Hora: Online Failure Prediction Framework for Component-based Software Systems Based on Kieker and Palladio

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Software Failure

Motivation: Failure Management

"A service failure, often abbreviated here to failure, is an event that occurs when the delivered service deviates from correct service." — Avizienis et al. [2004]

Hora: Online Failure Prediction Framework for CB Software Systems
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“A **service failure**, often abbreviated here to **failure**, is an event that occurs when the delivered service deviates from correct service.”

— Avizienis et al. [2004]
Reactive vs. Proactive Failure Mgmt.

Motivation: Failure Management

Reactive approach

- Failure detected
- Start recovery
- System recovered

QoS

100%
0%

Failure detected
Start recovery
System recovered
Reactive vs. Proactive Failure Mgmt.

Motivation: Failure Management

**Reactive approach**
- Failure detected
- Start recovery
- System recovered

**Proactive approach**
- Failure predicted
- Prepare recovery
- System recovered
1 Motivation: Failure Management

2 Online Failure Prediction: Foundations and Related Work

3 Hora: Online Failure Prediction for CB Systems

4 Hora: Framework and Implementation

5 Conclusion
OFP foresees imminent problems at runtime, e.g.,

- Resource exhaustion (hardware/software)
- Response time violations
- Hardware resource failures
Online Failure Prediction (OFP)

Online Failure Prediction: Foundations and Related Work

OFP foresees imminent problems at runtime, e.g.,

- Resource exhaustion (hardware/software)
- Response time violations
- Hardware resource failures

OFP requires

- Continuous monitoring
- Prediction techniques
Selected OFP Techniques

[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

- Time series analysis
  - Predicting values of future observations
- Machine learning and pattern recognition
  - Learning patterns and classifying runtime observations
Selected OFP Techniques

[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

- Time series analysis
  - Predicting values of future observations
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  - Predicting values of future observations
Selected OFP Techniques

[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

- **Time series analysis**
  - Predicting values of future observations
Selected OFP Techniques

[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

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Online Failure Prediction: Foundations and Related Work

- Time series analysis
  - Predicting values of future observations
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\[
\begin{align*}
&x_1 \\
\end{align*}
\]
Selected OFP Techniques

[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

- Time series analysis
  - Predicting values of future observations
- Machine learning and pattern recognition
  - Learning patterns and classifying runtime observations

Diagram:

```
\begin{itemize}
  \item \textbf{Time series analysis}
    \begin{itemize}
      \item Predicting values of future observations
    \end{itemize}
  \item \textbf{Machine learning and pattern recognition}
    \begin{itemize}
      \item Learning patterns and classifying runtime observations
    \end{itemize}
\end{itemize}
```
Selected OFP Techniques

[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

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Selected OFP Techniques

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Online Failure Prediction: Foundations and Related Work

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\[ x_1 \]
\[ x_2 \]
Selected OFP Techniques

[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

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Online Failure Prediction: Foundations and Related Work

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![Graph showing scatter plot with two variables, x1 and x2]
Selected OFP Techniques
[Salfner et al. 2010]

Online Failure Prediction: Foundations and Related Work

- Time series analysis
  - Predicting values of future observations
- Machine learning and pattern recognition
  - Learning patterns and classifying runtime observations
Architecture-based Approaches

Online Failure Prediction: Foundations and Related Work

- **Architecture-based reliability prediction** [Brosch 2012]

```
PCM-REL Instance
(with solved parameter dependencies)

Dependency Solver

PCM-REL Instance
(with reliability annotations)

Markov Transformation

Basic DTMC (absorbing)

Analysis Configuration Options:
- Markov Evaluation Level
- Markov State Reduction
- System Hardware States Handling

Full DTMC (absorbing)

System Reliability Metrics
(success and failure mode probabilities)
```
• Architecture-based reliability prediction [Brosch 2012]

![Diagram showing PCM-REL Instance, Markov Transformation, Basic DTMC, Full DTMC, and System Reliability Metrics]

- Markov Evaluation Level
- Markov State Reduction
- System Hardware States Handling

• Automatic Failure Diagnosis [Marwede et al. 2009]
1. Motivation: Failure Management

2. Online Failure Prediction: Foundations and Related Work

3. Hora: Online Failure Prediction for CB Systems

4. Hora: Framework and Implementation

5. Conclusion
Overview

Hora: Online Failure Prediction for CB Systems

Possible approaches to OFP for software systems:

1. Create one prediction model for the whole system
2. Create prediction models for important services
3. Hora: create one prediction model for each service and combine them
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1. Create one prediction model for the whole system
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Possible approaches to OFP for software systems:

1. Create one prediction model for the whole system
2. Create prediction models for important services
3. **Hora**: create one prediction model for each service and combine them

Component-level Prediction Models

\[ + \]

Component Dependency

\[ \Rightarrow \]

System-level Prediction Model
Component-level Prediction Models

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Component-level Prediction Models

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Component-level Prediction Models

Hora: Online Failure Prediction for CB Systems
### Component Dependency Table

Hora: Online Failure Prediction for CB Systems

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Limitations

1. History of failures
2. Time resolution
3. Concurrent and independent failures
System-level Prediction Model

Hora: Online Failure Prediction for CB Systems

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Advantages

- Failure time prediction
- Concurrent failure prediction
- Root cause analysis
- Updatable model
Hora: Online Failure Prediction for CB Systems

PCM
SLAStic
...

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Component Dependency Table → Component Prediction Models → System Prediction Model

PCM
SLA\textit{stic}
...

Hora: Online Failure Prediction Framework for CB Software Systems
Agenda

1. Motivation: Failure Management

2. Online Failure Prediction: Foundations and Related Work

3. Hora: Online Failure Prediction for CB Systems

4. Hora: Framework and Implementation

5. Conclusion
Applied Monitoring Records

- SMARTDataRecord
- LogMessageRecord
Applied Monitoring Records
- SMARTDataRecord
- LogMessageRecord

Applicable Monitoring Records
- CPUUtilizationRecord
- MemSwapUsageRecord
- ResourceUtilizationRecord
- OperationExecutionRecord
Continuous Monitoring

Hora: Framework and Implementation

Applied Monitoring Records
- SMARTDataRecord
- LogMessageRecord

Applicable Monitoring Records
- CPUUtilizationRecord
- MemSwapUsageRecord
- ResourceUtilizationRecord
- OperationExecutionRecord

Wish list
- HardwareTemperatureRecord
- NetworkStatusRecord
- ServiceStatusRecord
Extraction of architectural models

- Manual creation
- Static analysis
  - SoMox [Becker et al. 2010], ArchiMetrix [Platenius et al. 2012]
- Dynamic analysis
  - Kieker [van Hoorn et al. 2012]

Model transformation

- PCM to DTMC [Brosch 2012]
- PCM and SLAStic to CDT and to CTMC
Motivation: Failure Management

Online Failure Prediction: Foundations and Related Work

Hora: Online Failure Prediction for CB Systems

Hora: Framework and Implementation

Conclusion
Failure is not an option.
(It's bundled with the software.)
Failure is not an option. (It’s bundled with the software.)
Summary

Conclusion

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Next Steps

- Develop Hora as a reusable online prediction framework
  - Transformation of PCM to DTMC [Brosch 2012]
  - Selecting a suitable transition system for prediction model
  - Transformation of PCM, SLAStic to CDT and to prediction model
- Evaluate the approach by simulations and lab experiments
- Extend the approach to
  - integrate usage profile
  - self-tuning prediction models
- Integration into APM (ExplorViz)


