

⊖PAD:

Online Performance Anomaly Detection with Kieker

Tillmann Bielefeld¹ and André van Hoorn²

¹ empuxa GmbH, Kiel

² Software Engineering Group, Kiel University

7th Hamburg Web Performance Meetup

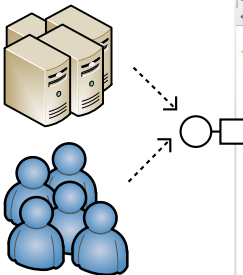
October 24, 2012 @ Microsoft, Hamburg



Motivation: Monitoring/Dynamic Analysis



Kieker: Framework Overview



Bücher versandkostenfrei - Hörbücher - eBooks - OYO - Musik - DVD - Blu-rays - Mozilla Firefox <2>

Datenschutz | Bearbeiten | Ansicht | Chronik | Lesezeichen | Extras | Hilfe

Bücher versandkostenfrei - Hörbüch...

www.thalia.de/shop/tra_homestartseite/show/

Anmelden | Mein Konto | Hilfe | Filialen & Events | Merkzettel (0) | Mein Warenkorb

Thalia.de

Alle Kategorien | Suchen

Bücher | eBooks | OYO | Hörbücher | Filme | Musik | Spielwaren | Games | Software

Schulbücher und Lernhilfen

Jetzt bestellen

Schulbücher | Europameisterschaft | Grillen & Sommerküche | Thilo Sarrazin

Taschenbücher

Aktuelle Themen

- Die ZEIT Post-Thriller-Box
- Tribute von Panem
- Event: Thalia Tainment
- Reduziert: OYO & Tasche
- TouchMe TFT-Reader

Thalia in Ihrer Nähe

PLZ oder Ort

Filiale suchen

Buchhändler Tipp

Eine Empfehlung von **Heike Fischer**
Thalia-Filiale Hürth

Warum Bibel?
Weil sie als Basistext für fast alle GrillerInnen...
mehr

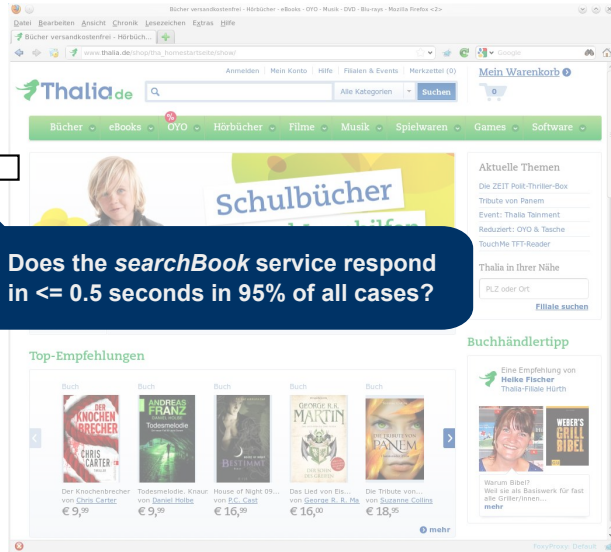
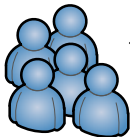
Top-Empfehlungen

Buch	Buch	Buch	Buch	Buch
Der Knochenbrecher von Chris Carter € 9,99	Todesmelodie, Knauer von Daniel Holbe € 9,99	House of Night 09... von P.C. Cast € 16,99	Das Lied von Eis... von George R. R. Martin € 16,00	Die Tribute von... von Suzanne Collins € 18,95

mehr

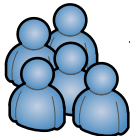
FoxyProxy: Default

Motivation: Monitoring/Dynamic Analysis



The screenshot shows the Thalia.de website interface. At the top, there is a search bar and navigation menus for 'Bücher', 'eBooks', 'OYO', 'Hörbücher', 'Filme', 'Musik', 'Spielwaren', 'Games', and 'Software'. A large banner for 'Schulbücher' is visible. Below the banner, there are sections for 'Aktuelle Themen' and 'Thalia in Ihrer Nähe'. The 'Top-Empfehlungen' section displays five book covers with their titles and prices: 'Der Knochenbrecher' (€ 9,99), 'Todesmelodie' (€ 9,99), 'House of Night 09...' (€ 16,99), 'Das Lied von Eis...' (€ 16,00), and 'Die Tribute von...' (€ 18,95). A 'Buchhändler Tipp' section features a recommendation from Helke Fischer for 'WEEB'S GRILL BIBEL'.

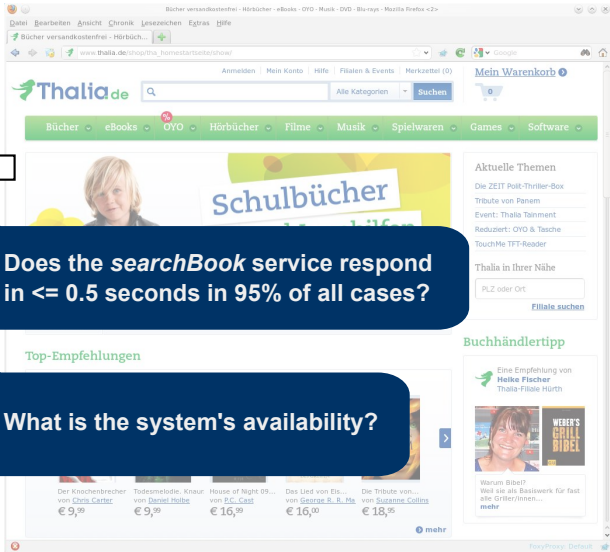
Motivation: Monitoring/Dynamic Analysis

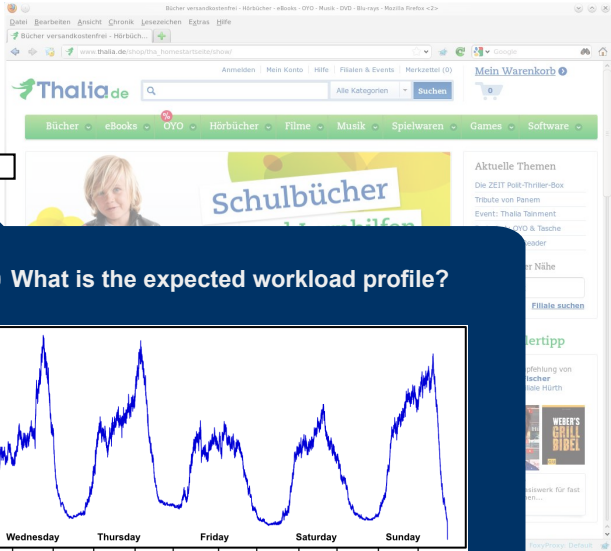
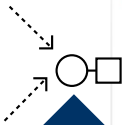
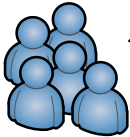


Does the *searchBook* service respond in ≤ 0.5 seconds in 95% of all cases?

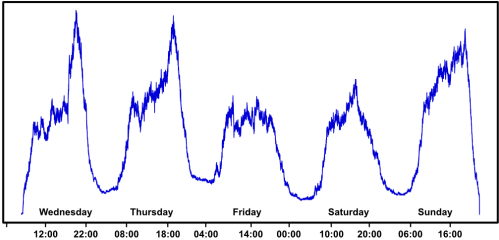


What is the system's availability?



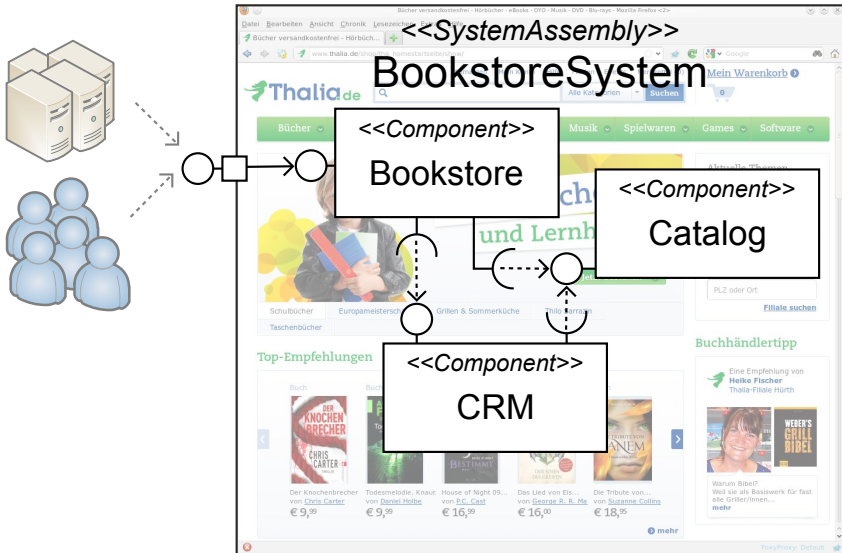


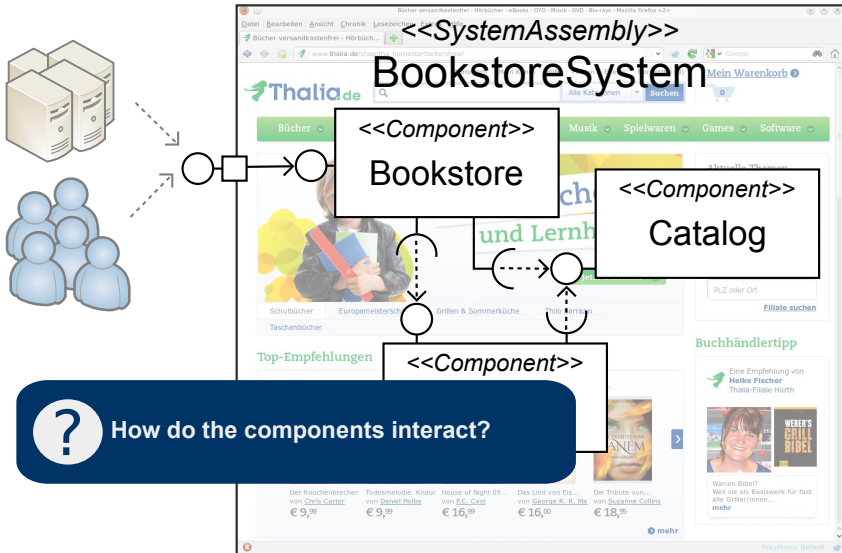
? What is the expected workload profile?

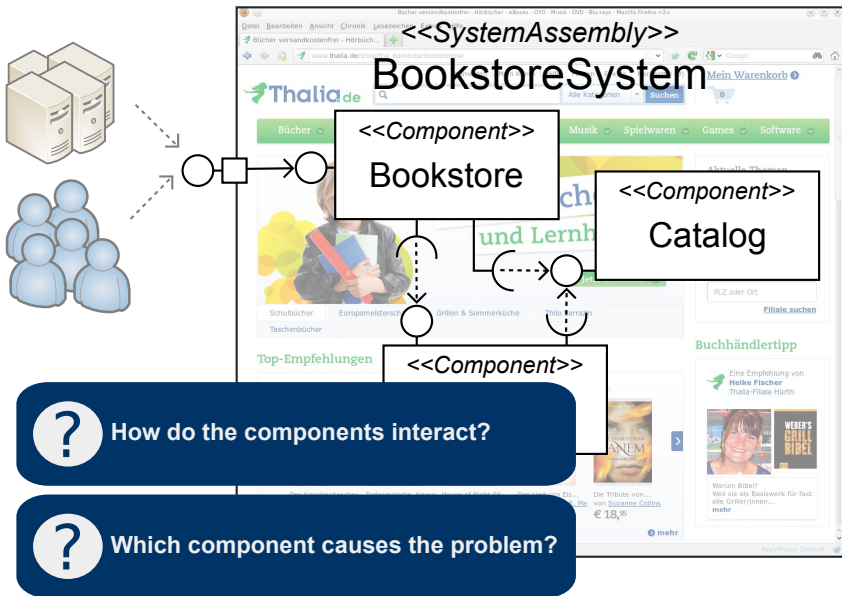


The graph displays workload over a week, with the x-axis labeled by day and time (12:00, 22:00, 08:00, 18:00, 04:00, 14:00, 00:00, 10:00, 20:00, 06:00, 16:00). The y-axis represents workload. The profile shows a clear daily cycle with peaks during the day and troughs at night. There are also significant peaks on the weekend, particularly on Sunday.

Motivation: Monitoring/Dynamic Analysis



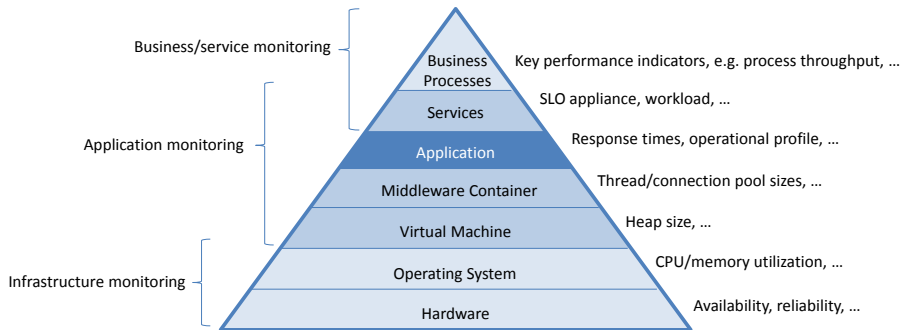




Motivation: Monitoring/Dynamic Analysis



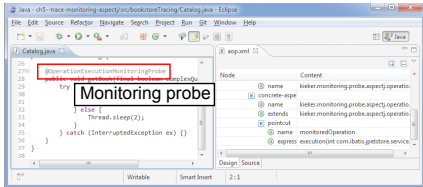
Continuous Monitoring of Software Systems



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

Kieker: Framework Overview

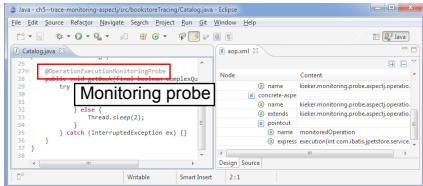


Software system with monitoring instrumentation

Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

Kieker: Framework Overview



```
26  
27  
28  
29 @OperationExecutionMonitoringProbe  
30 try  
31  
32 } else {  
33     Thread.sleep(2);  
34  
35 } catch (InterruptedException ex) {}  
36  
37  
38
```

Software system with monitoring instrumentation

Java probes/samplers:

Monitoring Probes/Samplers	Control-flow tracing	Manual instrumentation	
		AspectJ	Spring
		Servlet	CXF/SOAP
		<your interception technology>	
	Resource monitoring	Servlet	Sigar
			CPU utilization
			Memory usage
		<your technology>	
		<your monitoring probe>	

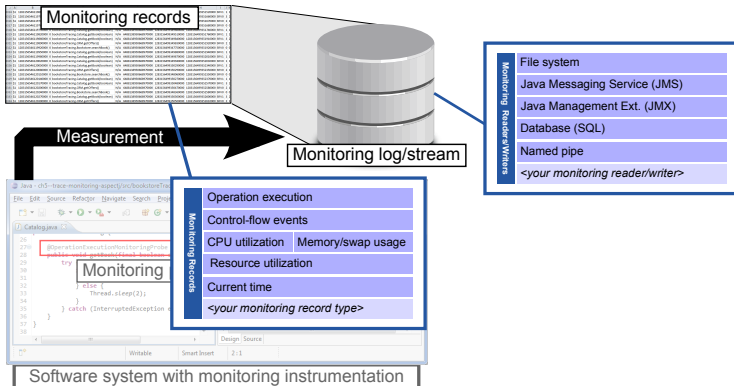
+ basic adapters for

- C#/.NET
- Visual Basic 6/COM
- COBOL

Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

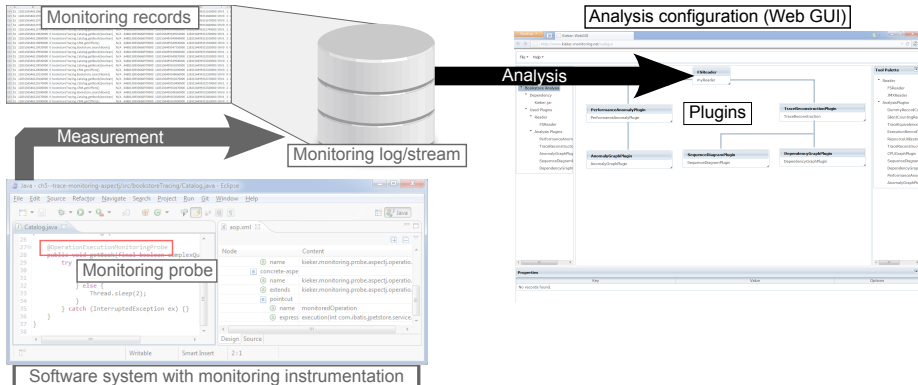
Kieker: Framework Overview



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

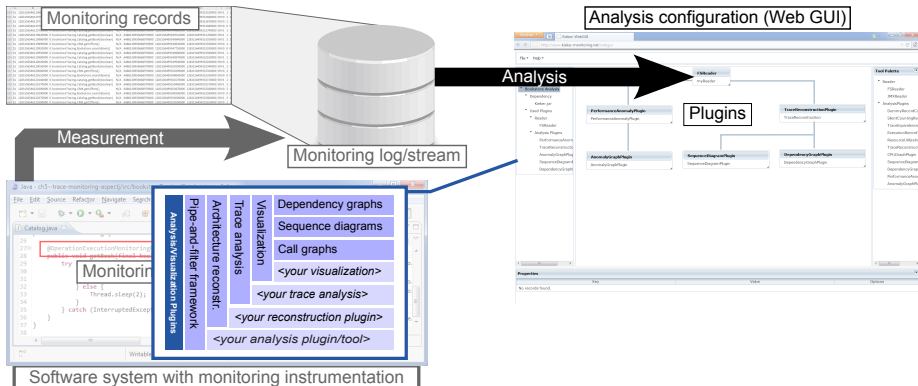
Kieker: Framework Overview



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

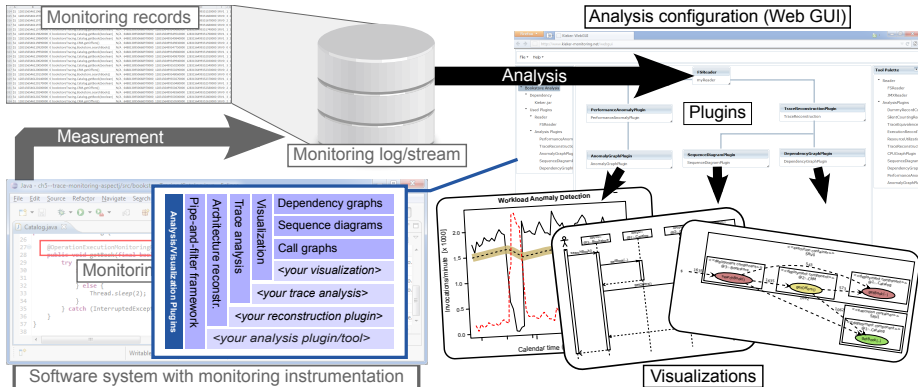
Kieker: Framework Overview



Kieker: Example Workflow and Use Cases

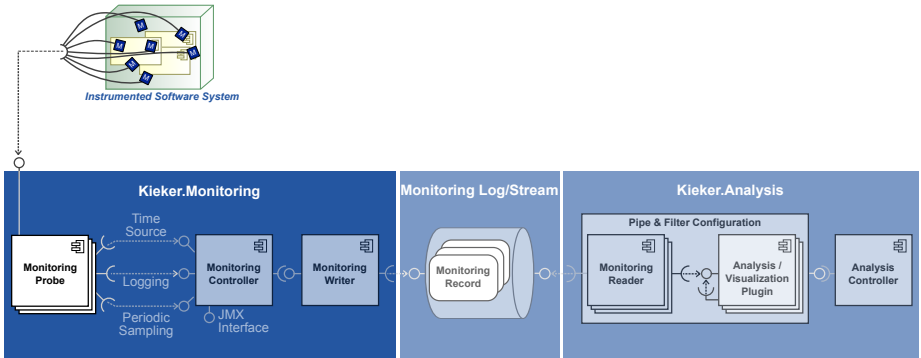
[van Hoorn et al. 2012]

Kieker: Framework Overview

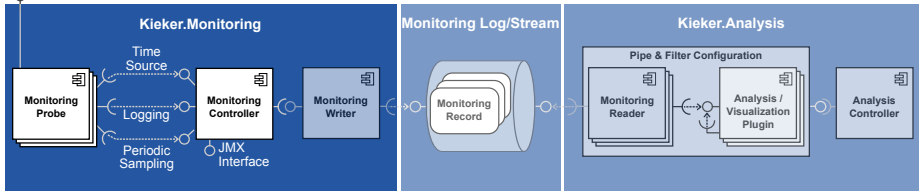
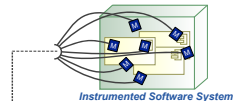


Core Kieker Framework Components

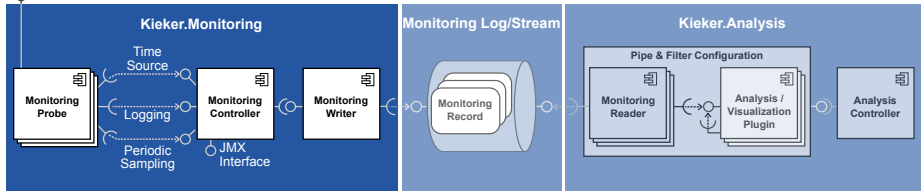
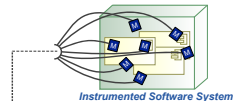
Kieker: Framework Overview



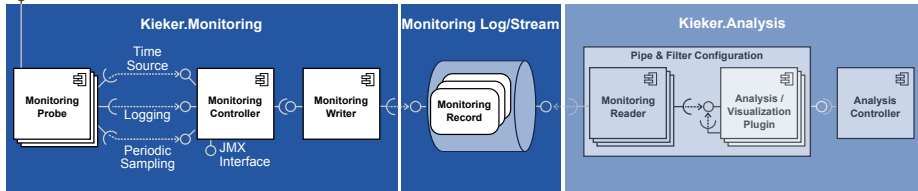
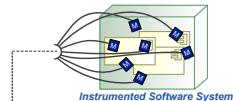
Core Kieker Framework Components



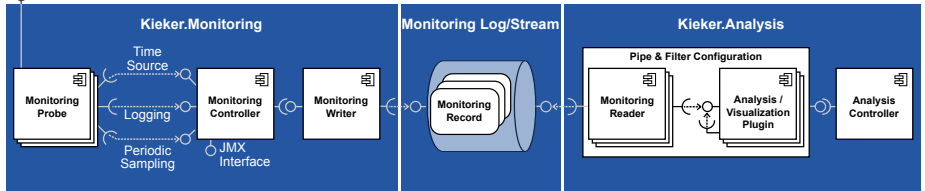
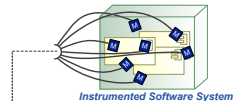
Core Kieker Framework Components



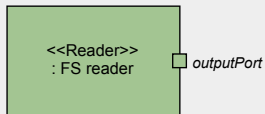
Core Kieker Framework Components



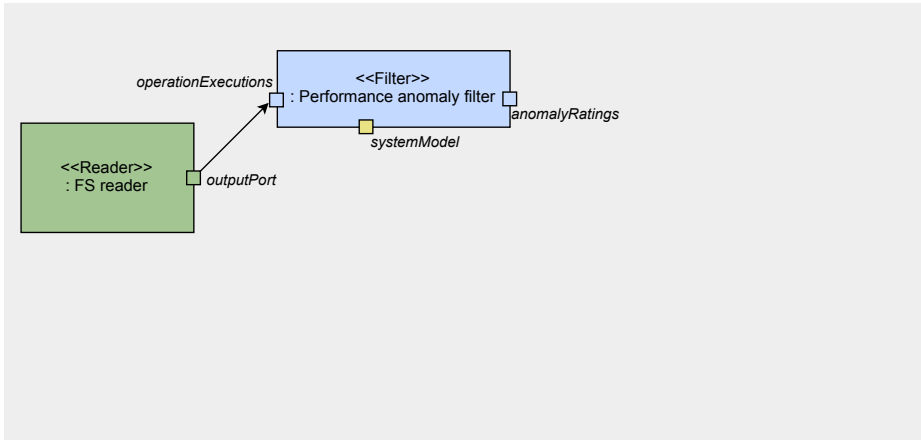
Core Kieker Framework Components



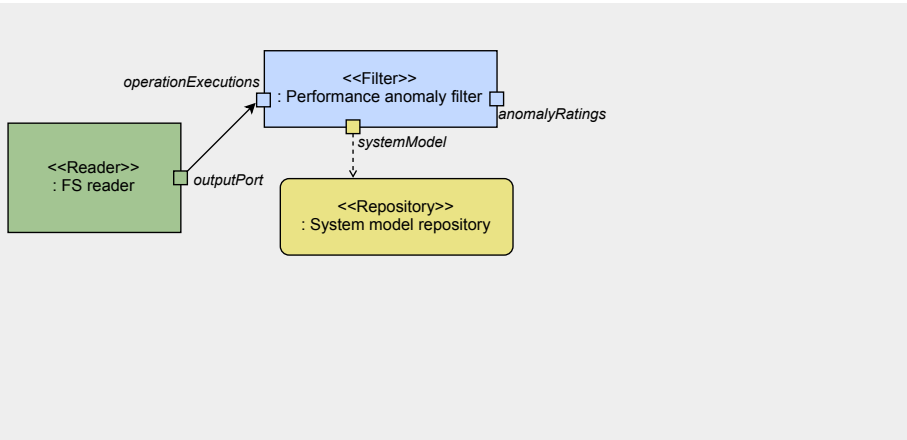
Example Pipe-and-Filter Configuration



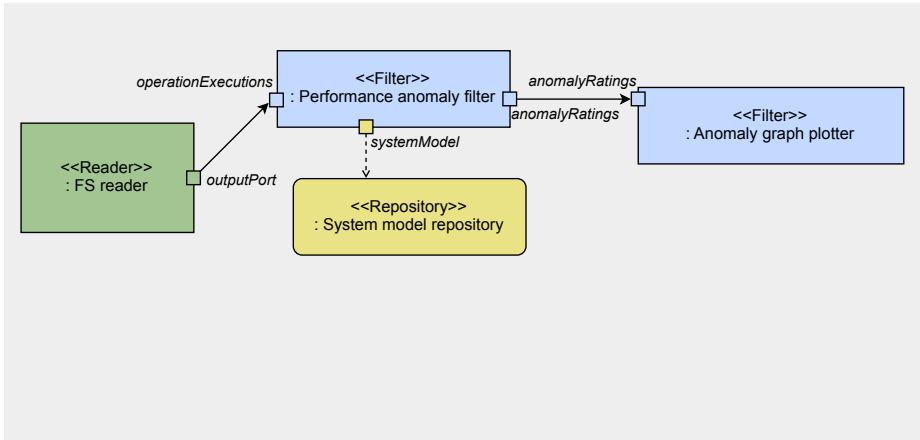
Example Pipe-and-Filter Configuration



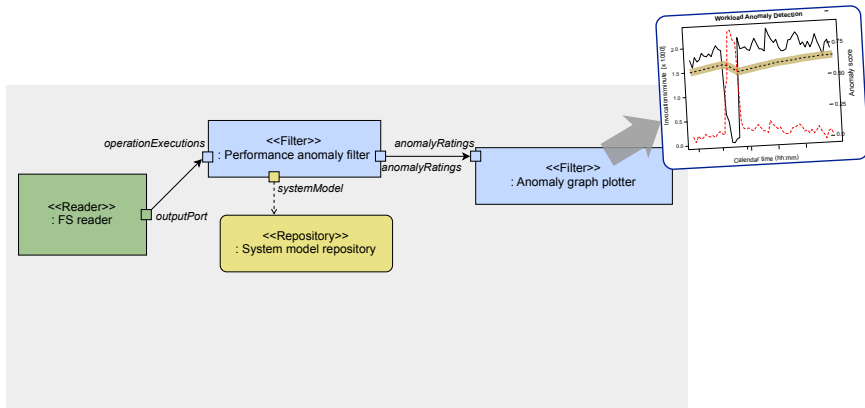
Example Pipe-and-Filter Configuration



Example Pipe-and-Filter Configuration



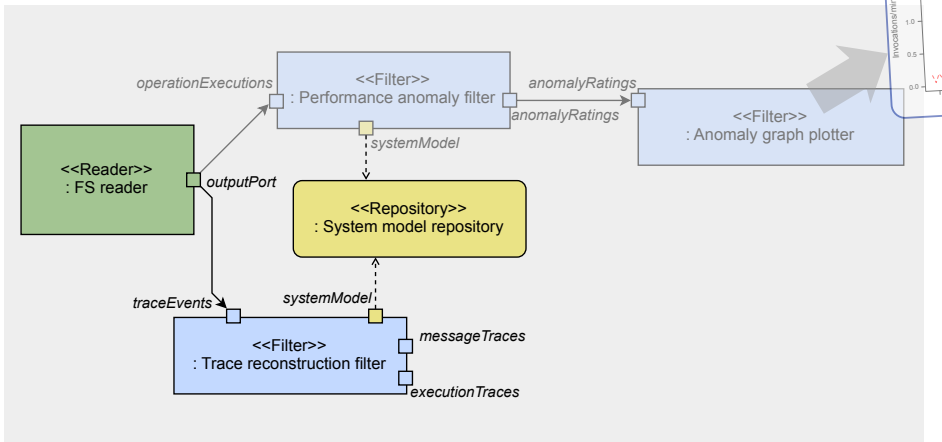
Example Pipe-and-Filter Configuration



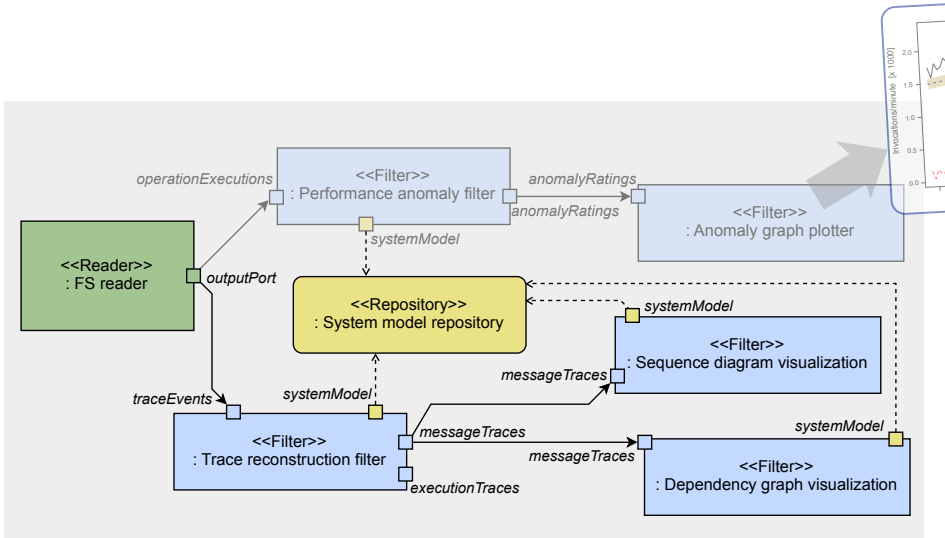
Kieker.Analysis example pipes-and-filters configuration

- Performance anomaly detection and visualization
- Architecture and trace reconstruction/visualization

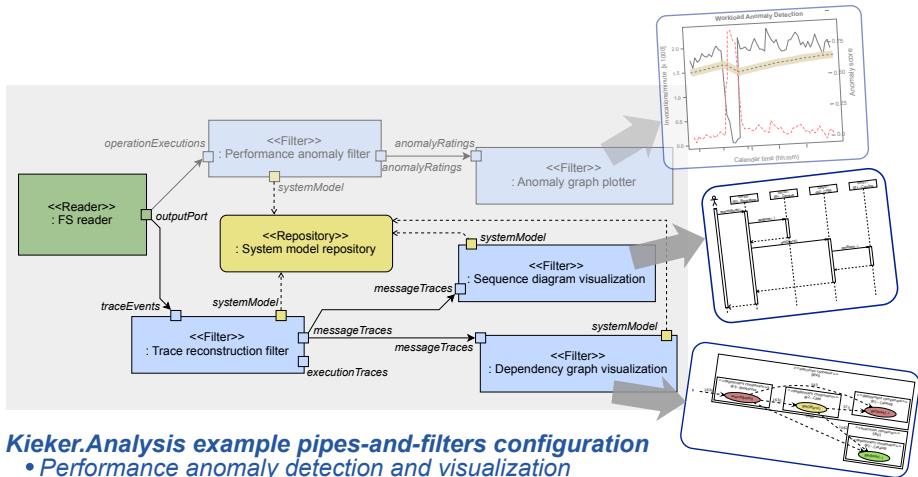
Example Pipe-and-Filter Configuration



Example Pipe-and-Filter Configuration



Example Pipe-and-Filter Configuration



Kieker.Analysis example pipes-and-filters configuration

- Performance anomaly detection and visualization
- Architecture and trace reconstruction/visualization

WebGUI (Beta) Included in Kieker 1.6



Kieker: Framework Overview

The screenshot shows the Kieker WebGUI welcome page. At the top left is the Kieker logo with the tagline "keeps an eye on you". A central message box says "Welcome to the Kieker.WebGUI" and explains that this is an early beta version. Below this is a login form with fields for "Username" (pre-filled with "Guest") and "Password", and a "Login" button. A note at the bottom states: "Note: The Kieker WebGUI requires Cookies and JavaScript in order to work correctly. Please make sure that both is enabled."

The screenshot shows the main dashboard of Kieker WebGUI. The title is "Kieker". Below the title are navigation tabs for "Analysis Editor", "Analysis", "Context Editor", and "Context". A "File" menu and "Guest" user indicator are visible. The main area contains a table with columns for "Project Name", "State", and "Last Modification". The table lists one project: "Bookstore-Example" with state "TERMINATED" and a last modification time of "Wed Oct 17 00:00:58 CEST 2012".

The screenshot shows the configuration page for the "Bookstore-Example" project. The title is "Kieker » Bookstore-Example". On the left is a dependency graph showing the relationships between various plugins. On the right is a list of "Available Plugins" categorized into "Reader" (MultiReader, CSVReader, JMSReader, JMXReader, FileReader) and "Filter" (MultiResponseTimeFilter, MultiResponseDataPointFilter, EventResponseTimeFilter, ContextThroughputFilter, ResponseResourceDefaultExec, SingleBufferFilter). At the bottom is a "Properties" table:

Property	Value
ClassName	kieker.siemens.plugins.jdbc.ch3.spl4bookstore.MyResponseTimeFilter
Name	MyResponseTimeFilter

The screenshot shows the log view for the "Bookstore-Example" project. The title is "Kieker » Bookstore-Example". Below the title are tabs for "Personal Log" and "AnalysisController Log". The log entries are:

- Mon Oct 22 11:12:30 CEST 2012 : Instantiating Analysis for project: 'Bookstore-Example'
- Mon Oct 22 11:12:33 CEST 2012 : Starting Analysis for project: 'Bookstore-Example'

At the bottom, there are four circular status indicators: three grey and one red.

WebGUI (Beta) Included in Kieker 1.6



Kieker: Framework Overview

KiekerWebGUI - Mozilla Firefox

File Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe

Kieker.WebGUI

Kieker » Bookstore-Example

Analysis Editor Analysis Cockpit Editor Cockpit

File Graph Help Guest

Available Plugins

- Reader
 - MyPipeReader
 - DbReader
 - FSReader
 - JMSReader
 - JMXReader
 - PipeReader
- Filter
 - MyResponseTimeFilter
 - MyResponseTimeOutputPrinter
 - EventRecordTraceReconstructionFilter
 - CountingFilter
 - CountingThroughputFilter
 - RealtimeRecordDelayFilter
 - StringBufferFilter

Properties

Property	Value
ClassName	kieker.examples.userguide.ch3and4bookstore.MyResponseTimeFilter
Name	MyResponseTimeFilter

Framework Features & Extension Points



- Modular, flexible, and extensible architecture (Probes, records, readers, writers, filters etc.)
- Pipes-and-filters framework for analysis configuration
- Distributed tracing (logging, reconstruction, visualization)
- Low overhead (designed for continuous operation)
- Evaluated in lab and industrial case studies

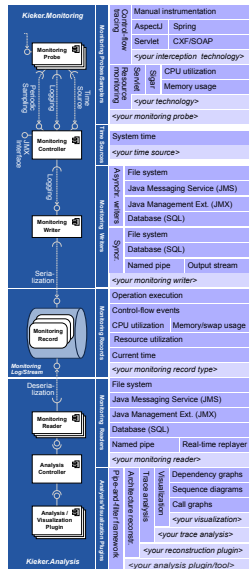


Kieker is open-source software (Apache License, V. 2.0)

<http://kieker-monitoring.net>

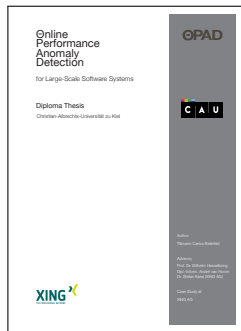
Kieker is distributed as part of SPEC® RG's repository of peer-reviewed tools for quantitative system evaluation and analysis

<http://research.spec.org/projects/tools.html>



- 1 Kieker: Framework Overview
- 2 **OPAD: Online Performance Anomaly Detection**
- 3 Conclusion

- 1 Design of online performance anomaly detection concept (Θ PAD)
- 2 Θ PAD implementation as **Kieker** plugin
- 3 Θ PAD integration with case study system
- 4 Evaluation @ **XING^x**

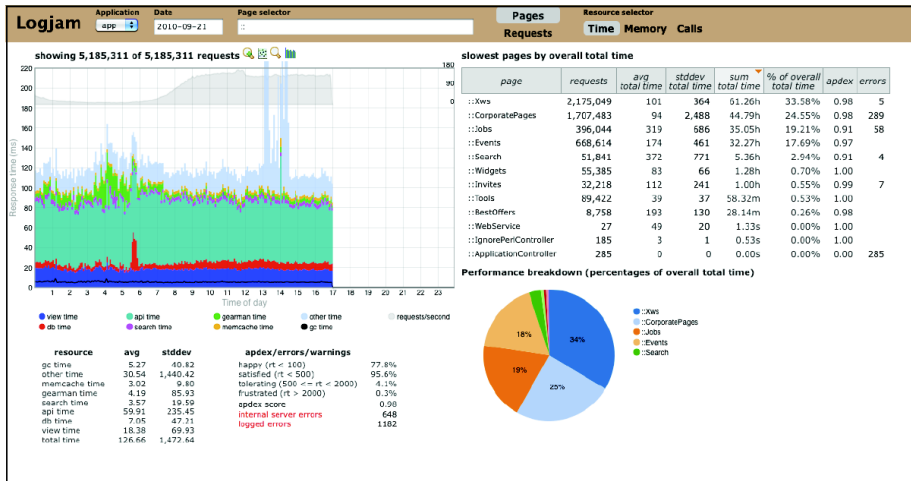


Tillmann C. Bielefeld:
“Online performance anomaly detection for large-scale software systems”
March 2012. Diploma Thesis, Kiel Univ.

Existing Logjam-based Monitoring @ XING



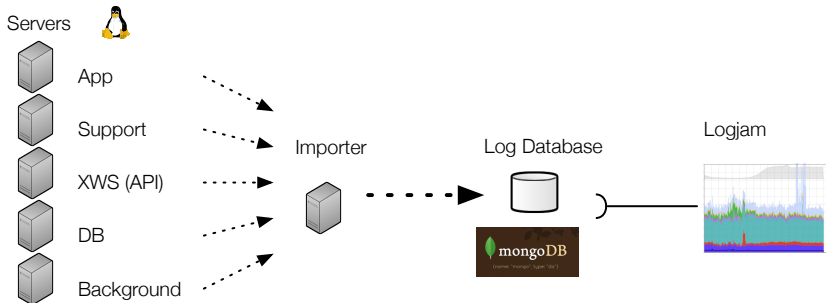
OPAD: Online Performance Anomaly Detection



Logjam-based monitoring already in place @ XING^X

Integration of Θ PAD in XING's Architecture

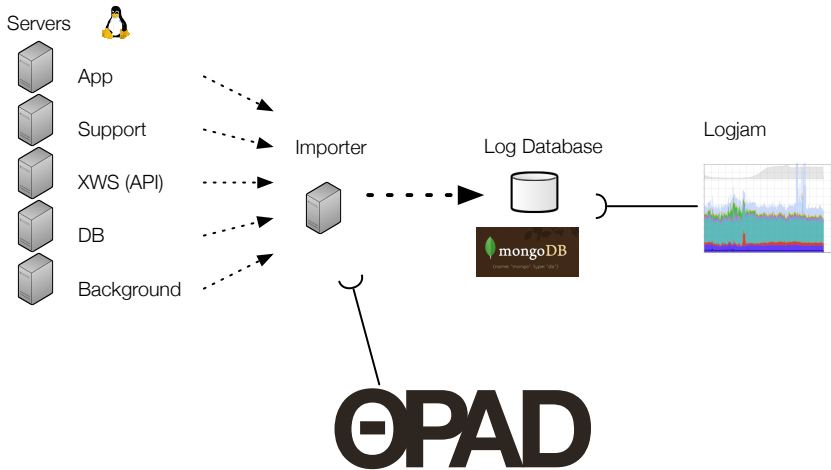
OPAD: Online Performance Anomaly Detection



XING's logging/monitoring architecture

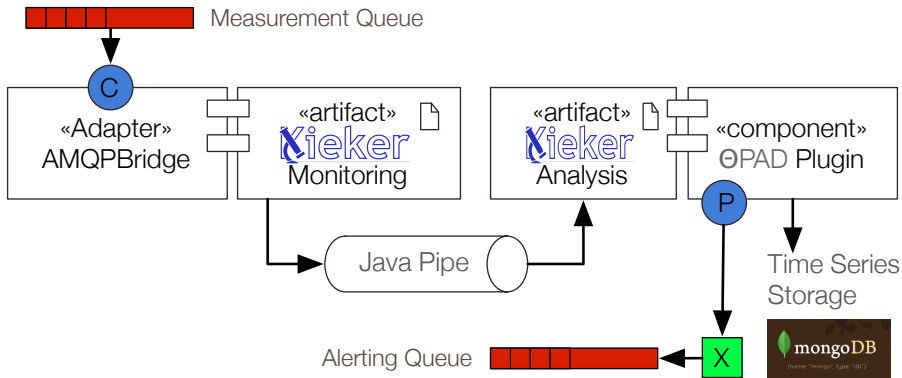
Integration of Θ PAD in XING's Architecture

OPAD: Online Performance Anomaly Detection



```
{  
  "count": 5204.903527993169,  
  "memcache_time": 6505.196318140181,  
  "api_time": 2207.0271495891297,  
  "db_time": 5004.8727338680155,  
  ...  
  "view_time": 3936.1623304929153,  
  "total_time": 1586.8188192888886,  
  "api_calls": 5546.250545491678  
}
```

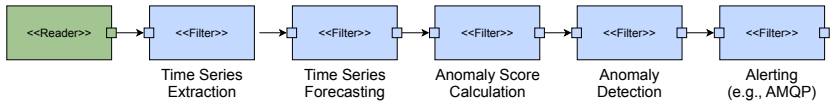
Input data received via AMQP and processed by Θ PAD



- 1 AMQP messages transformed into Kieker monitoring records
- 2 Θ PAD: pipes-and-filters processing of records
- 3 Θ PAD results passed to alerting queue and time-series storage

OPAD Processing Steps

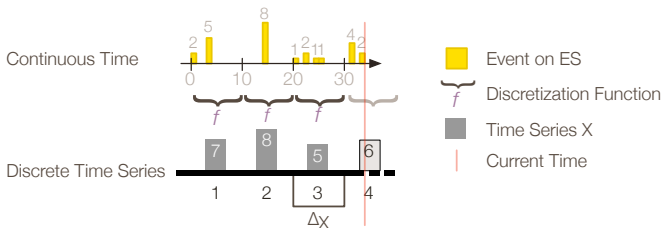
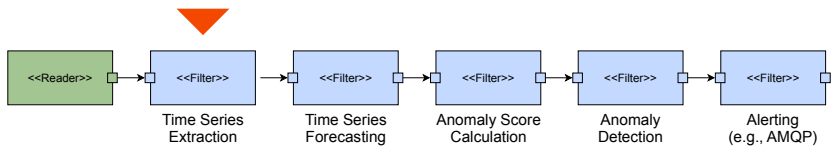
OPAD: Online Performance Anomaly Detection



Step 1: Time Series Extraction

OPAD Processing Steps (cont'd)

OPAD: Online Performance Anomaly Detection

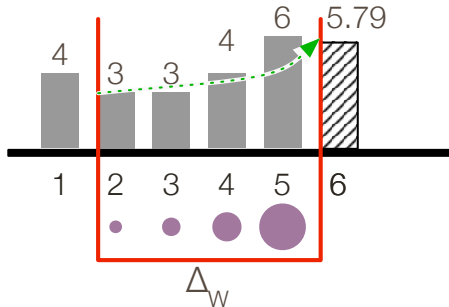
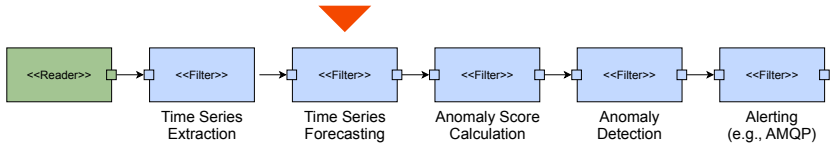


```
select sum(value) as aggregation
from MeasureEvent.win:time_batch( 1000 msec )
```

Step 2: Time Series Forecasting

OPAD Processing Steps (cont'd)

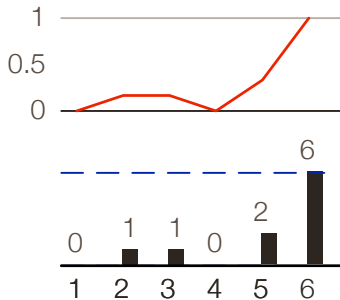
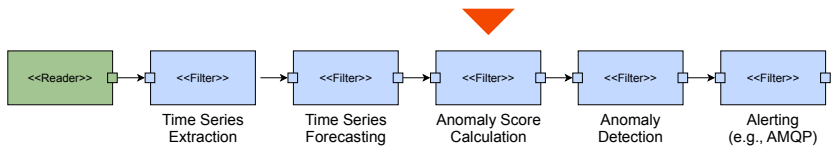
OPAD: Online Performance Anomaly Detection



Step 3: Anomaly Score Calculation

OPAD Processing Steps (cont'd)

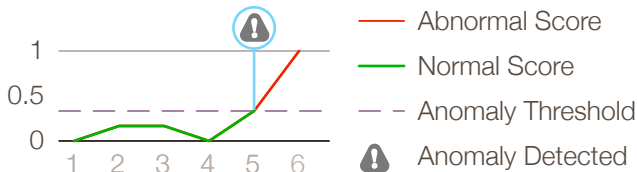
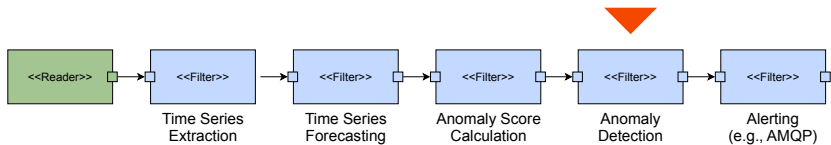
OPAD: Online Performance Anomaly Detection

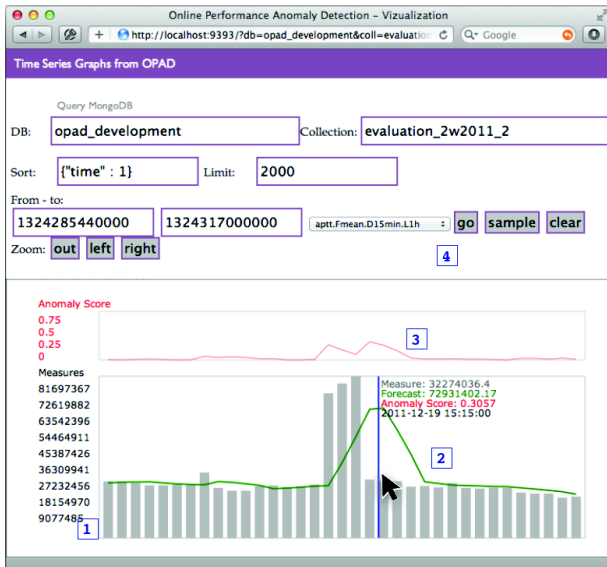


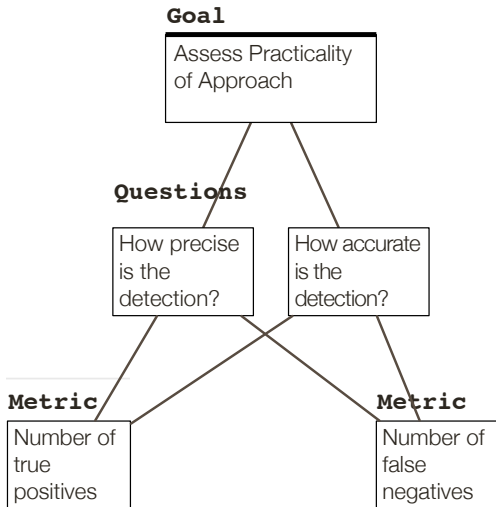
Step 4: Anomaly Detection

OPAD Processing Steps (cont'd)

OPAD: Online Performance Anomaly Detection





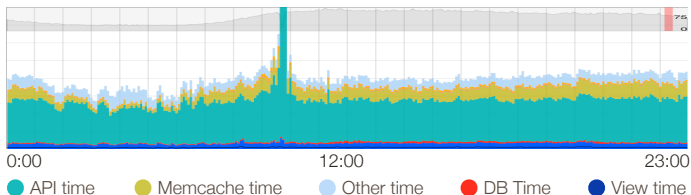


Goal/Question/Metric (GQM) plan (excerpt)

Manual Identification of Anomalies

Evaluation Methodology (cont'd)

OPAD: Online Performance Anomaly Detection



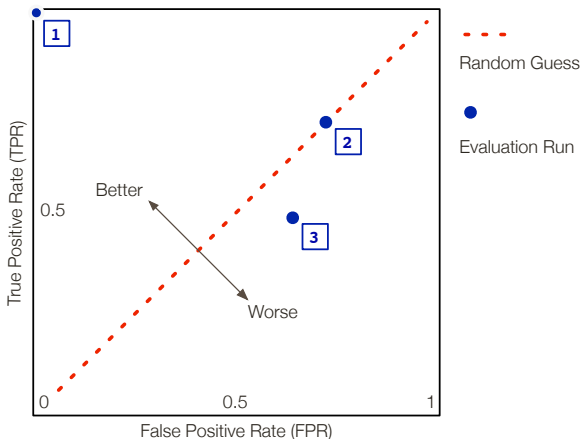
- Manual detection using the visualization tool
- 8 anomalies were detected



ROC Curves (Introduction)

Evaluation (cont'd)

OPAD: Online Performance Anomaly Detection



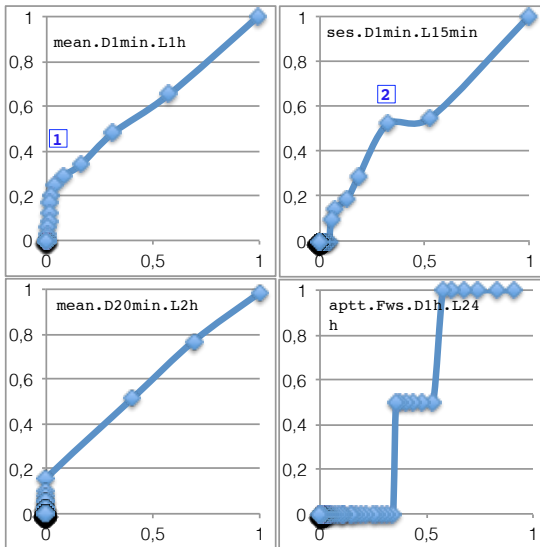
$$\text{TPR} = \frac{\text{TP}}{\text{TP} + \text{FN}} = \frac{\text{TP}}{\text{F}}$$

$$\text{FPR} = \frac{\text{FP}}{\text{FP} + \text{TN}} = \frac{\text{FP}}{\text{NF}} \quad (1)$$

ROC Curves (Θ PAD Results)

Evaluation (cont'd)

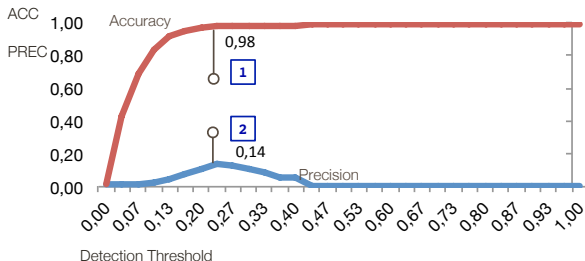
OPAD: Online Performance Anomaly Detection



Accuracy and Precision

Evaluation (cont'd)

OPAD: Online Performance Anomaly Detection



$$\text{PREC} = \frac{\text{TP}}{\text{POS}} = \frac{\text{TP}}{\text{TP} + \text{FP}} \quad (2)$$

$$\text{ACC} = \frac{\text{TP} + \text{TN}}{N} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{FN} + \text{TN}} \quad (3)$$



Tillmann C. Bielefeld:
“Online performance anomaly detection for large-scale software systems”
March 2012. Diploma Thesis, Kiel Univ.

Outlook

- Θ PAD to be released as part of Kieker
- Follow-up theses on Θ PAD

Contact Us

- till@empuxa.com
- avh@informatik.uni-kiel.de

KoSSE Symposium on Application Performance Management

Nov. 29/30, 2012 (Thu/Fri) @ Wissenschaftszentrum Kiel

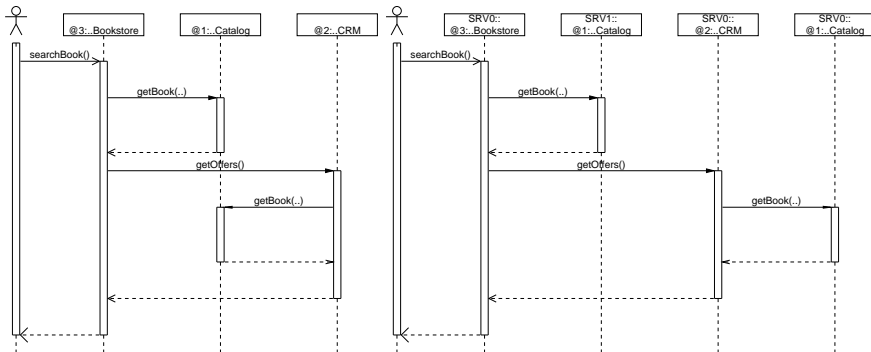
Invited talks by (see <http://kosse-sh.de> for details)

- b+m Informatik AG, Melsdorf
- Consist Software Solutions GmbH, Kiel
- empuxa GmbH, Kiel
- Karlsruhe Inst. of Technology (KIT)
- Kiel University
- QAware GmbH, Munich
- RWTH Aachen
- SAP Research, Karlsruhe
- XING AG, Hamburg

- Social event: Dinner at Forstbaumschule (Nov. 29, 18:30h)
- Registration required (no fee!): mail@diwish.de

- T. C. Bielefeld. Online performance anomaly detection for large-scale software systems. <https://tielefeld.s3.amazonaws.com/diploma/Bielefeld2012DA0nlinePerformanceAnomalyDetectionForLargeScaleSoftwareSystems.pdf>, Mar. 2012. Diploma Thesis, University of Kiel.
- Kieker Project. *Kieker 1.6 User Guide*. Software Engineering Group, University of Kiel, Germany, Oct. 2012a. URL <http://kieker-monitoring.net/documentation/>.
- Kieker Project. Kieker web site, 2012b. URL <http://kieker-monitoring.net/>.
- A. van Hoorn, M. Rohr, W. Hasselbring, J. Waller, J. Ehlers, S. Frey, and D. Kieselhorst. Continuous monitoring of software services: Design and application of the Kieker framework. Technical Report TR-0921, Department of Computer Science, University of Kiel, Germany, Nov. 2009. URL http://www.informatik.uni-kiel.de/uploads/tx_publication/vanhoorn_tr0921.pdf.
- A. van Hoorn, J. Waller, and W. Hasselbring. Kieker: A framework for application performance monitoring and dynamic software analysis. In *Proceedings of the 3rd ACM/SPEC International Conference on Performance Engineering (ICPE 2012)*, pages 247–248. ACM, Apr. 2012. ISBN 978-1-4503-1202-8. doi: 10.1145/2188286.2188326.

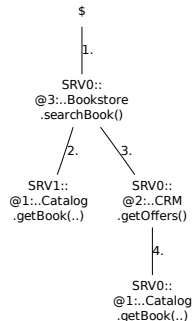
- 1 Sequence diagrams
- 2 Dynamic call trees
- 3 Hierarchical calling dependency graphs
- 4 System model



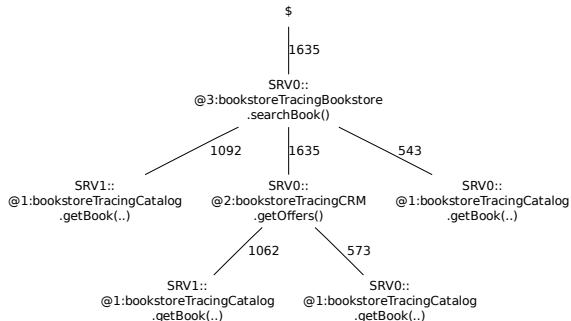
(a) Assembly-level view

(b) Deployment-level view

- 1 Sequence diagrams
- 2 **Dynamic call trees**
- 3 Hierarchical calling dependency graphs
- 4 System model

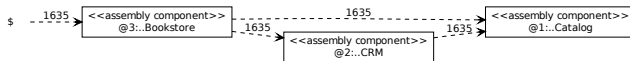


(a) Dynamic call tree (**single trace**)

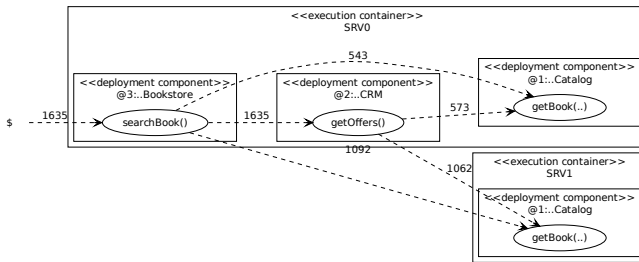


(b) **Aggregated** deployment-level call tree

- 1 Sequence diagrams
- 2 Dynamic call trees
- 3 **Hierarchical calling dependency graphs**
- 4 System model



(a) **Assembly-level component** dependency graph



(b) **Deployment-level operation** dependency graph

System Model (HTML Representation)

Kieker.TraceAnalysis Tool (cont'd)

Bonus



- 1 Sequence diagrams
- 2 Dynamic call trees
- 3 Hierarchical calling dependency graphs
- 4 **System model** (here: HTML representation)

System Model Reconstructed by Kieker.TraceAnalysis - Mozilla Firefox

System Model Reconstructed by Kieker.TraceAnalysis

Component Types

ID	Package	Name	Operations
3	bookstoreTracing	Bookstore	• searchBook(): N/A
2	bookstoreTracing	CRM	• getOffers(): N/A
1	bookstoreTracing	Catalog	• getBook(boolean): N/A

Operations

ID	Component type	Name	Parameter types	Return type
3	bookstoreTracing_Bookstore	searchBook		N/A
2	bookstoreTracing_CRM	getOffers		N/A
1	bookstoreTracing_Catalog	getBook	• boolean	N/A

Assembly Components

ID	Name	Component type
3	#3	bookstoreTracing_Bookstore
2	#2	bookstoreTracing_CRM
1	#1	bookstoreTracing_Catalog

Execution Containers

ID	Name
2	SRV0
1	SRV1

Deployment Components

ID	Assembly component	Execution container
4	#3_bookstoreTracing_Bookstore	SRV0
3	#2_bookstoreTracing_CRM	SRV0
2	#1_bookstoreTracing_Catalog	SRV0
1	#1_bookstoreTracing_Catalog	SRV1

Fertig FoxyProxy: Inaktiv