Game Balancing

Max jump height

Max jump length
Setup

@Helge: Pressed record?

@Class: Logged into iClicker cloud?
Scenes have multiple coordinate systems

• Often strongly related
  • Parts of the body
  • Object on top of each other
    • Next to each other…

Independent definition is bug prone

Solution: Transformation Hierarchies
Recap: Transformation Hierarchy Examples
Recap: Transformation Hierarchy Examples

\[ M_1 = T_{r(x,y)} \cdot \text{Rot} \theta_1 \]
\[ M_2 = M_1 \cdot T_{r(2.5,5.5)} \cdot \text{Rot} \theta_2 \]
\[ M_3 = M_2 \cdot T_{r(0,-3.5)} \cdot \text{Rot} \theta_3 \]
Recap: Transformation Hierarchies

world

<table>
<thead>
<tr>
<th>torso</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUleg</td>
</tr>
<tr>
<td>RUleg</td>
</tr>
<tr>
<td>LUarm</td>
</tr>
<tr>
<td>RUarm</td>
</tr>
<tr>
<td>head</td>
</tr>
<tr>
<td>LLleg</td>
</tr>
<tr>
<td>RLleg</td>
</tr>
<tr>
<td>LLarm</td>
</tr>
<tr>
<td>RLarm</td>
</tr>
<tr>
<td>Lhand</td>
</tr>
<tr>
<td>Rhand</td>
</tr>
</tbody>
</table>

rot(z, $\theta$) trans(0.30,0,0)
Recap: Forward vs. inverse kinematics

**Forward kinematics**
- **given joint axis, angle, and skeleton hierarchy**
- **compute joint locations**
  - start at the end-effector (e.g. arm)
    ‣ rotate all parent joints (up the hierarchy) by $\theta$
  - iteratively continue from child to parent

**Inverse kinematics**
- given skeleton hierarchy and goal location
- optimize joint angles (e.g. gradient descent)
- minimize distance between end effector (computed by forward kinematics) and goal locations
Cross-play

• **Short lecture until ~3:30 pm**

• **Cross-play**
  
  • starting at ~3:30 pm
  
  • four rounds, each (15 min):
    
    • *A plays B’s game (5-7min) and also B plays A’s game (5-7 min)*

  • fill out feedback form after each play (5 min)

• https://piazza.com/class/krpu7s953e6wt?cid=363
Team Presentations

• Showcase your game (live or video)
• Share one thing that worked well
• Share one thing that did not work/took longer

Update slides here:

https://docs.google.com/presentation/d/1vN4NcaJvd015AyxZ0GVFnPeu1EaYMISU0_XAEwsc4ts/edit?usp=sharing
Game Balancing

Max jump height

Max jump length
Fun to play?

Learning goals

- Know the different aspects of a game that can be balanced.
- Connecting game balancing to game theory
- Learn about common balancing steps
- Practice basic game balancing
Resources on Balancing


by Ian Schreiber
What does balanced mean?

- *Is chess balanced?*
- *Settlers of Catan?*
- *Is Tetris balanced?*
- *Is your game balanced?*
Modeling
Indirect relationships

Value of a piece

- it is not possible to get a knight for 3 pawns
- one can ‘trade’ pieces
- a currency

How to determine?

- Ask the users
- Auction house

Pawn = 1 point
Bishop = 3 points
Queen = 9 points
Knight = 3 points
Rook = 5 points
King = ? points
Numeric quantities

- *Values in your game?*
Relationships

- **Linear relations**
- **Exponential relations**
- **Triangular relationship**
  - 1, 3, 6, 10, 15, 21, 28, …
  - The difference increases linearly
  - The function has quadratic complexity
- **Periodic relations**
  (summer, winter, …)
Model interactions between relationships

- $2x \text{ item A} + 1x \text{ item B} = 5x \text{ item C}$
- $\text{Attack speed} \times \text{damage} = \text{damage / second}$
- Buff: $2x \text{ health} \text{ or } +100 \text{ health}$
  - what is better?
- Progression:
  - $\text{XP} \rightarrow \text{level up} \rightarrow \text{new skill} \rightarrow ?$
Game Theory

A mathematical concept

• Used for trading, road design, …

Terminology

• Dominant strategy: one path that is stronger than all others
• Fairness: equal chances to win
• Nash equilibrium: each player's strategy is optimal when considering the decisions of other players

Interested?

Kevin Leyton-Brown
Important Considerations

• Determinism vs. randomness
• Solvability
  • Has a best/dominant strategy
    • Is this desirable?
  • Can you solve a non-deterministic game?
• Intransitive games
  • simultaneous choice between opponents, e.g. Rock-Paper-Scissors
• Symmetric
  • same chances
• Game and meta game
Learning goals

• Know the different aspects of a game that can be balanced.

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• Learn about common balancing steps

• Practice basic game balancing
Breakout

• **List all relevant quantities in your game**
• **List their relations:**
  • Type: e.g., linear
  • Quantitatively: e.g., +5 gold per round,
    1 gold = 100 silver

• *Investigate interactions between relations*

• **What is your game’s currency?**
  • Gold, life, …?

6 min
select representative to report
Self study? Numerical Methods - Optimization

- **Iterative optimizers**
  - Single variable?
  - Multiple variables?
  - Gradient descent?

Lecture: [https://youtu.be/ZNsNZOmrM50](https://youtu.be/ZNsNZOmrM50)
- Balancing demo starts at 1h20
- Optimizer used at ~ 1h30
Learning goals

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Balancing example

• 10 enemies per level
• One tower does 1 damage / sec
• One tower costs 2 gold
• It takes enemies 10 seconds to pass

• How much gold should the player start with?

• Enemy health increases: 11,12,14,17,21,…
• How much gold should the player get in round 2?
• How much gold should each eliminated enemy give?
Demo
Difficulties:

• *Placement of towers changes the time damage is dealt*

• *Path of enemies can be hindered to increase time*

- **Measure during playtest**
  - cross-play

• *Some enemies are resistant to fire/magic/…?*
  • *kind of a periodic feature*
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Counter Measures

• **Transitive Mechanics**
  • *Repair costs*
  • *Consumables (food, potions, …)*
  • *Tax*
Asymptotic analysis?

- **Linear * linear?**
- **Linear + linear?**
- **Linear + exponential?**
- **Linear * exponential?**

Formally, given functions $f(x)$ and $g(x)$, we define a binary relation

$$f(x) \sim g(x) \quad (\text{as } x \to \infty)$$

if and only if (de Bruijn 1981, §1.4)

$$\lim_{x \to \infty} \frac{f(x)}{g(x)} = 1.$$
Numerical Methods - Optimization

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How to quantify difficulty?

- **Player vs. enemy strength**
- **Likelihood of winning**
- **Required skill**
  - Knowledge of the game
  - Reaction
  - Precision
  - Tactics

-> Estimate player strength in relation to skill level: beginner, intermediate, pro? 
-> requires user studies!
M4 balancing requirement

Carefully balance one aspect of your game (e.g., movement-speed, health points, strength, bonus,…).

• Report on the theoretical analysis
• Change log with testing results (before/after balancing)
Breakout II

- **Sketch progression**
  - Quantities over time
  - Interactions between quantities

- **Use pen & paper, plotting tool, or python**

- **Start balancing your game**
A/B Testing

Testing two variants of your game (with and w/o a feature)
• randomized participants (same pool)
• with respect to a measurable objective (e.g., clicks on website)

Related to
• two-sample hypothesis testing
• Clinical tests, e.g., testing of a COVID-19 vaccine
• Placebo effect

https://www.optimizely.com/optimization-glossary/ab-testing/