Dude, The Source of Lags is on Your Computer

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Outline

- Motivation
- Game Experience Monitor
- Data Collection
- Analysis
- Summary
Motivation
Motivation

- Lag is a constant headache to game players.
- Definition: the delay (or latency) between an action by a player and the reaction of the game.
Motivation

- Experts use tools to investigate/solve the problem.
What Do Gamers Do?
An Internet Survey [Tseng et al. 2011]

- How do players perceive lag?
- What do players think of the causes of lag?
- How do players react to lag?
An Internet Survey

- Number of subjects: 229
- Many gamers (81%) encounter lag at least occasionally.
- Most players (78%) never/seldom use any performance tools.

A lot of players (86%) demand an easy to use tool that can diagnose the cause of lag for them.
Game Experience Monitor
Game Experience Monitor (GEM)

GEM client
- Operation system resources (processor, memory access, etc)
- Game process performance (inter-frame time, etc)
- Network path quality (round-trip time, etc)

Gamer's Computer

hook

Game client

Internet

GEM server

Game servers
Local Observations

- Processor utilization
  - Number of processes
  - CPU busy time
  - Privileged time
  - Interrupt time
  - Interrupt rate
Local Observations

- Memory utilization
  - Page fault rate
  - Available bytes
  - Page read/write rate
Local Observations

- Game client performance
  - Inter-frame time: the time period between two consecutive frames (game screens)
  - Incoming packet stall time: the time an incoming network packet waits in the queue until the game client calls recv() socket function to retrieve it
Network Observations

- Quality of Internet path
  - RTT: round-trip time of each packet sending to game server
- Quality of LAN connection
  - LAN_RTT: round trip time to the first hop along the route to the game server
Lag Diagnosis Report

<table>
<thead>
<tr>
<th>Local Machine</th>
<th>Average</th>
<th>95%</th>
<th>Maximum</th>
<th>Standard Deviation</th>
<th>Detailed Graph</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU Utilization (%)</td>
<td>36.9</td>
<td>69.4</td>
<td>99.2</td>
<td>20</td>
<td></td>
<td>⭐⭐⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>Memory Utilization (page reads/s)</td>
<td>7.5</td>
<td>27.1</td>
<td>287.3</td>
<td>26.1</td>
<td></td>
<td>⭐⭐⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>Delay Analysis (ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>⭐⭐⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>Scheduling Delay</td>
<td>37.2</td>
<td>71.6</td>
<td>150.1</td>
<td>17.2</td>
<td></td>
<td>⭐⭐⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>Rendering Delay</td>
<td>44.7</td>
<td>89.5</td>
<td>199.4</td>
<td>23.6</td>
<td></td>
<td>⭐⭐⭐⭐⭐⭐⭐</td>
</tr>
<tr>
<td>Total Delay</td>
<td>83.7</td>
<td>110</td>
<td>153</td>
<td>14.6</td>
<td></td>
<td>⭐⭐⭐⭐⭐⭐⭐</td>
</tr>
</tbody>
</table>
# Lag Diagnosis Report

## Network

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>95%</th>
<th>Maximum</th>
<th>Standard Deviation</th>
<th>Detailed Graph</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network RTT (ms)</td>
<td>78.1</td>
<td>233</td>
<td>302</td>
<td>76.4</td>
<td></td>
<td>5 stars</td>
</tr>
<tr>
<td>Packet Loss Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 stars</td>
</tr>
</tbody>
</table>

## Delay Analysis (ms)

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>95%</th>
<th>Maximum</th>
<th>Standard Deviation</th>
<th>Detailed Graph</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAN</td>
<td>7.4</td>
<td>17.1</td>
<td>18</td>
<td>3.1</td>
<td></td>
<td>4 stars</td>
</tr>
<tr>
<td>Chunghwa Telecom</td>
<td>14.9</td>
<td>29</td>
<td>29</td>
<td>4.7</td>
<td></td>
<td>4 stars</td>
</tr>
<tr>
<td>GNET</td>
<td>14.3</td>
<td>19</td>
<td>19</td>
<td>1.5</td>
<td></td>
<td>5 stars</td>
</tr>
<tr>
<td>Total</td>
<td>13.9</td>
<td>19</td>
<td>19</td>
<td>1.5</td>
<td></td>
<td>5 stars</td>
</tr>
</tbody>
</table>
Perceived Experiences

Bubble Fighter Lag Survey

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did you perceive lag?</td>
<td>Yes, No</td>
</tr>
<tr>
<td>2. How often did you perceive lag?</td>
<td>Always, Often, Occasionally, Rarely</td>
</tr>
<tr>
<td>3. How did the level of lag change through time?</td>
<td>Does not change, Becomes less severe, Becomes more severe, Fluctuates</td>
</tr>
</tbody>
</table>

- With enough samples, we will be able to have a better understanding about how each metric is related to lag.
Data Collection
Bubble Fighter

- An online third-person shooter
- Developer: NEXON
- Operator in Taiwan: gamania
- Client-server architecture
- Data communication based on TCP
Bubble Fighter
## Collected Traces Summary

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td>2012/12/08 – 2012/12/10</td>
<td></td>
</tr>
<tr>
<td><strong>Number of participants</strong></td>
<td>514</td>
<td></td>
</tr>
<tr>
<td><strong>Uploaded compressed data</strong></td>
<td>400+ MB</td>
<td></td>
</tr>
<tr>
<td><strong>Monitored game session</strong></td>
<td>5,482 minutes</td>
<td></td>
</tr>
<tr>
<td><strong>Recorded network packets</strong></td>
<td>12,615,819 (38.36 pkts/sec)</td>
<td></td>
</tr>
<tr>
<td><strong>Intercepted send calls</strong></td>
<td>2,142,193 (6.51/sec)</td>
<td></td>
</tr>
<tr>
<td><strong>Intercepted recv calls</strong></td>
<td>2,720,961 (8.27/sec)</td>
<td></td>
</tr>
</tbody>
</table>
Analysis
Possible Causes of Lag

- Overloading of gamer's computer
  - Inter-frame time (ift)
- Unstable Internet connectivity
  - Round-trip time (rtt)
- Unstable LAN connectivity
  - First-hop round-trip time (lan_rtt)
Features of a Metric

- GEM traces are sequences of observed data over time.
- Features: basic statistics of each metric
  - mean
  - median
  - 95 (95 percentile)
  - 99 (99 percentile)
  - max (maximum)
  - sd (standard deviation)
- Ex. **ift_max**: the maximum value of the inter-frame times.
Correlation Analysis

- A strong cause of lag will have high correlation with whether players perceive lag.

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>median</th>
<th>95 percentile</th>
<th>99 percentile</th>
<th>max</th>
<th>sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>ift</td>
<td>0.26</td>
<td>0.17</td>
<td>0.25</td>
<td>0.29</td>
<td>0.22</td>
<td>0.25</td>
</tr>
<tr>
<td>rtt</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>rtt_lan</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.04</td>
<td>0.05</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Classification and Regression Trees

- A strong cause of lag can be used to predict whether a player will perceive lag.
- We use the features as predictors to build a classification and regression trees (CART) model for each metric.
- Cross validated accuracies are used to evaluate the trees.
Classification and Regression Trees

Cross validated accuracies

67.51% 56.81% 59.34%
Summary

- An easy to use lag diagnosis tool for ordinary gamers is in high demand.
- Although it is believed that network latency is the major cause of lag, our research indicates that overloading of gamers’ computers is more relevant to whether they perceive lag.
Thank you!