Context-Aware Mechanisms for Reducing Interactive Delays of Energy Management in Disks

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Outline

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Introduction

- Performance and energy consumption
  - delay
  - Stopping or slowing the rotation of disk of disk platters during periods of idleness
  - Timeliness of power mode transitions
    - the system’s responsiveness

Figure 1: Anatomy of an idle period.
Introduction

- Interaction-Aware Spin-up Predictor (IASP)
  - user interactions can be easily monitored
  - and exploited to increase the timeliness and accuracy of prediction mechanisms
  - gather contextual information from user’s mouse interactions within a GUI
    - predicting an upcoming I/O request
Design

- IASP
  - The key idea
    - The correlation of user interactions and disk I/O activity
  - requirements
    - User interactions have to be captured transparently without modification of applications
    - Capture and prediction should be efficient to prevent excessive energy consumption by the CPU to train and generate prediction
    - The system should handle multiple applications in a graphically rich environment
Design

- IASP
  - requirements (cont.)
    - User behavior correlation and classifications should be performed online and without direct user involvement
      - by the proposed predictor design (the Naïve Predictor Naïve Predictor)

Figure 2: IASP architecture.
Design

- The Naïve Predictor
  - Naïve All-Click Spin-Up mechanism (ACSU)
    - if the user actively interacts with an application, then…
    - the disk shuts down after timeout without interacting
    - The lower bound on spin-up delays
Design

- Monitoring & correlating I/O activity
  - two levels of correlation
    - The application’s file I/O activity is captured by the kernel
    - Using `sys_read()` to see if it resulted in an actual disk I/O or it was satisfied by the buffer cache
  - prediction table
    - a hash table indexed by the hash calculated using the mouse event IDs
  - In the experimental implementation
    - only two possible states for the disk: standby and sleep
      - the decision to spin-up the disk is binary
**Design**

<table>
<thead>
<tr>
<th>Observed Buttons</th>
<th>Click ID</th>
<th>Bookkeeping</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>File</td>
<td>C1</td>
<td>C1</td>
<td>Sequence of clicks is being recorded</td>
</tr>
<tr>
<td>Page Setup</td>
<td>C2</td>
<td>C1, C2</td>
<td>Longer idle period, potentially signaling end of sequence</td>
</tr>
<tr>
<td>Portrait</td>
<td>C3</td>
<td>C1, C2, C3</td>
<td>C1 - root of the tree observed, sequence collection restarted</td>
</tr>
<tr>
<td>OK</td>
<td>C4</td>
<td>C1, C2, C3, C4</td>
<td></td>
</tr>
<tr>
<td>File</td>
<td>C1</td>
<td>C1</td>
<td></td>
</tr>
<tr>
<td>Open</td>
<td>C5</td>
<td>C1, C5</td>
<td></td>
</tr>
<tr>
<td>File Select</td>
<td>C6</td>
<td>C1, C5, C6</td>
<td></td>
</tr>
<tr>
<td>Open</td>
<td>C7</td>
<td>C1, C5, C6, C7</td>
<td></td>
</tr>
</tbody>
</table>

**DISK I/O**

Figure 3: Example of interaction sequences.

**Figure 4:** IASP decision flowchart.
Methodology

- the performance
  - ACSU and IASP, comparing them to ALT+
- using a trace-based simulator
  - The modified strace utility allows us to obtain the PID, access type, time, file descriptor
- focusing on predicting spin-ups
  - the timeout set to 20 seconds (breakeven time)
- using an LRU managed buffer cache of size 512MB
Methodology

<table>
<thead>
<tr>
<th>Appl.</th>
<th>Number of I/O Periods</th>
<th>Read (MB) Without Cache</th>
<th>Write (MB) Without Cache</th>
<th>Read (MB) With Cache</th>
<th>Write (MB) With Cache</th>
<th>Number of Clicks</th>
<th>Number of IDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firefox</td>
<td>814</td>
<td>1903.35</td>
<td>350.8</td>
<td>851.91</td>
<td>120.39</td>
<td>3857</td>
<td>130</td>
</tr>
<tr>
<td>Writer</td>
<td>1385</td>
<td>2043.62</td>
<td>2186.28</td>
<td>1434.05</td>
<td>2120.47</td>
<td>5755</td>
<td>195</td>
</tr>
<tr>
<td>Impress</td>
<td>1485</td>
<td>1230.42</td>
<td>263.6</td>
<td>517.06</td>
<td>60.44</td>
<td>25375</td>
<td>194</td>
</tr>
<tr>
<td>Calc</td>
<td>2846</td>
<td>1840.4</td>
<td>116.7</td>
<td>1280.7</td>
<td>59.67</td>
<td>9102</td>
<td>35</td>
</tr>
<tr>
<td>Gimp</td>
<td>844</td>
<td>1443.32</td>
<td>957.3</td>
<td>796.9</td>
<td>936.54</td>
<td>8465</td>
<td>157</td>
</tr>
<tr>
<td>Dia</td>
<td>6362</td>
<td>174.31</td>
<td>65.3</td>
<td>123.64</td>
<td>10.28</td>
<td>46864</td>
<td>118</td>
</tr>
</tbody>
</table>

Table 1: Applications and execution details

<table>
<thead>
<tr>
<th>State</th>
<th>WD2500JD</th>
<th>40GNX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read/Write Power</td>
<td>10.6W</td>
<td>2.5W</td>
</tr>
<tr>
<td>Seek Power</td>
<td>13.25W</td>
<td>2.6W</td>
</tr>
<tr>
<td>Idle Power</td>
<td>10W</td>
<td>1.3W</td>
</tr>
<tr>
<td>Standby Power</td>
<td>1.8W</td>
<td>0.25W</td>
</tr>
<tr>
<td>Spin-up Energy</td>
<td>148.5J</td>
<td>17.1J</td>
</tr>
<tr>
<td>Shutdown Energy</td>
<td>6.4J</td>
<td>1.08J</td>
</tr>
<tr>
<td>State Transition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spin-up time</td>
<td>9 sec.</td>
<td>4.5 sec.</td>
</tr>
<tr>
<td>Shutdown time</td>
<td>4 sec.</td>
<td>0.35 sec</td>
</tr>
</tbody>
</table>

Table 2: Disk energy consumption specifications.
Results

Figure 5: Prediction accuracy normalized to the total number of disk spin-ups \textit{without} the buffer cache.

Figure 6: Prediction accuracy normalized to the total number of spin-ups \textit{with} the buffer cache.
Results

Figure 7: Hit/Miss ratio and I/O activity period coverage vary as the acceptable confidence level is increased.
Results

Figure 8: Average delay in seconds, WD2500JD.

Figure 9: Average delay in seconds, 40GNX.
Results

Figure 10: Energy consumption, WD2500JD.

Figure 11: Energy consumption, 40GNX.
Results

Figure 12: The experimental setup used for measuring power.

Figure 13: Power consumption in a selected 550 second period from Dia under Demand-based spin-up. ACSU and IASP.
Conclusion

- two proposed disk spin-up mechanisms
  - ACSU and IASP
- Reducing the spin-up delays provides twofold benefit
  - less lags due to disk spin-ups
  - shorter delays allow the system to accomplish tasks quicker, and less energy consumed by other components
- The primary goal
  - reduce interactive delays due to disk spin-up
    - ACSU reduces spin-up delays on average by over 60% (>5s)
    - IASP reduces spin-up delays on average by 35% (>3s)