Exercise Intensity-driven Level Design

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Outline

- Motivation
- Approach
- Running Example: Reflex
- User Study & Result
- Extra Features
- Limitation
- CS410 Course Project
Problem & Motivation
Motion-Based Games

- Kinect Sports
- Just Dance
The Lab: Longbow
Procedural Design/Generation

- Apply algorithms for producing objects and scenes
- The rules may either be embedded into the algorithm, configurable by parameters, or externally provided
- Make it Home: Automatic Optimization of Furniture Arrangement. SIGGRAPH 2011
Procedural Design ... More

- City

- Pattern

- Games
Approach

**Input**

Chunk Types:

... Target Exercise Parameters: Calories, Intensity, Duration

**Initialization:***

**Update Level by a Move:**
- Add
- Remove
- Modify

**RJMCMC Optimizer**

Synthesized Level:

- Optimized?
  - Yes
  - No
Input Chunks

Target Exercise Parameters: Calories, Intensity, Duration
RJMCMC Optimizer

Initialization:

Update Level by a Move:
- Add
- Remove
- Modify

Optimized?
- Yes
- No

Synthesized Level:
RJMCMC Optimizer (Continue)

Iteration 10

Iteration 50

Iteration 200
How do we obtain chunk properties?

- **Measurement**
  - 10 healthy participants were recruited to help us obtain data
  - Non-athlete
  - Polar Heart Rate Sensor

- **Calculation**
  - Karvonen Heart Rate Formula
  - Estimating Calories Method from Keytel, L.R. et al.
  - Others: Duration, Variation, etc.
Procedural

- **Devices**
  - HTC Vive
  - Polar Heart Rate Sensor

- **Measurement**
  - Play a level with 10 identical chunks
  - Record Heart Rate
Intensity: Karvonen Heart Rate

\[ H_{\text{max}} = 220 - a \]

\[ H = (H_{\text{max}} - H_{\text{rest}})I_i + H_{\text{rest}} \]

\[ I_i = \frac{H - H_{\text{rest}}}{H_{\text{max}} - H_{\text{rest}}} \]
Calories

\[ \epsilon(c_i) = G(c_i)D(c_i) \]

\[ G(c_i) = (\mu_1 + \mu_2 H(c_i) + \mu_3 w + \mu_4 a)\mu_1 \text{ (Keytel)} \]

- Gender-specific coefficients:
  - Male: \( \mu_1 = -55.0969, \mu_2 = 0.6309, \)
  - Female: \( \mu_1 = -20.4022, \mu_2 = 0.4472, \)
  - For Both Gender: \( \mu_3 = -0.1263, \mu_4 = 0.0740, \mu_5 = \frac{1}{4.084 \times 60} \)
More Formulation

- Duration/Length
- Intensity Variation
- Adjacent Chunk Variation
- Designer’s Definition
- …
Reflex
Novel Results

Easy    Medium    Hard
## RATE OF PERCEIVED EXERTION (RPE)

<table>
<thead>
<tr>
<th>BORG RPE</th>
<th>MODIFIED RPE</th>
<th>BREATHING</th>
<th>TRAINING ZONE</th>
<th>% of MHR*</th>
<th>EXERCISE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0</td>
<td>No Exertion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>Very Light</td>
<td>1</td>
<td>50%-60%</td>
<td>Warm up</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>Deeper but comfortable breathing. Able to hold a conversation.</td>
<td>2</td>
<td>60%-70%</td>
<td>Recovery</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>Aware that breathing is harder; able to talk but difficult to hold conversation</td>
<td>3</td>
<td>70%-80%</td>
<td>Aerobic</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>4</td>
<td>Starting to breathe hard and getting uncomfortable</td>
<td>4</td>
<td>80%-90%</td>
<td>Anaerobic</td>
</tr>
<tr>
<td>15</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>Deep and forceful breathing. Uncomfortable and not wanting to talk</td>
<td>5</td>
<td>90-100%</td>
<td>VO2 Max</td>
</tr>
<tr>
<td>17</td>
<td>7</td>
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<td></td>
<td></td>
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</tr>
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<td>18</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>9</td>
<td>Extremely hard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>Maximum exertion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* % of maximum heart rate
User Study

- 21 participants of age 16 to 37 from university
- Healthy and familiar with virtual reality
- Single-Blinded Study
- Flow:
  - Setting: Wearing HTC Vive and Polar heart rate sensor, and start record resting heart rate
  - Play a level, when finished record the heart rate and RPE scale.
  - Take 5 minutes break, or when participant’s heart rate is closed to his or her resting heart rate.
User Result

![Bar charts showing intensity, calories burned, and RPE for easy, medium, and hard exercises.](chart.png)
Longbow Man
Longbow Man Result

Completion Rate:
- Easy: 96%
- Medium: 75%
- Hard: 53%

Completion Rate ↓ Level Difficulty ↑
Extension: Fixing Chunks
Extension: Different Duration

(a) 30-second level

(b) 60-second level
Limitation

- Length of the game
  - 3 minutes vs traditional 45 minutes sessions
- HTC Vive (wired)
  - Basic Poses
CS410: Course Project

- Goal: Polish or even Remake Reflex
  - Friendly User Interface
    - Open scene, menus, UI, etc.
  - Game Mechanics
    - Mainly implementing game features.
- Artist
  - Logos, environments, sounds, haptics, etc.

If you are interested in working this project with me, please contact me, and let me know what you want to work on:

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Thanks..