Multi-scale Real-time Grid Monitoring with Job Stream Mining

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2 Streaming Jobs

3 Monitoring Outputs
   • Monitoring on short-time scale
   • Clustering Quality
   • Monitoring on medium-time scale
   • Monitoring on large-time scale
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Multi-scale Realtime Grid Monitoring System

Streaming jobs

Data Pre-processing/Normalization

Grid Monitoring System

AP

StrAP

Super Clustering

Output

Online Monitor

Post-monitor Analysis
### Multi-scale Realtime Grid Monitoring System

**Grid Monitoring System**

- **Data Pre-processing/Normalization**
- **StrAP**
- **Super Clustering**
- **AP**
- **Output**
  - **Online Monitor**
  - **Post-monitor Analysis**

#### Streaming jobs

<table>
<thead>
<tr>
<th>Job</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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#### Percentage of jobs assigned (%)

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<thead>
<tr>
<th>Clusters</th>
<th>1</th>
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<th>4</th>
<th>5</th>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **exemplar shown as a job vector**

**Monitoring system:** Grid adapted StrAP

**Streaming Jobs**

**Monitoring Outputs**

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Grid Monitoring with Job Stream Mining
Multi-scale Realtime Grid Monitoring System

Streaming jobs

Data Pre-processing/Normalization

AP

StrAP

Super Clustering

Output

Online Monitor

Post-monitor Analysis

<table>
<thead>
<tr>
<th>Job ID</th>
<th>Days</th>
</tr>
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<tbody>
<tr>
<td>job1</td>
<td>8 5 7 12 156 193</td>
</tr>
<tr>
<td>job2</td>
<td>8 5 6 11 0 0</td>
</tr>
<tr>
<td>job3</td>
<td>8 5 7 9 228 193</td>
</tr>
<tr>
<td>job4</td>
<td>10 1 2 14 216 133</td>
</tr>
<tr>
<td>job5</td>
<td>8 2 4 9 253 72</td>
</tr>
<tr>
<td>job6</td>
<td>8 1 2 5 156 84</td>
</tr>
<tr>
<td>job7</td>
<td>9 1 2 12 0 0</td>
</tr>
<tr>
<td>job8</td>
<td>8 6 6 7 0 0</td>
</tr>
<tr>
<td>job9</td>
<td>8 5 6 12 3095 73</td>
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<td>job10</td>
<td>8 6 6 8 193 84</td>
</tr>
<tr>
<td>job11</td>
<td>8 5 7 10 0 0</td>
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<tr>
<td>job12</td>
<td>8 5 7 10 157 85</td>
</tr>
<tr>
<td>job13</td>
<td>11 4 5 13 181 133</td>
</tr>
<tr>
<td>job14</td>
<td>3 11 12 17 225 4488</td>
</tr>
</tbody>
</table>

Distribution of jobs like [7 0 0 0 0]

Distribution of jobs like [0 0 0 0 0]
Multi-scale Realtime Grid Monitoring System

Affinity Propagation (AP)
- A clustering method: group similar points together

StrAP (Streaming AP)
- Online Clustering streaming data based on AP
Why AP ??

**Affinity Propagation (AP)**

- A *clustering* method
- Group similar points together
- Converge by Iterations of Message passing
  - $\Rightarrow$ *more stable results*
- No need of K (the number of clusters)
  - $\Rightarrow$ *less prior knowledge*
- A real point as an exemplar to represent a cluster
  - $\Rightarrow$ *avoid meaningless averaged centers*

---

How AP works ??
How AP works??

non-exemplar  exemplar

ITERATION #1
How AP works??

non-exemplar exemplar

ITERATION #2
How AP works ??

non-exemplar exemplar

ITERATION #3
How AP works??

![Diagram of non-exemplar and exemplar categories]

ITERATION #4
How AP works??

non-exemplar exemplar

ITERATION #5
How AP works??

![Diagram showing non-exemplar and exemplar classification](image.png)

**Monitoring system:** Grid adapted StrAP
- Streaming Jobs
- Monitoring Outputs

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[Grid Monitoring with Job Stream Mining](#)
How AP works??

![Diagram showing non-exemplar and exemplar points with convergence on a graph.](image)
Grid adapted StrAP

Grid adapted StrAP (Streaming AP):

- **Online clustering** streaming jobs
  - > *one-scan* of the stream
- **Incremental update** of model
  - > *keep tracking* the stream
- **Detecting** distribution changes in stream
  - > *absorb new patterns*

Data streaming with Affinity propagation. Xiangliang Zhang, Cyril Furtlehner, Michele Sebag. ECML 2008.
Stream clustering
Stream clustering

Does $x_t$ fit the current model ??

- if yes, update the model
- otherwise, go to reservoir
Stream clustering

Does $x_t$ fit the current model??

- if yes, update the model
- otherwise, go to reservoir
Stream clustering

Does $x_t$ fit the current model ??
- if yes, update the model
- otherwise, go to reservoir
Stream clustering

Has the distribution changed??

CHANGE TEST
- if yes, rebuilt the model
- otherwise, continue
Stream clustering

Has the distribution changed??

CHANGE TEST
- if yes, rebuilt the model
- otherwise, continue
### Our Model

#### Output
- $e_i$, the **exemplar** (center of cluster)
- $n_i$, **size** of cluster
- $\Sigma_i$, average distance of points to their exemplar
- $T$, **time stamp** when the cluster was latterly visited

#### Parameters
- $\epsilon$, **threshold** of comparing each point with model (set to a round value of $\Sigma_i$ in the initial model)
- $\Delta$, **decay window** (decrease the weight of old exemplars)
- Page-Hinkley parameters (change detection)
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   - Monitoring on large-time scale
EGEE (Enabling Grids for E-sciencE)

- Funded by European Commission (contribution: 32,000,000 euro)
- Start in April 2004
- Grid infrastructure available to scientists 24 hours-a-day.
- http://public.eu-egee.org/
EGEE Jobs

- EGEE logs of 39 RBs during 5 months (2006-01-01 to 2006-05-31)
- collected by Real Time Monitor (RTM) system (http://gridportal.hep.ph.ic.ac.uk/rtm/)
- 5,268,564 jobs
- for each job, its
  - final status (good or type of errors)
  - UI, RB, CE
  - time stamps of every services happened
Job attributes

- **registration_time**: time for registering the job
- **match_time**: time to find a matching resource
- **upto_scheduled_transfer_time**: time acceptance and transfer (waiting + ready time), as reported by the JobController (JC)
- **upto_scheduled_acceptance_time**: the same as Ready_for_Transfer_Time, but as reported by the LogMonitor (LM)
- **logmonitor_ce_scheduled_time**: time job waiting in a queue
- **logmonitor_wn_time**: execution time
Multi-scale Realtime Grid Monitoring System

Grid Monitoring System

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AP

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job1: 8 5 7 12 156 193
job2: 8 5 6 11 0 0
job3: 8 5 7 9 228 193
job4: 10 1 2 14 216 133
job5: 8 2 4 9 253 72
job6: 8 1 2 5 156 84
job7: 9 1 2 12 0 0
job8: 8 6 6 7 0 0
job9: 8 5 6 12 3095 73
job10: 8 6 6 8 193 84
job11: 8 5 7 10 0 0
job12: 8 5 7 10 157 85
job13: 11 4 5 13 181 133
job14: 3 11 12 17 225 4488

............
Pre-processing and Normalization

Pre-processing
- 6 boolean attributes
- indicate whether the services were reached or not

Normalization
- by centering with standard deviation 1
- job $x_i$ is normalized to $x'_i = \frac{x_i - \mu}{s}$
- where, $\mu$ and $s$ are mean and standard deviation from a part of streams.
Load of jobs per day

![Graph showing the load of jobs per day with days on the x-axis and number of jobs per day on the y-axis. The data points are differentiated by day of the week (Sat & Sun, Mon, Tue, Wed, Thu, Fri), with a line representing the trend.]
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Monitoring on a short-time scale
Real-time Monitoring: when change detected

![Bar chart showing percentage of jobs assigned to clusters.](image-url)
Real-time Monitoring: when change detected

The assignment of jobs between restart 1 and restart 2

<table>
<thead>
<tr>
<th>Restart</th>
<th>1</th>
<th>2</th>
<th>3</th>
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</table>
Real-time Monitoring: when change detected

the assignment of jobs between restart 2 and restart 3
Real-time Monitoring: when change detected

the assignment of jobs between restart 3 and restart 4
the assignment of jobs between restart 4 and restart 5
Real-time Monitoring: when change detected

the assignment of jobs between restart 5 and restart 6

LogMonitor is getting clogged
Who is responsible for the clogging ??

Distribution of Attr4/Attr3

Distribution of all jobs over 39 RBs

Distribution of jobs from 9-th RB
Who is responsible for the cloggong??

Which RB??

![Graph showing correlation coefficients over RBs]

- gdrb04.****.ch
- gdrb03.****.ch
- lappgrid07.****.fr
Clustering Quality Assessment
Clustering Purity

Purity = 100% \times \left( \sum_{i=1}^{K} \frac{|C_i^d|}{|C_i|} \right) / K

where \( K \) is the number of clusters,
\(|C_i|\) is the size of cluster \( i \),
\(|C_i^d|\) is the number of majority class items in cluster \( i \).
Discuss

- Real-time quality:
  - on average 10000 jobs in 1 minute vs maximum load: 80000 per day
  - Intel 2.66GHz Dual-Core PC with 2 GB memory coding in matlab
  - on average 60000 jobs in 1 minute coding in C/C++
  - compact and live description of job patterns
  - proportion of good jobs and failed jobs
  - different time cost of services the jobs went through
Monitoring on a medium-time scale
Rupture steps

- keep tracking the **evolving** of job distribution
- provides intuitive view of grid regime and its stability
Monitoring on a large-time scale
Large-time scale Monitoring: Global view

- Clustering the **exemplars** $\rightarrow$ Super exemplars
- Super clusters: Cluster of exemplars
- the history behavior of these super clusters
Bad Super Examples: day view

Re-check of “early stopped error” type of errors (first row)

<table>
<thead>
<tr>
<th>Date</th>
<th>Jan 7~13</th>
<th>Jan 30 ~ Feb 3</th>
<th>Mar 16~21</th>
<th>May 17~19</th>
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<td>A1</td>
<td>B1</td>
<td>D1 and A1</td>
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</tbody>
</table>

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Grid Monitoring with Job Stream Mining
Discussion and Conclusion

- **real-time monitoring** Grid job streams
- **providing multi-scale** models to describing the status of Grid
  - proportion of different type of job patterns (realtime-view, day-view, week-view ...)
  - rupture steps
  - offline globally analysis
- **good quality clustering** is guaranteed
Future work

- more comprehensive description of the jobs, e.g., related to UI and CE
- interpret the model dynamics, e.g., relating the rebuild frequency to calendar or social events, in collaboration with the operation teams.
Thank you

Questions ??