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: Poker
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 in RPGs
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 × % 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>
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<td>3</td>
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<td>4</td>
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<td>1.92</td>
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<td>5</td>
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<td>1.61</td>
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<tr>
<td>7</td>
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<td>1.12</td>
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<td>8</td>
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<td>.93</td>
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<tr>
<td>9</td>
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<td>.77</td>
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<tr>
<td>10</td>
<td>16%</td>
<td>.65</td>
<td>16.77</td>
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<td>…</td>
<td>…</td>
<td>…</td>
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<tr>
<td>50</td>
<td>0.01%</td>
<td>0.0004</td>
<td>19.998</td>
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</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
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 \textit{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 known 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

Digital Games

- Advantages
  - Hiding Information
  - Complex mechanics
  - Long-distance play

- Disadvantages
  - Adaptability
  - Product life span

Nondigital Games

- Advantages
  - “House Rules”
  - Portability/life span
  - Multiplayer psychology

- Disadvantages
  - Complex mechanics
  - Hidden information
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