Game Balancing

CS 2501 – Intro to Game Programming and Design

Credit: Some slide material courtesy Walker White (Cornell)
Dungeons and Dragons

• D&D is a fantasy roll playing system
• Dungeon Masters run (and sometimes create) campaigns for players to experience
• These campaigns have several aspects
  – Roll playing
  – Skill challenges
  – Encounters
• We will look at some simple balancing of these aspects
Probabilities of D&D

- Skill Challenge
- Example: The player characters (PCs) have come upon a long wall that encompasses a compound they are trying to enter
- The wall is 20 feet tall and 1 foot thick
- What are some ways to overcome the wall?
- How hard should it be for the PCs to overcome the wall?
Probabilities of D&D

• How hard should it be for the PCs to overcome the wall?
• We approximate this in the game world using a Difficulty Class (DC)

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Probabilities of D&D

- Easy – not trivial, but simple; reasonable challenge for untrained character
- Medium – requires training, ability, or luck
- Hard – designed to test characters focused on a skill

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Balancing

• Balancing a game is can be quite the black art
• A typical player playing a game involves intuition, fantasy, and luck – it’s qualitative
• A game designer playing a game... it’s quantitative
  – They see the systems behind the game and this can actually “ruin” the game a bit
Building Balance

• General advice
  – Build a game for creativity’s sake first
  – Build a game for particular mechanics
  – Build a game for particular aesthetics

• Then, after all that...
  – Then balance
  – Complexity can be added and removed if needed
  – Other levers can be pulled

• Complexity vs. Depth
What makes a game balanced?

• When evaluating a game for balance, we typically look at three aspects:
  – Fairness
  – Stability
  – Engagement
Fairness

• A game is considered fair if each of an evenly matched group of players has an a priori equal chance of winning for any given starting position

• In a normal fair game for two players, each player should win about 50% of the time with both players playing at the same level
Fairness

• What does it mean for two players to be equally matched?
Fairness

- What does it mean for two players to be equally matched?
  - Similar heuristics
  - Ability to search the outcome tree the same distance ahead
  - Knowledge of probabilities
What’s the Probability of Winning?

• Consider older games
• Consider modern games
• What’s the probability of winning?
• How does save games affect this probability?
The “Going First” Problem

• A traditional problem in fairness is the “who goes first” problem
• Assume you have a game in which the player that goes first wins 2/3 of the time
• How would you fix this problem?
The “Going First” Problem

- Rotate who goes first
  - Who lost last game?
  - Randomize
  - Age / skill
- Disadvantaged player gets some extra resources
- Reduce effectiveness of the first turn
  - Limited move set
Reinforcing Behaviors

• As players do things in games, we want to either reinforce or punish certain behaviors to establish appropriate balance and pacing
• Positive feedback encourages a behavior to be repeated in the future
• Negative feedback discourages a behavior to be repeated in the future
• Adjusting feedback adjusts the game balance
Reinforcing Behaviors

- Consider basketball
  - When you scores, the other team gets the ball
  - This is negative feedback
  - We don’t want a team to be able to get ahead too quickly

- Consider Mario Kart
  - When you’re in the lead, you get crappy items
  - This is negative feedback
  - Rubber-bandining is also negative feedback
Reinforcing Behaviors

• Consider RPGs
  – If you use a sword a lot, it might level up
  – Leveling up a sword makes it hit harder or more accurately
  – If the sword is better than the axe, you’ll use it more
  – This is positive feedback
Reinforcing Behaviors

• Both types of feedback have their own place in games
• We use different feedbacks to move players along or to increase challenge
Stability

• A game is considered stable if:
  – Feedback is negative at the opening, slightly positive at midgame, and very positive at endgame
  – It has multiple viable strategies to win (called stable Nash equilibria)
Stability Curve

A feedback curve for a two-player game.
Curve of Progression

Game Duration

Player Advantage

A

B
No Feedback Provided
Curve of Progression

Player Advantage

Game Duration
Too Little Positive Feedback

![Graph showing player advantage over game duration](chart.png)
Curve of Progression
Too Much Positive Feedback
Curve of Progression

Player Advantage vs. Game Duration
Powerful Negative Feedback
Curve of Progression

![Graph showing player advantage over game duration](image)

*Player Advantage* vs *Game Duration*
Ideal Game Progression

Game Duration

Player Advantage

A

B
Multiple Strategies

• For good balance (and for engagement), there should be multiple ways to reach the win condition
  – Doesn’t necessarily mean there needs to be multiple win states, but that can be done as well

• We can mathematically reason about winning outcomes

• Def of “utility” = anything used to measure progress toward victory
Multiple Strategies

- Player optimal outcome - my utility is as high as possible
- Pareto optimal outcome - my utility cannot increase without decreasing another player's
- Equitable outcome - everyone's utility is the same and as high as it can be
- Efficient outcome - the sum of everyone's utility is as high as it can be
- Nash optimal outcome - my utility is as high as it can be, given other players played to their own interests
Multiple Outcomes

• Some of these outcomes are not necessarily feasible for all games
• Some require at least one player to play to lose
• Nash optimal is the most common as it assumes all players are playing to win and your ability to win is limited by how well others play (to some degree)
Thinking Down the Tree
Thinking Down the Tree

• When players play this game, they use a minimax algorithm working backward from the optimal outcomes for their goal
• This is a zero-sum game, where one score affects the other
• The only real outcome here is a tie if players are playing rationally
• Thus the game is not balanced because there is only one possible outcome
Differences in Scale vs. Kind

• Why does this matter?
• How does this play into engagement?
Randomness

- Computers are actually horrible at being truly random
- Which is both good and bad
- Bad for security purposes
- Good for networked games to have the same state without transmitting that state
- Probability of any value is written as $P(x)$
Traditional Randomness

• Cards and dice are still used as metaphors for randomness
• (and non-metaphors...)
• We still uses these items in both board and video games for randomness
Cards and Dice

• Card notation:
  – 4S – 4 of Spades
  – AH – Ace of Hearts

• Dice notation
  – xdn, where x is the number of dice to roll and n is the number of sides on each dice
  – 2d6 – roll 2 6-sided dice, values will be 2-12
  – 3d8+4 – roll 3 8-sided dice and add 4 to the result, values will be 7-28
The Outcome Tree

- We can calculate the probability of any random event by working out the outcome tree and counting the possibility
- Monte Carlo simulations run the function for a large number of times and using that to determine percentages
Dice Expected Values

- $E(1d4) = 2.5$
- $E(1d6) = 3.5$
- $E(1d8) = 4.5$
- $E(1d10) = 5.5$
- $E(1d12) = 6.5$
- $E(1d20) = 10.5$
Probabilities of Catan

• Let’s look at the math of Catan to figure out how probabilities play into the game

• Quick overview of the rules of Settlers of Catan
  – http://www.catan.com/service/game-rules
Probabilities of Catan

• It’s actually pretty easy to know what’s the “best” option
  – Just add up the dots!

• Probability and randomness plays a HUGE role in Catan working “correctly.”

• What about games in which probability and randomness is the entire game?
Chutes and Ladders
Chutes and Ladders

• The game is ALL RANDOM.
• But a video game that is ALL SKILL can eventually get boring!
  – You’ve learned every pattern
  – You’ve seen every level and enemy
  – Nothing varies!
• We need to consider games that have some aspects of both!
Why do people gamble?

• Let’s face it – gambling in Vegas is a losing proposition
• Over time, everyone loses money
• But in the (very) short term, it’s definitely possible to win
• And besides – risk and uncertainty can be a lot of fun!
Psychology of Randomness

• Player’s like longshots!
  – How many times have you gone for the “super move” to win the game?
  – Even if it’s a low probability, players will optimize for it!

• Player’s suffer from too much Monte Carlo
  – “Oh, I’ve gotten bad results for so long... a good card/good roll has to come up soon!”
  – Probability does not care what the last roll was, but players will think the game is “unfair” otherwise!
Psychology of Randomness

• But think about it another way – I bet you remember those big payoff moments

• And THAT’S what gets you coming back to a game!
Other Forms of Risk

• Imperfect information can add to the challenge/risk in a game without as much randomness

• Perhaps you don’t know everything about the game state
  – Either AI or another player

• Perhaps don’t know about the game might change
Fog of War - Partial
Fog of War - Total
Information Types

• Info known to all players
• Info known by one player
• Info known by the game only
  – Some game state information, like next card in the deck
• Info unknown
  – Next random number to be generated
Difference Between Video and Board

• Table top games rely on randomness to work
  – Information that the game only knows can be hard to manage
  – D&D does this through a Dungeon Master

• However, while computers aren’t as good at randomness, they are fantastic at managing information

• Implementation and adherence to rules also varies greatly