Modeling and Extracting Load Intensity Profiles

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http://descartes.tools/limbo
http://research.spec.org/tools/limbo
Motivation

Page Requests for the German Wikipedia
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- Page Requests for the German Wikipedia
Additive decomposition into seasonal part, trend, and remainder. Created using \textit{BFAST} [1].
Related Work

User Behavior Models (e.g. using Markov Chains)
- van Hoorn et al. (2008): probabilistic, intensity-varying workloads
- Roy et al. (2013): workload volatility of a streaming system

Workload Models
- Barford et al. (1998): file popularity and distribution (web)
- Casale et al. (2012): bursts
- Beich et al. (2010): data popularity and user classes (cloud)

Statistical Models
- Feitelson (2002): workload representativity through statistical characteristics
Descartes Load Intensity Model (DLIM)

- Describes arrival rate variations over time
- Provides structure for piece-wise mathematical functions
- Independent of work/request type

![Diagram of load intensity model](image)

- Workload Units
- Time
- Seasonal Trends & Breaks
- Overlaying Seasonal Burst Noise
- + / ×
- Created using LIMBO eclipse plugin
- Contains *Seasonal* part, *Trends*, and *Burst*

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1LIMBO: [http://descartes.tools/limbo](http://descartes.tools/limbo)
Benefits of DLIM:
- Powerful and expressive
- Easy derivation of arrival rates or request time-stamps

Drawbacks of DLIM:
- Instances can become complex
- Large trees may be unintuitive

Solution: **high-level DLIM**
- Fewer parameters for load intensity profile description
- Strictly structured into single *Seasonal*, *Trend*, recurring *Burst*, and *Noise* parts
hl-DLIM Seasonal and Trend parts

- **hl-DLIM Seasonal part:**

- **hl-DLIM Trend part:**

  - List of maximum target Seasonal Arrival Rate Peaks
  - Number of Seasonal Periods within one Trend = 2
hl-DLIM Burst and Noise parts

hl-DLIM **Burst** part:

hl-DLIM **Noise** part:

**Uniform Distribution**
- Minimum Noise Rate
- Maximum Noise Rate
Automated Model Instance Extraction

- Automated process for extracting DLIM or hl-DLIM instances from existing arrival rate traces
- Structured into Seasonal, Trend, Burst, and Noise part extraction
- Noise reduction and extraction is optional and separate
Seasonal Part:
- Extracts median local min/max within *Seasonal* iterations
- Interpolates using DLIM *Functions*

Trend Part:
- Adds at each maximum *Seasonal* Peak to trend-list
Burst Part:
- Bursts are detected at strong positive deviations from predicted Seasonal and Trend behavior
- Peak is set to match arrival rate in trace

Noise Part:
- Before Extraction: High frequencies are reduced using a gaussian filter
- After Extraction: Reduced noise (normal) distribution is added to model instance
- **Simple DLIM Extraction Process (s-DLIM):**
  - Uses a single Trend-List to describe one overlying *Trend Part*
  - Extracts a DLIM instance

- **Periodic DLIM Extraction Process (p-DLIM):**
  - Uses a multiple recurring Trend-Lists to describe repeating trends
  - Extracts a DLIM instance

- **high-level DLIM Extraction Process (hl-DLIM Extraction):**
  - Modified version of the Simple Model Instance Extraction Process
  - Extracts an hl-DLIM instance
- EMF-based modeling platform
- Uses DLIM for load intensity description
- New Model Creation Wizard based on hl-DLIM
- Allows arrival rate and request time-stamp generation
- Visualizes and compares arrival rate profiles
- Provides automated model instance extraction
- Accepted into the SPEC RG tool repository

\(^a\)http://research.spec.org/tools/limbo
Evaluated using 9 real world web server traces
- Traces contain tuples of arrival rate / time
- All traces 2 weeks or longer
- All traces have human user influence

Error metric: median arrival rate deviation
- s-DLIM and hl-DLIM extraction applied to all traces
- p-DLIM to traces longer than one month
- Most accurate of the extraction processes
- Does not require noise reduction
- Median deviation across all traces: **12.4%**

French Wikipedia s-DLIM result, median deviation: **7.6%**
<table>
<thead>
<tr>
<th>Trace</th>
<th>s-DLIM relative median error (%)</th>
<th>BFAST relative median error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClarkNet-HTTP</td>
<td>12.409</td>
<td>12.243</td>
</tr>
<tr>
<td>NASA-HTTP</td>
<td>18.812</td>
<td>-</td>
</tr>
<tr>
<td>Saskatchewan-HTTP</td>
<td>26.492</td>
<td>-</td>
</tr>
<tr>
<td>WorldCup98</td>
<td>12.979</td>
<td>-</td>
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<tr>
<td>BibSonomy</td>
<td>21.479</td>
<td>-</td>
</tr>
<tr>
<td>de.wikipedia.org</td>
<td>8.538</td>
<td>11.223</td>
</tr>
<tr>
<td>fr.wikipedia.org</td>
<td>7.6</td>
<td>8.511</td>
</tr>
<tr>
<td>ru.wikipedia.org</td>
<td>9.912</td>
<td>5.809</td>
</tr>
<tr>
<td>wikipedia.org</td>
<td>4.855</td>
<td>2.302</td>
</tr>
</tbody>
</table>

- s-DLIM performs on average **8354** times faster than BFAST
- Both processes are less accurate than s-DLIM
- hl-DLIM: “recurring bursts” - limitation may lead to phantom bursts
- p-DLIM: ignores small deviations from recurring periodic patterns

<table>
<thead>
<tr>
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<th>p-DLIM</th>
<th>hl-DLIM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12.4</td>
<td>36.0</td>
<td>15.7</td>
</tr>
</tbody>
</table>
Observations

- **s-DLIM** is the most accurate of the extraction processes
- **p-DLIM** works well for regular load intensity profiles
- **hl-DLIM** heavily relies on noise reduction
- Challenge: Seasonal pattern drift in long traces
  - Extraction uses one seasonal pattern for approximation
Two Meta-Models for load intensity variation description

- **DLIM**: Powerful and expressive
- **hl-DLIM**: Abstract and concise

Modeling Platform: **LIMBO**

- Enables creation of custom load intensity variations for open workload based benchmarking
- Provides automated load intensity profile extraction

Automated model instance extraction:

- **s-DLIM**: most accurate, median deviation: 12.4%
- **p-DLIM**: good for regular profiles, median deviation: 36.0%
- **hl-DLIM**: relies on noise reduction, median deviation: 15.7%

**LIMBO** is open-source\(^2\) and already being used in different contexts.

\(^2\)LIMBO: [http://descartes.tools/limbo](http://descartes.tools/limbo)
Thank you for your Interest!

Our future work on LIMBO:
- Extraction of multiple and overlaying seasonal patterns
- Change detection
- Advanced calibration and noise reduction
- Include additional meta-information

Ideas for integration/extension
- Extend user-session models to use LIMBO (or reverse)
- Extend architecture level performance models (PCM / DML) to use DLIM instances or LIMBO timestamps
- Use DLIM models for improving anomaly detection accuracy


