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 with Choice
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.
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>
<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>
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<tr>
<td>6</td>
<td>33%</td>
<td>1.34</td>
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<tr>
<td>7</td>
<td>28%</td>
<td>1.12</td>
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<tr>
<td>8</td>
<td>23%</td>
<td>.93</td>
<td>15.35</td>
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<tr>
<td>9</td>
<td>19%</td>
<td>.77</td>
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<tr>
<td>10</td>
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<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>
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Expected Value and RTS Games
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
Benefits of Randomness

• Randomness can improve **replayability**
  • Similar actions ≠ similar outcomes
  • Player must adapt if actions fail to pay off
  • Encourages wider exploration of game space

• Basis of modern **RogueLite** movement
  • Content is randomly generated/experienced
  • Each playthrough feels fresh and different
  • But level design is very difficult (**later**)
Should Your Game Have Randomness?

• Do you want to **emphasize strategy**?
  • Common in real-time/turn-based strategies
  • Pay-offs are a strategic cost-benefit decision
  • Randomness keeps strategies from being dominant

• Do you want to **simplify complex systems**?
  • Randomness is often an alternative to **simulation**
  • Makes complete sense in board game setting
  • But computers are good at simulation, so why?
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

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Will return to this with prototyping
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