Game Theory and Game Balance

EECS 494

10/30/06 by J. Laird and Sugih Jamin

Based on a talk by Michael van Lent
Game Balance

Three kinds of game balance:

• Player/player
  • A player’s performance is based on skill (and a little luck)
    • Races are balanced in StarCraft
    • Characters are balanced in fighting games

• Player/game
  • A player shouldn’t find the game too hard or too easy to win
    • Difficulty of puzzles in adventure games
    • Number of monsters in action games

• Cost/power
  • A game feature’s cost must match its power
    • Broodwar adjusted the cost/power balance of many units
Approaches to Game Balance

• Ensure that a few random elements don’t determine outcome
  • Skill matters

• Symmetry isn’t much fun
  • All players have identical choices
  • Features identical except for 2 parameters (power and cost)

• Good gameplay involves a variety of interesting choices
  • In Starcraft players choose from three races
    • Each race has 13 types of units, 18 buildings, special powers and weaknesses
    • Huge variety of strategies

• Need to insure that no race or strategy is unbeatable
  • Rock - Paper - Scissors model
  • Game Theory
  • Lots of playtesting
Game Theory

• What is game theory?
  • Field of economics/mathematics
  • Also psychology (Theory of Social Situations)
  • Mathematical theory of bargaining or action selection
  • Cooperative and Non-cooperative

• Attempt to find a set of strategies that will maximize my payoff no matter what my opponent does
  • Assumes rational players (you and the opponent)
  • Assumes each player knows everything about the game
  • Assumes the “payoff” is a complete measure of worth
  • A strategy is a complete plan for playing the entire game
# Prisoner’s Dilemma

(years in jail)

<table>
<thead>
<tr>
<th></th>
<th>Don’t confess</th>
<th>Confess</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t confess</td>
<td>A=1; B=1</td>
<td>A=10; B=0</td>
</tr>
<tr>
<td>Confess</td>
<td>A=0; B=10</td>
<td>A=5; B=5</td>
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Prisoner’s Dilemma

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• What strategy should A choose to minimize jail time?
  • Confess = less jail time no matter what the other person does
    • Nash Equilibrium
  • If both players work together each gets only 1 year
  • But can you trust the other player?

• Example of Public Goods Problems
  • Giving to charity
  • Pricing between companies
  • Social Security
Game Theory for Game Balance

- Game theory insures that no “strategy” is dominant
- Payoff matrix

<table>
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<th>Paper</th>
<th>Scissors</th>
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<tbody>
<tr>
<td>Rock</td>
<td>0</td>
<td>+1</td>
<td>-1</td>
</tr>
<tr>
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<td>-1</td>
<td>0</td>
<td>+1</td>
</tr>
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- Zero Sum game
  - One player’s loss is another player’s gain
- No single best strategy (no dominant)
  - Each column sums to zero
  - Optimal strategy is a mixed strategy (choose randomly)
What if different moves have different costs?
• Each move bets money - winner takes all (Zero Sum)
  • Rock: $3, Paper: $2, Scissors: $1
• Player B plays paper and player A plays rock
  • Player B outcome: +$3
  • Player A outcome: -$3
  • Player B ends up $6 ahead

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<tbody>
<tr>
<td>Rock</td>
<td>0</td>
<td>+6</td>
<td>-2</td>
</tr>
<tr>
<td>Paper</td>
<td>-6</td>
<td>0</td>
<td>+4</td>
</tr>
<tr>
<td>Scissors</td>
<td>+2</td>
<td>-4</td>
<td>0</td>
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Optimal strategy (Nash Equilibrium) is mixed
• paper and scissors more frequently chosen
• must still choose rock occasionally
## Starcraft Balance

<table>
<thead>
<tr>
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<th>Human Wins</th>
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Alpha Centauri

• 9 vehicle types

• Dominance determined by
  • Who attacks first
  • Terrain of attacks
  • State of vehicle (in air or on ground)
  • Morale of vehicle
  • Weapon (10 levels) and shielding (8 levels) technology
Fighting Game Balance

• Soul Caliber has 12 characters each with about 100 moves
  • How to be sure no character dominates another?

• Create a bunch of huge game matrices
  • One matrix for each pair of characters
  • Each move is a strategy

• Make sure the optimal strategy is mixed in each case
  • Can’t win by repeating a single “unbeatable” move
Game Theory and Computer Games

• Classical game theory has limited applications
  • Far too many “strategies”
  • Usually hidden information
  • Can be used for game balance

• Combinatorial game theory
  • Assumes sequential moves
  • Still requires no hidden information
  • Applies to parlor games
    • Chess
    • Checkers
    • Go
    • Connect 4 (Solved)

• Interactive games have too many “moves” in any situation
Game Trees

- Represent a game as a tree
  - Nodes are game states
  - Branches are moves
  - Leaves are wins/losses

- Choose next move by searching the tree
  - Search n levels deep
    - n depends on time available
  - Evaluate board positions
  - Propagate evaluations up
MiniMax

My Move: Maximize
Opponent Move: Minimize

My Move: Maximize
Opponent Move: Minimize
My Move: Maximize

Complication: what evaluation function to use?
Alpha Beta Pruning

My Move: Maximize (\( \geq \) alpha)

Opponent Move: Minimize (\( \leq \) beta)

Complication: horizon effect, can’t see far enough
Making a “fun” racing game

- As designers, we want to recreate racing, not just driving around on a track
- Competition is a crucial part of that
- Need to increase likelihood of a close race
- So we could count on players getting good or, essentially, we could cheat
How do we cheat well?

• We have to slow the front, speed the back
• Easiest way is just with speed
  • Cars in front slow down, in back, speed up
• This can be very obvious to players
  • Violate “fairness” and “consistency”
• And, worse, risks removing player feel of interaction
Dynamic Difficulty Adjustment

- This is a fairly well studied thing
- Game monitors player behavior
- As player struggles, game changes to try and help the player through it
- If player does well, game becomes harder
- Examples?
Risks of DDA approaches

• It seems obvious adaptive models are better for tuning an experience

• However, if a player realizes they are involved, they can exploit them

• Slowing down until the end of the race, for instance
Players use the rules

Players learn to win at the provided rule-system, not the ideas in your head

• They don’t learn the manual
• They don’t play what you thought was cool
  • If the way to “win” is to fight, you can say “hide” all you want, but they will fight
• They don’t only do “reasonable” things
• They poke and prod the systems, and exploit any weaknesses they can find
  • If there are bugs in the rules, they will find and exploit them, even if they enjoy it less