A Framework for System Event Classification and Prediction by Means of Machine Learning

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Stuttgart, Germany

Dec 10, 2014 @ VALUETOOLS 2014, Bratislava
Microsoft recovering from seven-hour long Outlook.com outage

By Tom Warren on August 14, 2013 05:32 PM

Sorry, there seems to be a problem with Outlook

Problem Updates
We're having a problem accessing email. You might not be able to see the updates.
We identified a solution to the problem and have brought it up gradually.
Show earlier updates

DON'T MISS STORIES FOLLOW THE VERGE

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Failure Events

Motivation: Failure Management

Microsoft recovering from seven-hour long Outlook.com outage

AWS Server Issues Take Down Instagram, Vine, Airbnb And IFTTT
Failure Events

Motivation: Failure Management

Microsoft recovering after long Outlook.com outage

AWS Server Issues Take Down Instagram, Airbnb and IFTTT

Google goes dark for 2 minutes, kills 40% of world's net traffic

Systemwide outage knocks every service offline
Motivation: Failure Management

T. Pitakrat et al. (U Stuttgart)

A Framework for System Event Classification and Prediction by Machine Learning

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Reactive vs. Proactive Failure Mgmt.

Motivation: Failure Management

Reactive

Failure detected
Start recovery
System recovered

QoS
100%
0%
Reactive vs. Proactive Failure Mgmt.

Motivation: Failure Management

Reactive
Failure detected
Start recovery
System recovered
QoS 100%

Proactive
Failure predicted
Prepare recovery
System recovered
QoS 100%
Log Files

Motivation: Failure Management

- Log files can be used for
  - understanding system’s behavior
  - diagnosing problems
  - detecting and predicting failures
Log Files

Motivation: Failure Management

- Log files can be used for
  - understanding system’s behavior
  - diagnosing problems
  - detecting and predicting failures

- Example

  INFO: Reading file X
  INFO: Reading complete
  INFO: Executing Routine A
  INFO: Reading file Y
  FATAL: Critical Temperature in Segment Z
Goals
- Automatic classification of similar events
- Automatic prediction of future events
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- Automatic prediction of future events

Challenges
- Log files are huge
- Some information is redundant
- Correlated events may not be close to each other
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- Automatic prediction of future events

Challenges
- Log files are huge
- Some information is redundant
- Correlated events may not be close to each other

Approach: SCAPE framework
- System event Classification And PrEdiction
- Supports an extensible set of machine learning algorithms
- Part of Hora approach for online failure prediction
SCAPE as Part of Hora Approach

Motivation: Failure Management

Hora
System-level Predictor
Monitoring
Reader
!
!
Kieker, Weka, R, ESPER, ...
CDT
PAD
HDD Failure Predictor
SCAPE
Component-level Predictors
PCM
SLAstic
...

Hora

Kieker, Weka, R, ESPER, ...

Agenda

1. Motivation: Failure Management
2. SCAPE Approach
3. Evaluation
4. Conclusion
SCAPE: Framework Architecture

SCAPE Approach

- Processing steps
  1. Event Preprocessing
  2. Event Classification
  3. Event Prediction

*Builds on*
- Kieker [van Hoorn et al. 2012]
- Weka [Hall et al. 2009]

*Currently supports*
- Blue Gene/L log format
- Weka's machine learning algorithms
SCAPE: Framework Architecture

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Preprocessing Filter
Prediction Filter
Training Filter
Labelling Filter
Shuffling Filter
Evaluation Filter
Log message
Classification and prediction results
SCAPE: Framework Architecture

SCAPE Approach

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Classification and prediction results
Event Preprocessing

SCAPE Approach

- **Normalization** [Liang et al. 2007]

- **Filtering**
Event Preprocessing

SCAPE Approach

**Normalization** [Liang et al. 2007]

1. Removing punctuation, e.g., . ; : ? ! = - [ ] | < > +
2. Removing definite and indefinite articles, e.g., a, an, the
3. Removing weak words, e.g., be, is are, of, at, such, after, from
4. Replacing all numbers by the word NUMBER
5. Replacing all hex addresses with $N$ digits by the word NDigitHex_Addr
6. Replacing domain specific identifiers by corresponding words such as REGISTER or DIRECTORY
7. Replacing all dates by DATE

**Filtering**
Event Preprocessing

SCAPE Approach

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• Filtering
  • Adaptive Semantic Filter (ASF) [Liang et al. 2007]
    - Removes highly correlated events (uses Phi correlation coefficient)
  • Duplicate Removal Filter (DRF)
    - Removes similar events
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Before normalization

number torus receiver x input pipe error detected
number torus receiver x input pipe error detected
number register edram error detected
number register edram error detected
error receiving packet expecting type number
number torus receiver y input pipe error detected
number torus receiver z input pipe error detected

After normalization
number torus receiver x input pipe error detected
number torus receiver x input pipe error detected
number register edram error detected
number register edram error detected
error receiving packet expecting type number
number torus receiver y input pipe error detected
number torus receiver z input pipe error detected

Before filtering
Event Preprocessing: Example

Filtering
SCAPE Approach

Before filtering

After filtering
## SCAPE Approach

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<th>Count</th>
<th>Message</th>
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<td>KERNCON KERNEL FATAL MailboxMonitor::serviceMailboxes() lib_ido_error: -1033 BGLERR_IDO_PKT_TIMEOUT</td>
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<td>KERNPAN KERNEL FATAL kernel panic</td>
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<td>KERNSERV KERNEL FATAL Power Good signal deactivated: R73-M1-N5. A service action may be required.</td>
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<td>KERNMICRO KERNEL FATAL Microloader Assertion</td>
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<td>APPTO APP FATAL ciod: Error reading message prefix on CioStream socket to 172.16.96.116:41739, Connection timed out</td>
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<td>APPUNAV APP FATAL ciod: Error creating node map from file /home/auselton/bgl/64mps.sequential.mapfile</td>
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Event Classification: Example

SCAPE Approach

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After classification
Event Prediction

SCAPE Approach

Observation window

Lead time

Prediction window

$t$

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SCAPE Approach

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SCAPE Approach

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Investigated parameters:

- Size of observation window
- Lead time
- Size of prediction window
- Sensitivity
Motivation: Failure Management

SCAPE Approach

Evaluation

Conclusion
• Research questions
  • RQ1: How do different machine learning algorithms perform for system event classification and prediction?
  • RQ2: What is the impact of event preprocessing on the size of the dataset and on the event classification?
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• Blue Gene/L supercomputer [Oliner and Stearley 2007]
  - 131,072 processors and 32,768 GB of RAM
  - 4,747,963 event messages collected over 215 days
  - 10-fold cross-validation
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<td>37</td>
<td>MASABNORM</td>
<td>BGLMASTER FAILURE mmcs_server exited abnormally due to signal: Aborted</td>
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<td>KERNSERV</td>
<td>KERNEL FATAL Power Good signal deactivated: R73-M1-NS. A service action may be required.</td>
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<td>144</td>
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<td>LINKIAP</td>
<td>LINKCARD FATAL MidplaneSwitchController::receiveTrain() iap failed: R72-M1-L1-U18-A, status=beeaabff ec000000</td>
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<td>KERNPOW</td>
<td>KERNEL FATAL Power deactivated: R05-M0-N4</td>
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<td>KERNSOCK</td>
<td>KERNEL FATAL MailboxMonitor::serviceMailboxes() lib_ido_error: -1019 socket closed</td>
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<tr>
<td>320</td>
<td>APPCHILD</td>
<td>APP FATAL ciod: Error creating node map from file /p/gb2/cabot/miranda/newmaps/8k_128x64x1_8x4x4.map</td>
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<td>342</td>
<td>KERNMC</td>
<td>KERNEL FATAL machine check interrupt</td>
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<td>512</td>
<td>APPBUSY</td>
<td>APP FATAL ciod: Error creating node map from file /p/gb2/pakin1/sweep3d-5x5x4-100mk-3mmi-1024pes-sweep/sweep.map</td>
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<tr>
<td>720</td>
<td>KERNMNT</td>
<td>KERNEL FATAL Error: unable to mount filesystem</td>
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<td>816</td>
<td>APPOUT</td>
<td>APP FATAL ciod: LOGIN chdir(p/gb1/stella/RAPTOR/2183) failed: Input/output error</td>
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<td>KERNMICRO</td>
<td>KERNEL FATAL Microloader Assertion</td>
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<td>APP FATAL ciod: Error reading message prefix on CioStream socket to 172.16.96.116:41739, Connection timed out</td>
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<td>3983</td>
<td>KERNRTSP</td>
<td>KERNEL FATAL rts panic: - stopping execution</td>
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<td>5983</td>
<td>APPREAD</td>
<td>APP FATAL ciod: failed to read message prefix on control stream CioStream socket to 172.16.96.116:33399</td>
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<td>6145</td>
<td>KERNREC</td>
<td>KERNEL FATAL Error receiving packet on tree network, expecting type 57 instead of type 3</td>
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<td>23338</td>
<td>KERNTERM</td>
<td>KERNEL FATAL rts: kernel terminated for reason 1004rts: bad message header</td>
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<td>KERNEL FATAL Lustre mount FAILED: bglio11 : block_id : location</td>
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<td>KERNSTOR</td>
<td>KERNEL FATAL data storage interrupt</td>
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<td>152734</td>
<td>KERNDTLB</td>
<td>KERNEL FATAL data TLB error interrupt</td>
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<td>4399503</td>
<td>-</td>
<td>KERNEL INFO instruction cache parity error corrected</td>
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</table>
Naive Bayes with normalized log

C4.5 with normalized log
Event Preprocessing Result

**Evaluation**

**Original log**

**Original ASF**

**Tuned ASF**

**DRF**
Impact of Event Preprocessing

Evaluation

![Box plot comparing F-Measure for Original ASF, Tuned ASF, and DRF](chart.png)

- Original ASF
- Tuned ASF
- DRF

T. Pitakrat et al. (U Stuttgart) A Framework for System Event Classification and Prediction by Machine Learning Dec. 10, 2014 @ VALUETOOLS
Investigated parameters:

- Size of observation window
- Lead time
- Size of prediction window
- Sensitivity
## Event Prediction Result (Preliminary)

### Evaluation

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Lead time (sec)</th>
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<td>120</td>
<td>300</td>
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<td>2800</td>
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<td>NaiveBayes</td>
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<td>0.589</td>
<td>0.547</td>
<td>0.517</td>
<td>0.506</td>
<td>0.511</td>
<td>0.506</td>
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<tr>
<td>C4.5</td>
<td><strong>0.877</strong></td>
<td>0.672</td>
<td>0.634</td>
<td>0.627</td>
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<thead>
<tr>
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<th>Prediction window (sec)</th>
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<td>0.511</td>
<td>0.532</td>
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<tr>
<td>C4.5</td>
<td>0.579</td>
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<td>0.624</td>
<td>0.640</td>
<td>0.625</td>
<td><strong>0.635</strong></td>
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## Event Prediction Result (Preliminary)

### Evaluation

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<td>C4.5</td>
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<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Sensitivity</th>
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<tr>
<td>NaiveBayes</td>
<td>0.546</td>
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<tr>
<td>C4.5</td>
<td>0.523</td>
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</table>
Motivation: Failure Management

SCAPE Approach

Evaluation

Conclusion
**Summary**

**Conclusion**

- **Monitoring Reader**
  - Hora
  - System-level Predictor
  - Kieker, Weka, R, ESPER, ...

- **Component-level Predictors**
  - PCM
  - SLAStic

- **Observation window**
- **Lead time**
- **Prediction window**

- **Preprocessing Filter**
- **Prediction Filter**
- **Training Filter**
- **Labelling Filter**
- **Shuffling Filter**
- **Evaluation Filter**

- **Classification and prediction results**

- **Supplementary material:** [http://www.iste.uni-stuttgart.de/rss/people/pitakrat/scape](http://www.iste.uni-stuttgart.de/rss/people/pitakrat/scape)
**Summary**

**Conclusion**

![Diagram of system event classification and prediction by machine learning](image)

**Observation window**

**Lead time**

**Prediction window**

- $e_i$
- $e_{i+1}$
- $e_{i+2}$
- $e_{i+3}$
- $e_{i+4}$

**Filters**

1. **Preprocessing Filter**
2. **Labelling Filter**
3. **Shuffling Filter**
4. **Evaluation Filter**
5. **Log message**

**Classification and prediction results**

**Supplementary material:**

[http://www.iste.uni-stuttgart.de/rss/people/pitakrat/scape](http://www.iste.uni-stuttgart.de/rss/people/pitakrat/scape)
### Summary

#### Conclusion

**Hora**

**System-level Predictor**

**Monitoring**

**Reader**

**Kieker, Weka, R, ESPER, ...**

**CDT**

**PAD**

**HDD Failure Predictor**

**SCAPE**

**Component-level Predictors**

**PCM**

**SLAstic**

**...**

---

Observation window Lead time Prediction window

\( e_i \quad e_{i+1} \quad e_{i+2} \quad e_{i+3} \quad e_{i+4} \)

Preprocessing Filter

Prediction Filter

Training Filter

Labelling Filter

Shuffling Filter

Evaluation Filter

Log message

Classification and prediction results

Supplementary material:

http://www.iste.uni-stuttgart.de/rss/people/pitakrat/scape
Next Steps

Conclusion

- Improve event prediction
- Extend evaluation settings
  - Evaluate with event log from other systems
- Integrate SCAPE into Hora framework
  - Combine with architectural model to infer the failure probability of other components


