</td>
<td>1.12</td>
<td>14.42</td>
</tr>
<tr>
<td>8</td>
<td>23%</td>
<td>.93</td>
<td>15.35</td>
</tr>
<tr>
<td>9</td>
<td>19%</td>
<td>.77</td>
<td>16.12</td>
</tr>
<tr>
<td>10</td>
<td>16%</td>
<td>.65</td>
<td>16.77</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>50</td>
<td>0.01%</td>
<td>0.0004</td>
<td>19.998</td>
</tr>
</tbody>
</table>
Expected Value and *Warcraft*
Psychology of Randomness

- Players favor **longshots**
  - Rare event that has very high payoff
  - Will work towards it even if not optimal
  - Especially if failure is cheap

- Players have “Monte Carlo syndrome”
  - After a bad run, expect a good result
  - Otherwise, the game is “unfair”
Psychology of Randomness

• **Payoff** influences the perception
  • Players remember events with bigger payoff
  • Will think it is “more likely”
  • Even if two events equally likely

• **Corollary**: Lightning never strikes twice
  • A bad outcome is unlikely to happen again
  • A good outcome will probably happen again
Psychology of Nonrandomness

- Players can view the nonrandom as random

- **Example**: paper-scissors-rock

![Diagram of Paper, Scissors, and Rock]

- Paper beats rock
- Scissors beat paper
- Rock beats scissors

Uncertainty & Risk
Psychology of Nonrandomness

• Players can view the nonrandom as random

• **Example**: paper-scissors-rock
  • Opponent is *uncertain*, not *random*
  • But there is no choice is better than others
  • How do you choose?

• Any game with heavy negative feedback

• “*Random*” = lack of meaningful choice
Instability vs. Random

- **Physics** can be sensitive!
  - Small input change = big output change
  - Games can “feel random”

- **Instable challenges**
  - Difficult to repeat success
  - Very difficult to tune
  - But popular trend in modern puzzle games
Imperfect Information

- Player may lack information about that game
  - May not know complete game state
  - May not know all of the rules
- Can reason about *likelihood*
  - Rules eliminate certain possibilities
  - Model opponent psychology
  - But less precise than probability
Example: Fog of War
Making Information Imperfect

• Hide information
  • Fog of war
  • Hidden moves
  • Hidden die rolls

• Generate random noise
  • (Partial) scanner jamming
  • Inaccurate troop measurements
Information Types

• Information known to all players
• Information known to one player
• Information known only to the game
  • **Example**: the next card in a deck
• Randomly generated information
  • **Example**: die rolls
Information in Clue
Computers and Information

• Very good at managing information
  • Can easily hide information from players

• Can hide very complex information
  • Humans have hard time hiding and managing
  • Also, too easy to cheat if hidden

• Particularly good at
  • Information known only to one player
  • Information know only to the game
Randomness vs Imperfect Information

- Randomness used heavily in board games
  - Nice way to introduce uncertainty/risk
  - Easier to manage than imperfect information

- But not as important for computer games
  - Imperfect information is easy to manage
  - Complex rules (physics) may seem random

- **Deterministic** rules are easier to tune
  - Even board games realize this (*Puerto Rico*)
## Digital vs. Nondigital Games

<table>
<thead>
<tr>
<th>Digital Games</th>
<th>Nondigital Games</th>
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</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>- Hiding Information</td>
<td>- “House Rules”</td>
</tr>
<tr>
<td>- Complex mechanics</td>
<td>- Portability/life span</td>
</tr>
<tr>
<td>- Long-distance play</td>
<td>- Multiplayer psychology</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>- Adaptability</td>
<td>- Complex mechanics</td>
</tr>
<tr>
<td>- Product life span</td>
<td>- Hidden information</td>
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Summary

• Uncertainty and risk are **important**
  • Otherwise player is (eventually) unchallenged
  • No possibility of strategic choice

• Ways of introducing uncertainty/risk
  • Through skill-based challenges
  • Through randomness
  • Through incomplete information
  • Latter is primary strength of computers