

Dynamic Analysis of Software Systems with Kieker

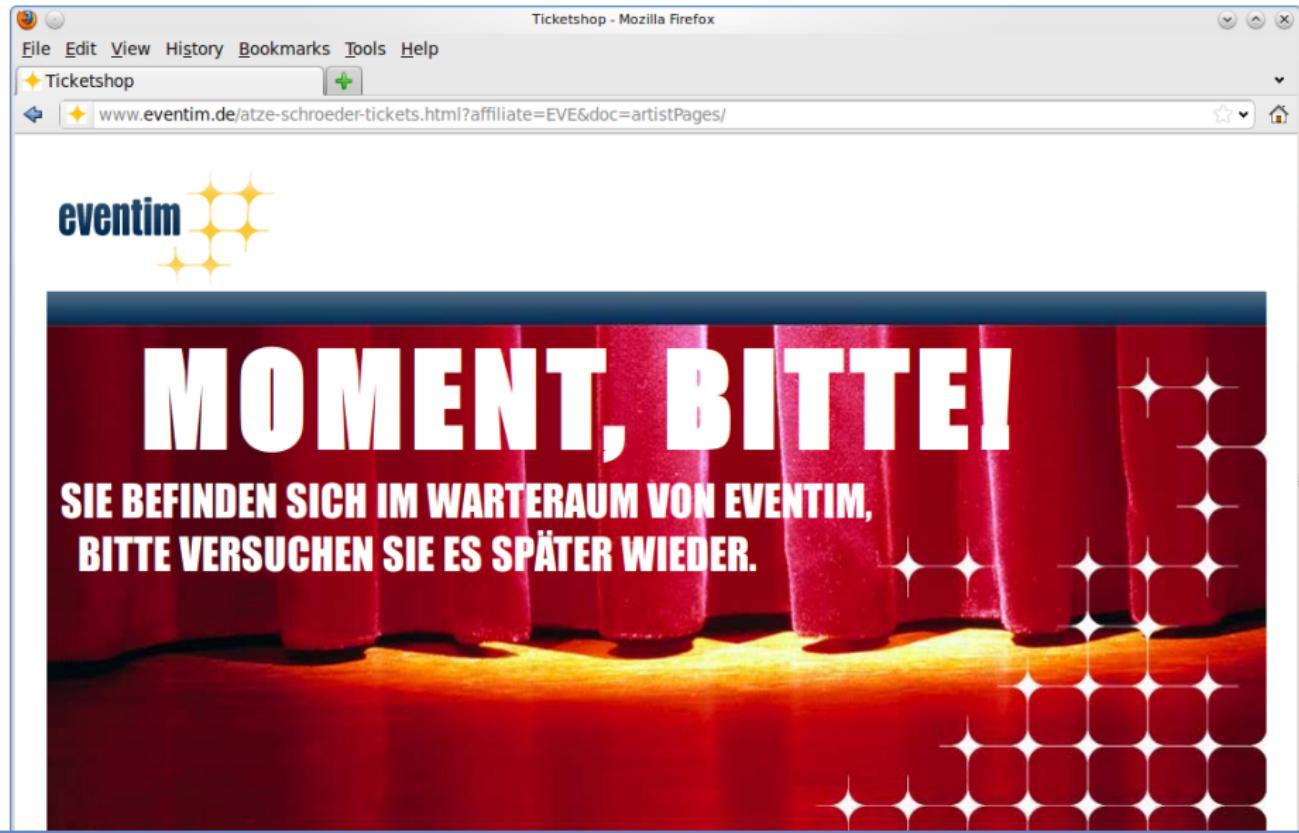
—A Hands-On Lecture—

Guest Lecture in the Course “Enterprise Digital Infrastructure”

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Contact: van.hoorn@informatik.uni-stuttgart.de
(including contributions by many colleagues)
May 21, 2014 @ University of Pavia, Italy

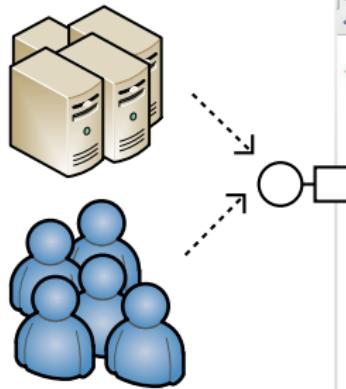


Introduction and Overview of Approach



Monitoring/Dynamic Analysis

Introduction and Overview of Approach



Screenshot of the Thalia.de website:

- Header:** Bücher versandkostenfrei - Hörbücher - eBooks - OYO - Musik - DVD - Blu-rays - Mozilla Firefox <2>
- User Options:** Datei, Bearbeiten, Ansicht, Chronik, Lesezeichen, Extras, Hilfe
- Search Bar:** Bücher versandkostenfrei - Hörbuch... (with a green search button)
- Navigation:** Anmelden, Mein Konto, Hilfe, Filialen & Events, Merkzettel (0), Mein Warenkorb (0)
- Main Content:** **Schulbücher und Lernhilfen** (with a "Jetzt bestellen" button)
- Category Links:** Schulbücher, Europameisterschaft, Grillen & Sommerküche, Thilo Sarrazin, Taschenbücher
- Side Panel:** Aktuelle Themen (Die ZEIT Polit-Thriller-Box, Tribut von Panem, Event: Thalia Tainment, Reduziert: OYO & Tasche, TouchMe TFT-Reader), Thalia in Ihrer Nähe (PLZ oder Ort, Filiale suchen), and a recommendation from Helke Fischer.
- Top-Empfehlungen:** A grid of five book covers:
 - Der Knochenbrecher by Chris Carter (€ 9,99)
 - Todesmelodie, Knaur by Daniel Holbe (€ 9,99)
 - House of Night 09... by P.C. Cast (€ 16,99)
 - Das Lied von Els... by George R.R. Martin (€ 16,00)
 - Die Tribute von Panem by Suzanne Collins (€ 18,95)
- Buchhändler-Tipp:** A recommendation from Helke Fischer for Weber's Grill Bibel.



Dynamic analysis,

or the *analysis of data gathered from a running program.*

has the potential to
provide an **accurate picture**
of a software^{system} **system's actual behavior.**
because it exposes the

This picture can range

from

class-level details

up to

**high-level
architectural views** [...]



(Cornelissen et al. 2009)



Among the **benefits over static analysis** are the **availability of runtime information** and, in the context of object-oriented software, the **exposure of object identities** and the **actual resolution of late binding**.

A **drawback** is

that **dynamic analysis** can only provide a **partial picture of the system**, i.e., the results obtained are valid for the **scenarios that were exercised during the analysis**.



(Cornelissen et al. 2009)

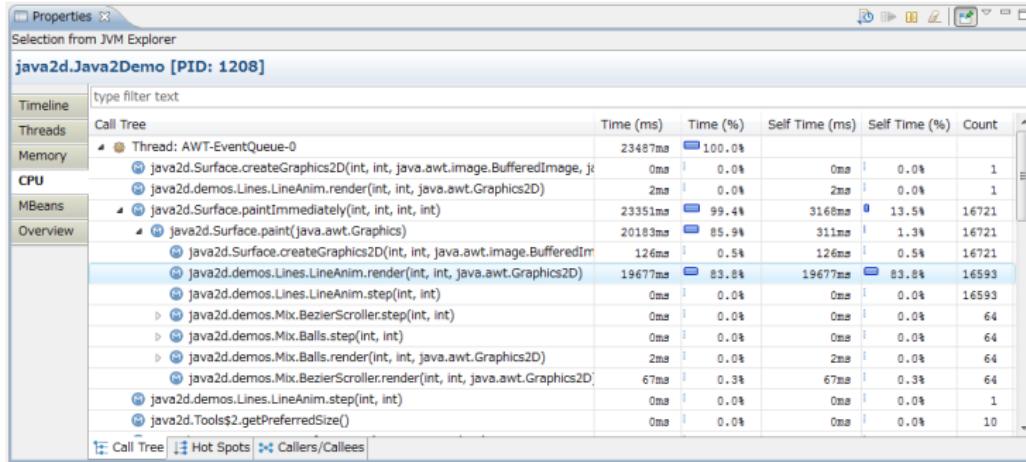
How to Gather Runtime Data from Executing Systems?

Profiling

- employed in development environments
- considerable performance overhead

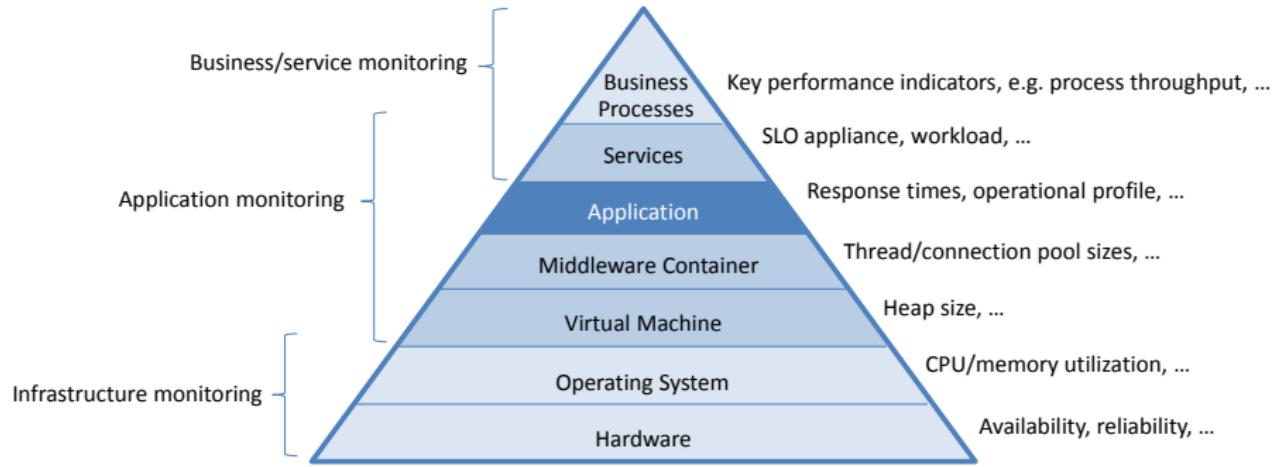
Monitoring

- employed in production environments
- captures real usage profile



http://www.jvmmonitor.org/doc/index.html#Getting_started

Introduction and Overview of Approach

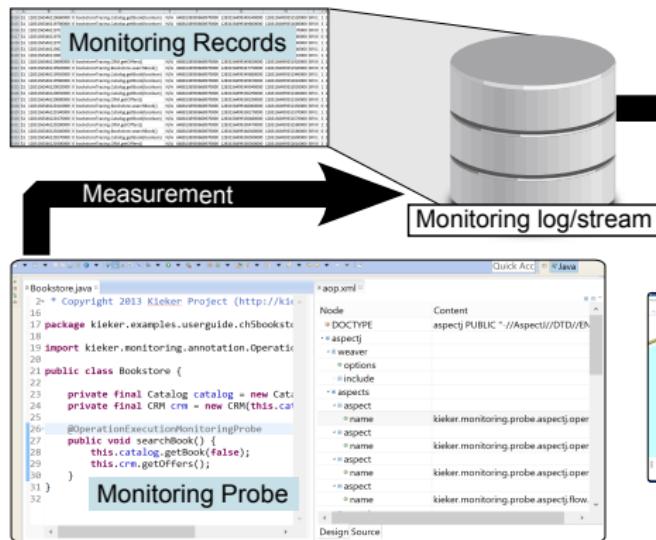


Monitoring practice in the “real world” (based on what we’ve seen)

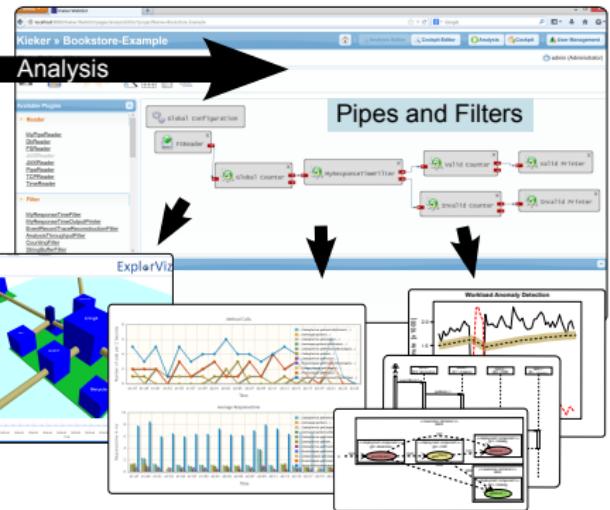
- Focus on system level metrics (availability, resource utilization)
- No systematic instrumentation on application level
- Only basic automation of analysis/alarming
- Reactive addition of monitoring probes

Kieker: Dynamic Analysis Workflow

Introduction and Overview of Approach



Analysis Configuration (via API and WebGUI)

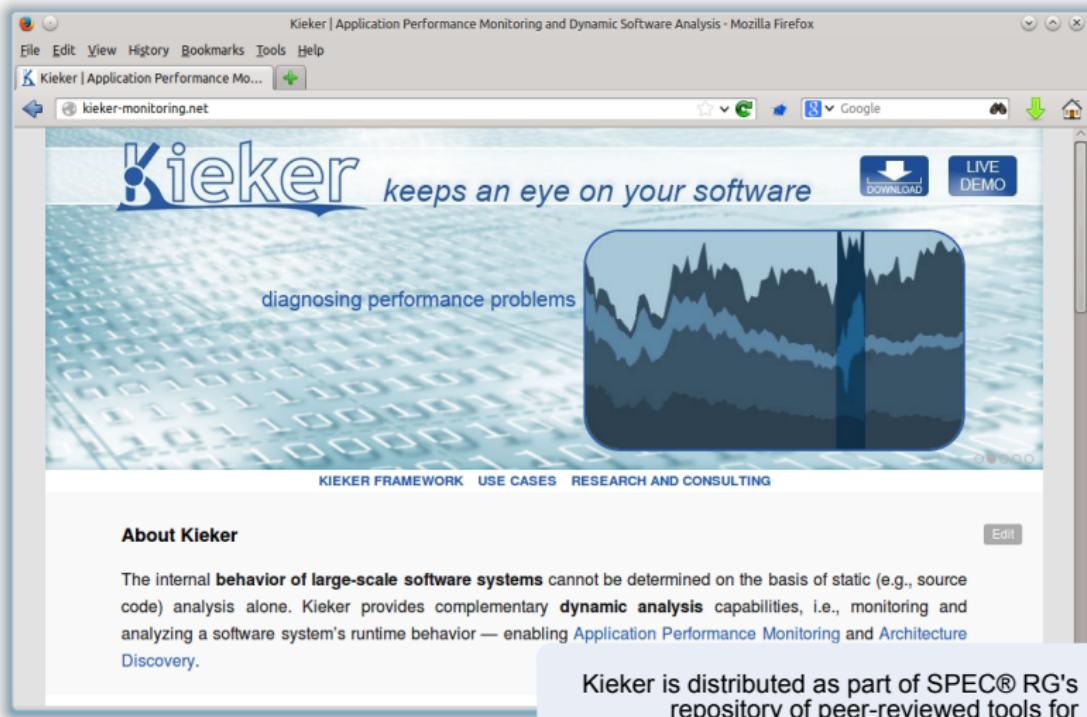


Software System with Monitoring Instrumentation

Online and Offline Visualization

- 1 **Introduction and Overview of Approach**
 - Interactive: Quick Start
- 2 **Use Cases in Research and Practice**
- 3 **Kieker's Monitoring Component**
- 4 **Kieker's Analysis Component & WebGUI**
 - Interactive: WebGUI
- 5 **Interactive: Java EE Monitoring with Kieker**
- 6 **A Detailed Look at Selected Use Cases**

Introduction and Overview of Approach



The screenshot shows a Mozilla Firefox browser window displaying the Kieker website. The title bar reads "Kieker | Application Performance Monitoring and Dynamic Software Analysis - Mozilla Firefox". The address bar shows "kieker-monitoring.net". The main content area features the Kieker logo and the tagline "keeps an eye on your software". Below this, a large graphic shows a 3D surface plot of binary code. A callout box highlights the text "diagnosing performance problems". To the right is a chart showing fluctuating data over time. Navigation links at the bottom include "KIEKER FRAMEWORK", "USE CASES", and "RESEARCH AND CONSULTING". An "About Kieker" section is visible, containing text about the internal behavior of large-scale software systems and the Kieker framework's capabilities. A "Edit" button is located in the top right corner of this section.

About Kieker

The internal **behavior of large-scale software systems** cannot be determined on the basis of static (e.g., source code) analysis alone. Kieker provides complementary **dynamic analysis** capabilities, i.e., monitoring and analyzing a software system's runtime behavior — enabling [Application Performance Monitoring](#) and [Architecture Discovery](#).

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>



Thanks to All Contributors



Introduction and Overview of Approach

Various people contributed to Kieker in the past years.

***Tillmann (Till) Bielefeld, Peer Brauer, Philipp Döhring,
Jens Ehlers, Nils Ehmke, Florian Fittkau, Thilo Focke,
Sören Frey, Tom Frotscher, Henry Grow,
Wilhelm (Willi) Hasselbring, André van Hoorn, Reiner Jung,
Benjamin Kiel, Dennis Kieselhorst, Holger Knoche, Arnd Lange,
Marius Löwe, Marco Lübecke, Felix Magedanz, Nina Marwede,
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Sönke Reimer, Bettual Richter, Matthias Rohr, Nils Sommer,
Lena Stöver, Jan Waller, Robin Weiß, Björn Weißenfels,
Matthias Westphal, Christian Wulf***

—Alphabetic list of people who contributed in different form
(source code, bug reports, promotion, etc) and intensity

- 1 **Introduction and Overview of Approach**
 - **Interactive: Quick Start**
- 2 Use Cases in Research and Practice
- 3 Kieker's Monitoring Component
- 4 Kieker's Analysis Component & WebGUI
 - **Interactive: WebGUI**
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- 6 A Detailed Look at Selected Use Cases

Also refer to the Kieker User Guide

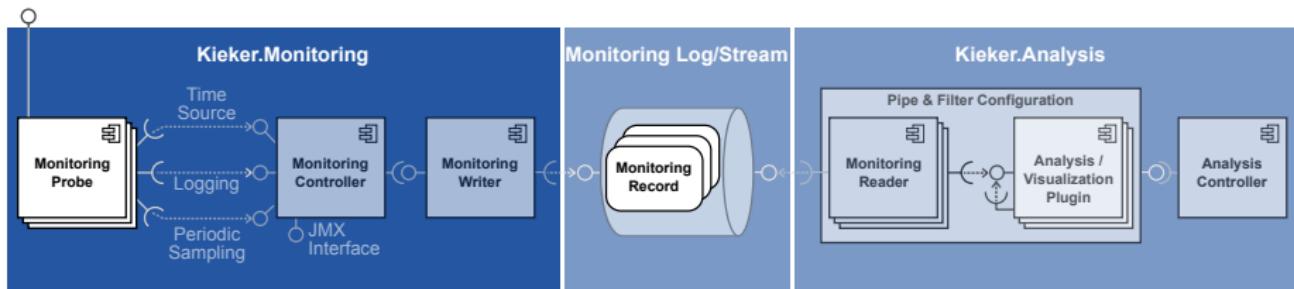
- ① Chapter 2 (Download and installation)
- ② Chapter 2 (Bookstore example)
- ③ Chapter 5 (AspectJ-based instrumentation)
- ④ Chapter 5 (TraceAnalysis tool)
- ⑤ Appendix A (Wrapper scripts)



Core Kieker Framework Components



Introduction and Overview of Approach > Interactive: Quick Start



Java probes/samplers:

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

+ basic adapters for

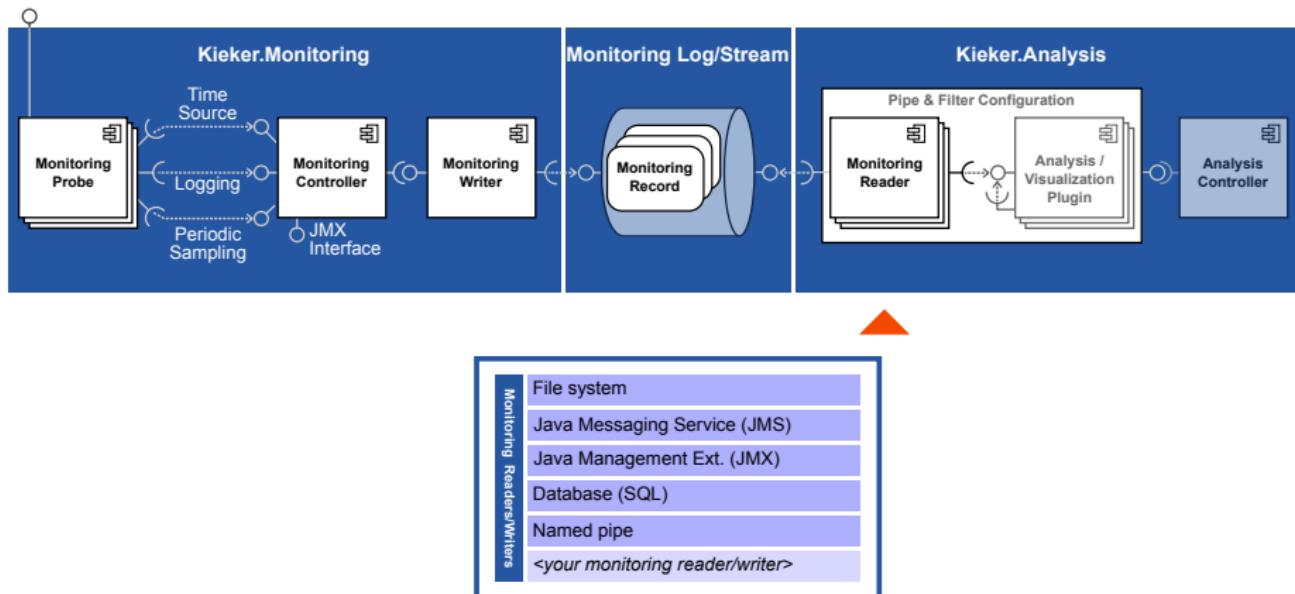
- C#/.NET
- Visual Basic 6/COM
- COBOL

Monitoring Records
Operation execution
Control-flow events
CPU utilization
Memory/swap usage
Resource utilization
Current time
<your monitoring record type>

Core Kieker Framework Components



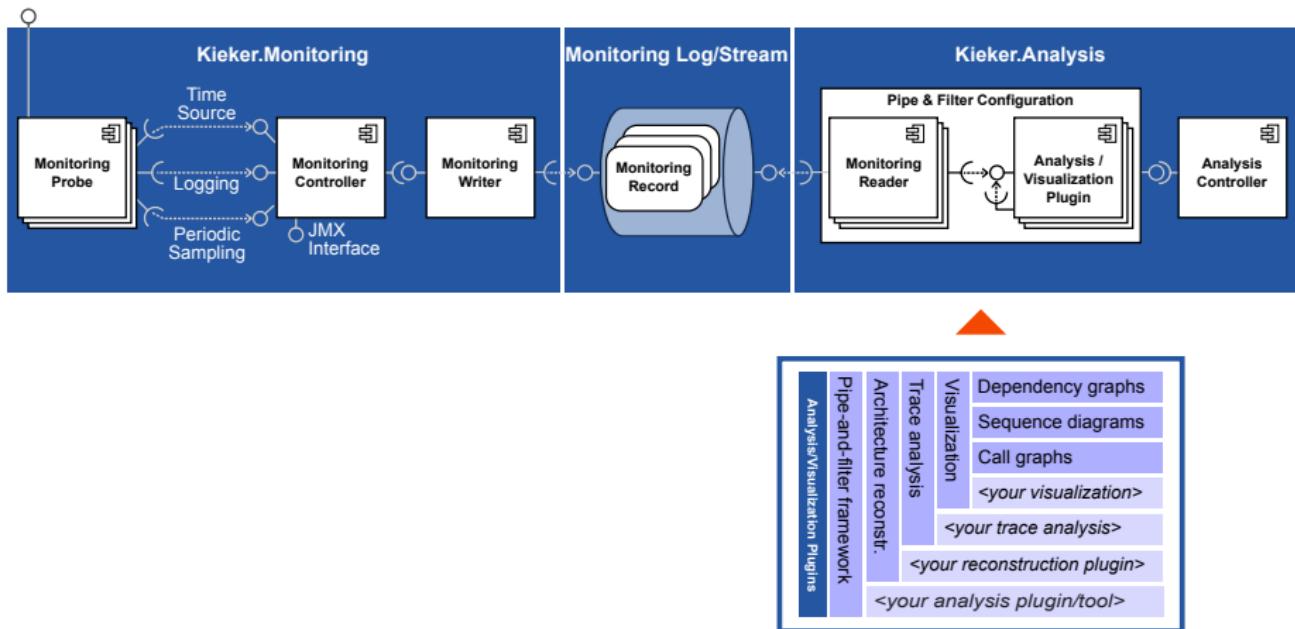
Introduction and Overview of Approach > Interactive: Quick Start



Core Kieker Framework Components



Introduction and Overview of Approach > Interactive: Quick Start



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① Architecture Discovery (Dynamic/Hybrid Analysis)

- Extraction of **architectural models** (structure, behavior)
- **Reverse engineering** of legacy systems
- Software **visualization** (2D/3D, static/interactive)
- Trace-based **architecture analysis**

② Application Performance Management

- Continuous **QoS monitoring** + feedback (**self-***)
- Distributed **tracing** and trace-based analysis
- **Architecture-based** performance analysis
- Automatic **problem detection and diagnosis**
- Extraction of **usage profiles** (workload intensity, navigational patterns)

③ Characteristics (cross-cutting)

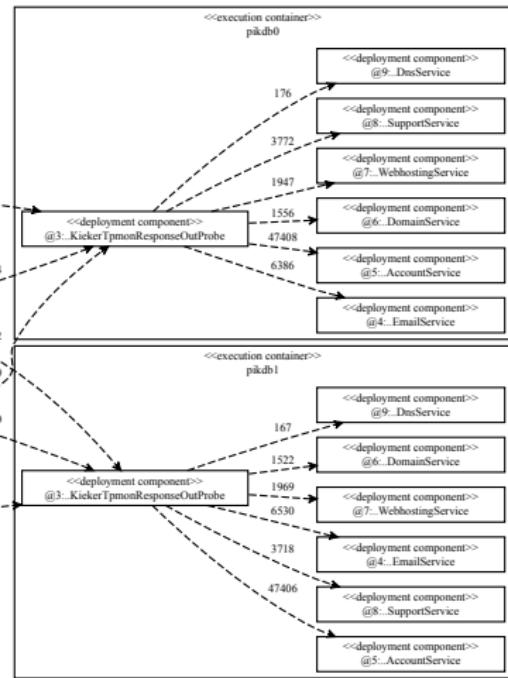
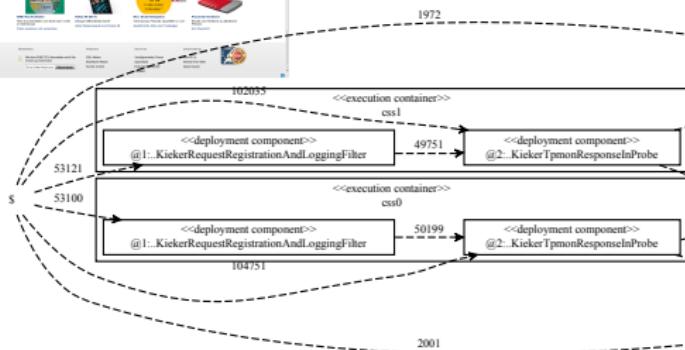
- Modular, flexible, and **extensible** architecture
- Non-intrusive instrumentation
- Low performance **overhead**
- Model-driven instrumentation and analysis
- Evaluated in lab and industrial **case studies**

Selected Topics and Results

[van Hoorn et al. 2009, van Hoorn 2014]

Use Cases in Research and Practice

Architecture Discovery: Model Extraction + Visualization (cont'd)

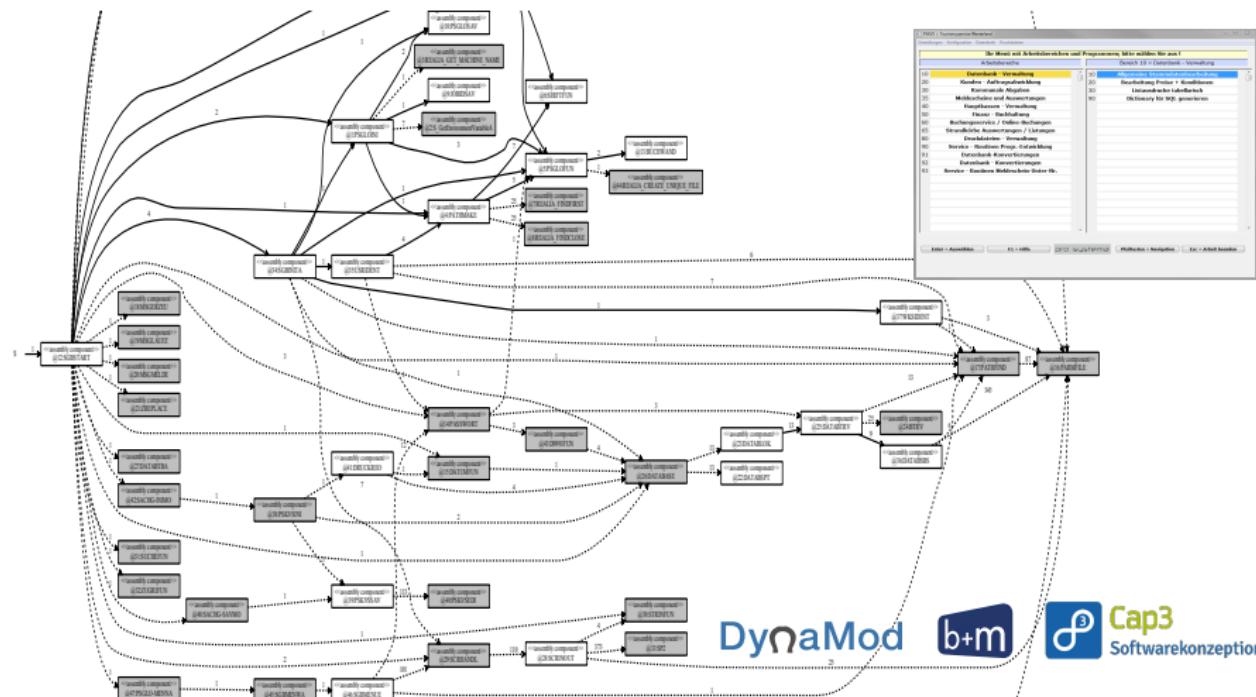


Selected Topics and Results (cont'd)

[Richter 2012]

Use Cases in Research and Practice

Architecture Discovery: Model Extraction + Visualization (cont'd)

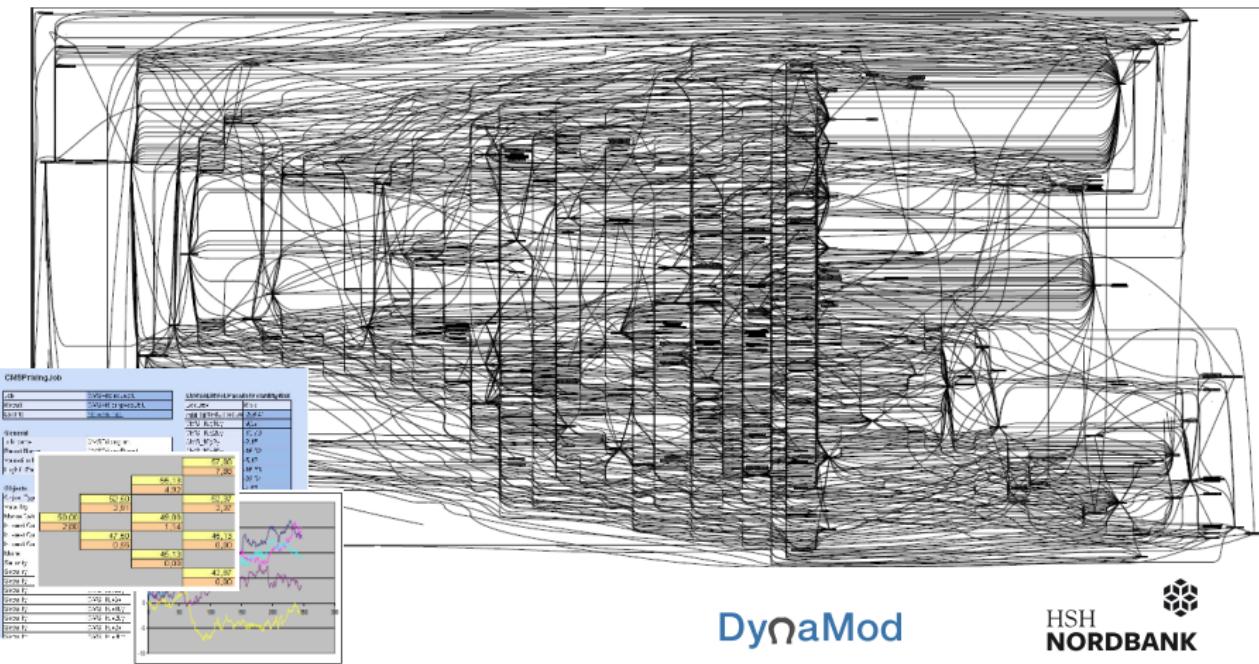


DynaMod

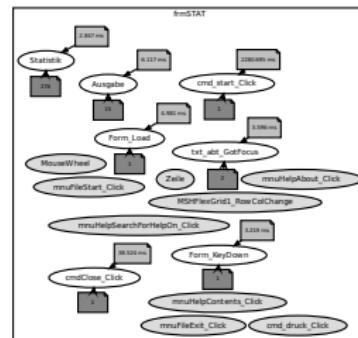
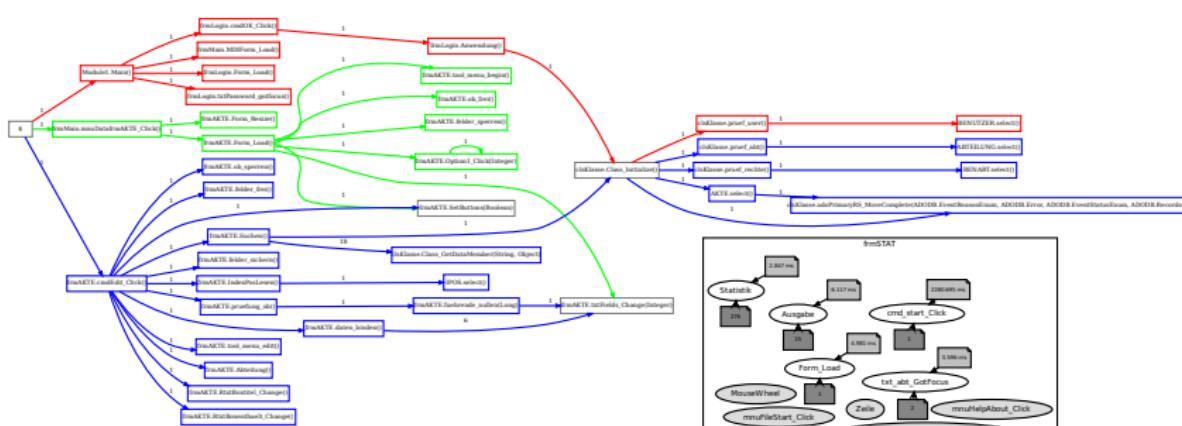
b+m

Cap3
Softwarekonzeption

Architecture Discovery: Model Extraction + Visualization (cont'd)



Architecture Discovery: Model Extraction + Visualization (cont'd)



DynaMod

b+m

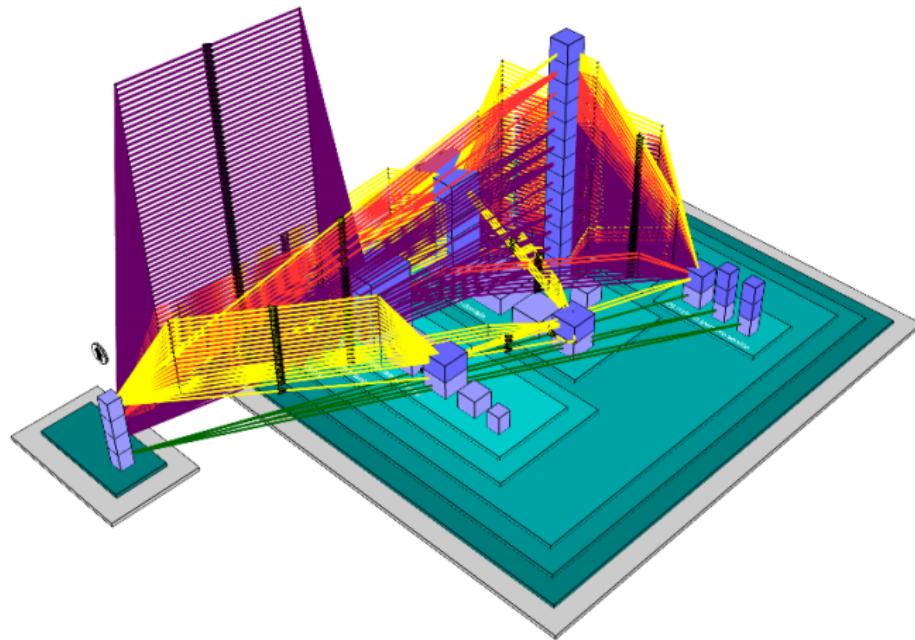
dataport

Selected Topics and Results (cont'd)

[Döhring 2012, Waller et al. 2013] (based on [Wulf 2010])

Use Cases in Research and Practice

Architecture Discovery: Model Extraction + Visualization (cont'd)

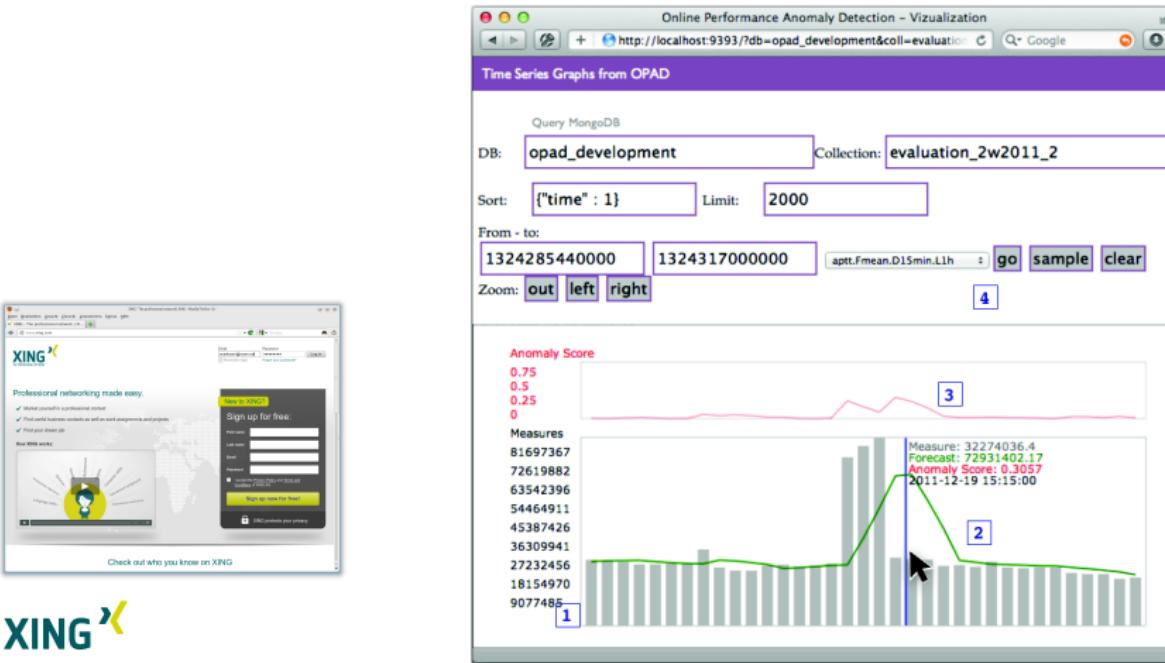


Selected Topics and Results (cont'd)

[Bielefeld 2012, Frotscher 2013]

Use Cases in Research and Practice

APM: Anomaly Detection + Diagnosis (cont'd)



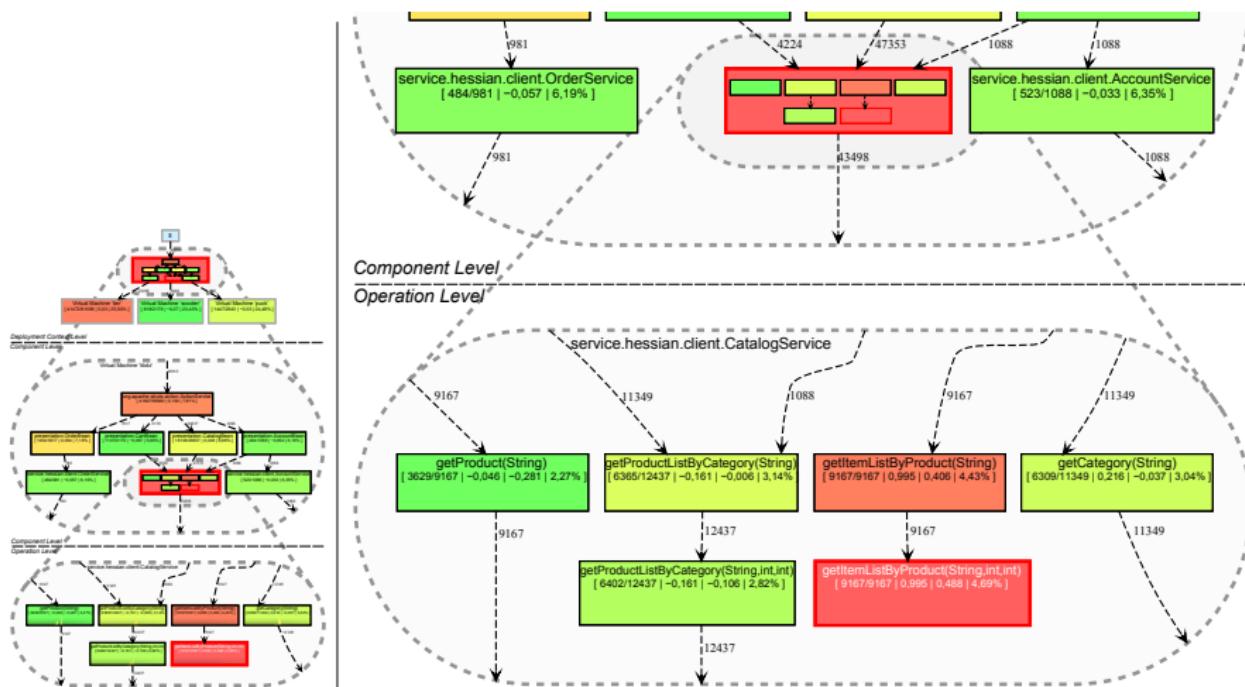
Selected Topics and Results (cont'd)

[Marwede et al. 2009]

Use Cases in Research and Practice



APM: Anomaly Detection + Diagnosis (cont'd)

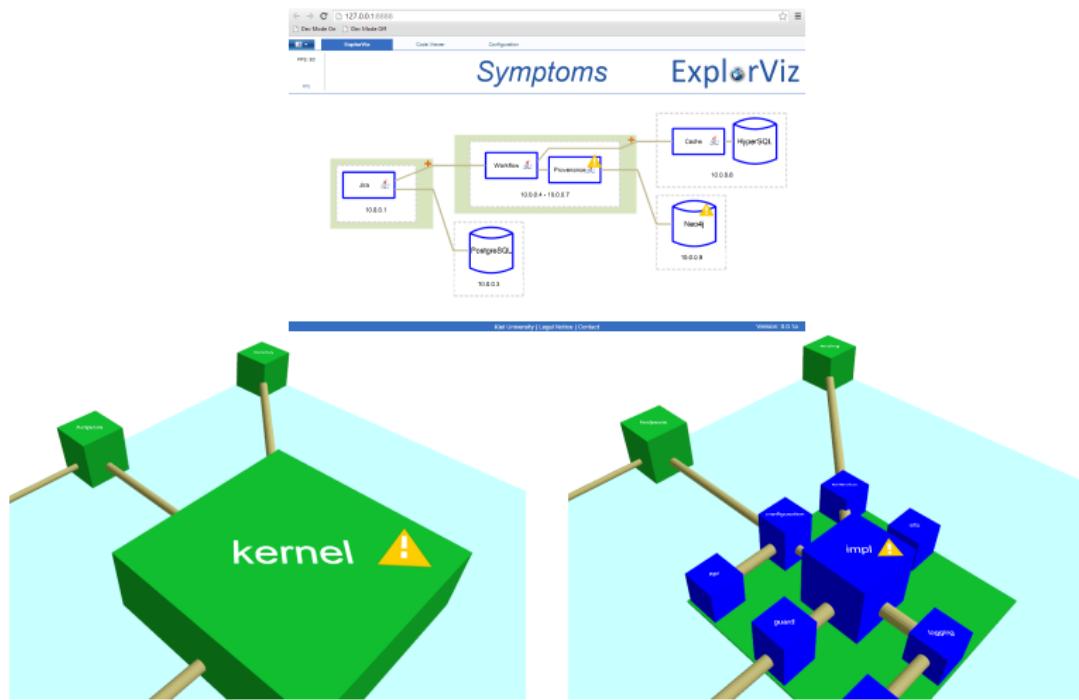


Selected Topics and Results (cont'd)

[Fittkau et al. 2013; 2014]

Use Cases in Research and Practice

APM: Anomaly Detection + Diagnosis (cont'd)

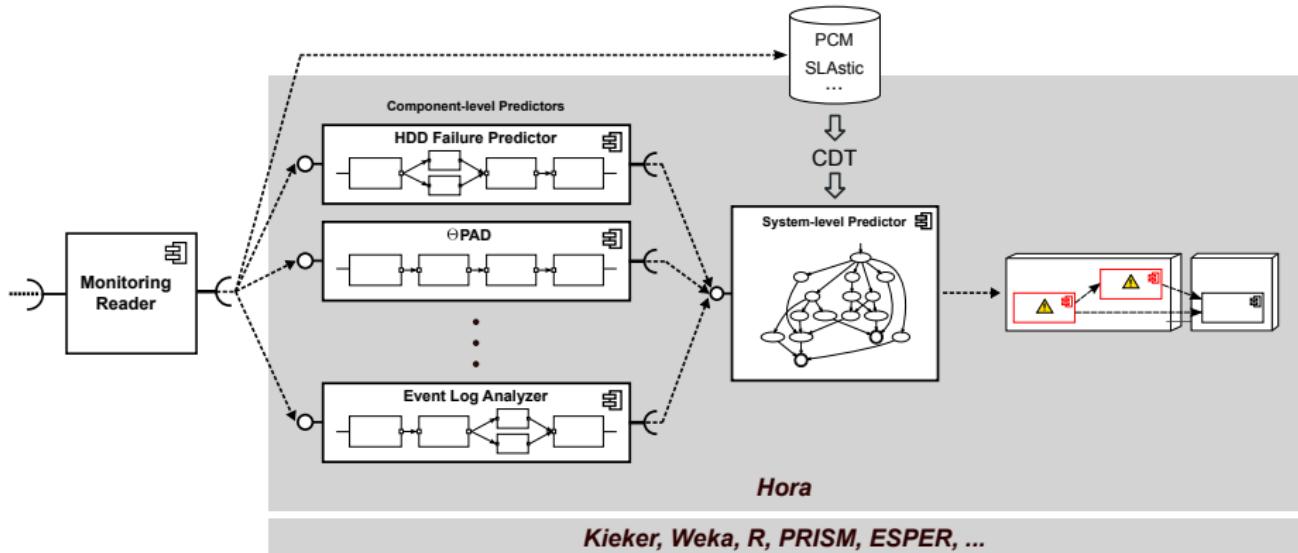


Selected Topics and Results (cont'd)

[Pitakrat 2013, Pitakrat et al. 2014]

Use Cases in Research and Practice

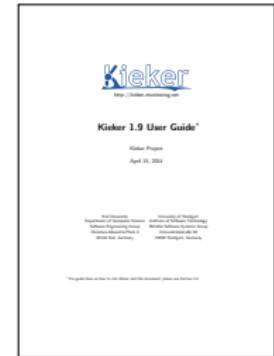
APM: Anomaly Detection + Diagnosis (cont'd)



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Also refer to the Kieker User Guide

- ① Ch. 2 (Quick start monitoring)
- ② Ch. 3 (Details on the Monitoring component)
- ③ Ch. 3 (Custom records, probes, writers)
- ④ Ch. 5 (Monitoring trace information)
- ⑤ Appendix E (Configuration file)



Program Instrumentation (Here: Manual)



Example: Monitoring Operation Executions

Kieker's Monitoring Component

Application code:

```
public void getOffers() {  
    // EXECUTION to be monitored:  
    catalog.getbook(false);  
}
```

Monitoring probe code (schematic):

```
// BEFORE execution to be monitored  
if (!isMonitoringEnabled()) {  
    collectDataBefore();  
}
```

```
// AFTER execution to be monitored  
if (!isMonitoringEnabled()) {  
    collectDataAfter();  
    writeMonitoringData();  
}
```

Instrumentation — Getting the *monitoring probe* into the *code*

- ① Manual instrumentation
- ② Aspect-oriented programming (AOP), middleware interception, ...

```
private static final IMonitoringController MONITORING_CONTROLLER =
    MonitoringController.getInstance();
```

```
final long tin = MONITORING_CONTROLLER.getTimeSource().getTime();
this.catalog.getBook(false); // <-- the monitored execution
final long tout = MONITORING_CONTROLLER.getTimeSource().getTime();

final OperationExecutionRecord record =
    new OperationExecutionRecord(
        "public void Catalog.getBook(boolean)",
        NO_SESSION_ID, NO_TRACEID,
        tin, tout, "myHost",
        NO_EOI_ESS, NO_EOI_ESS);
// Pass record to controller:
MONITORING_CONTROLLER.newMonitoringRecord(record);
```

MonitoringController

▶ Instantiation (static)

- + IMonitoringController: `getInstance()`
- + IMonitoringController: `createInstance(Configuration)`

▶ Writing

- + boolean: `newMonitoringRecord(IMonitoringRecord)`

▶ Adaptive Monitoring

- + boolean: `isProbeActivated(String)`
- + boolean: `activateProbe(String)`
- + boolean: `deactivateProbe(String)`

▶ Periodic Sampling

- + ScheduledSamplerJob: `schedulePeriodicSampler(ISampler, ..., TimeUnit)`
- + boolean: `removeScheduledSample(ScheduledSamplerJob)`

Controller State

- + boolean: `isMonitoringEnabled()`
- + boolean: `isMonitoringTerminated()`
- + boolean: `disableMonitoring()`
- + boolean: `enableMonitoring()`
- + boolean: `terminateMonitoring()`
- + String: `getHostname()`
- + String: `toString()`

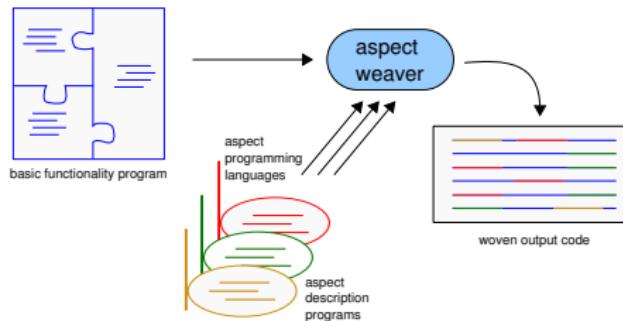
Time Source

- + TimeSource: `getTimeSource()`

JMX

Registry

Kieker's Monitoring Component



```
11  
12     @OperationExecutionMonitoringProbe  
13     public void getOffers() {  
14         catalog.getBook(false);  
15     }  
16 }
```

Annotation-based (AOP) instrumentation for monitoring trace information

Listing 1: META-INF/aop.xml

```
<!DOCTYPE aspectj PUBLIC "-//AspectJ//DTD//EN" "http://www.aspectj.org←
    /dtd/aspectj_1_5_0.dtd">
<aspectj>
    <weaver options="">
        <include within="*"/>
    </weaver>
    <aspects>
        <aspect name="kieker.monitoring.probe.aspectj.operationExecution.←
            OperationExecutionAspectFull"/>
    </aspects>
</aspectj>
```

Start the monitored application:

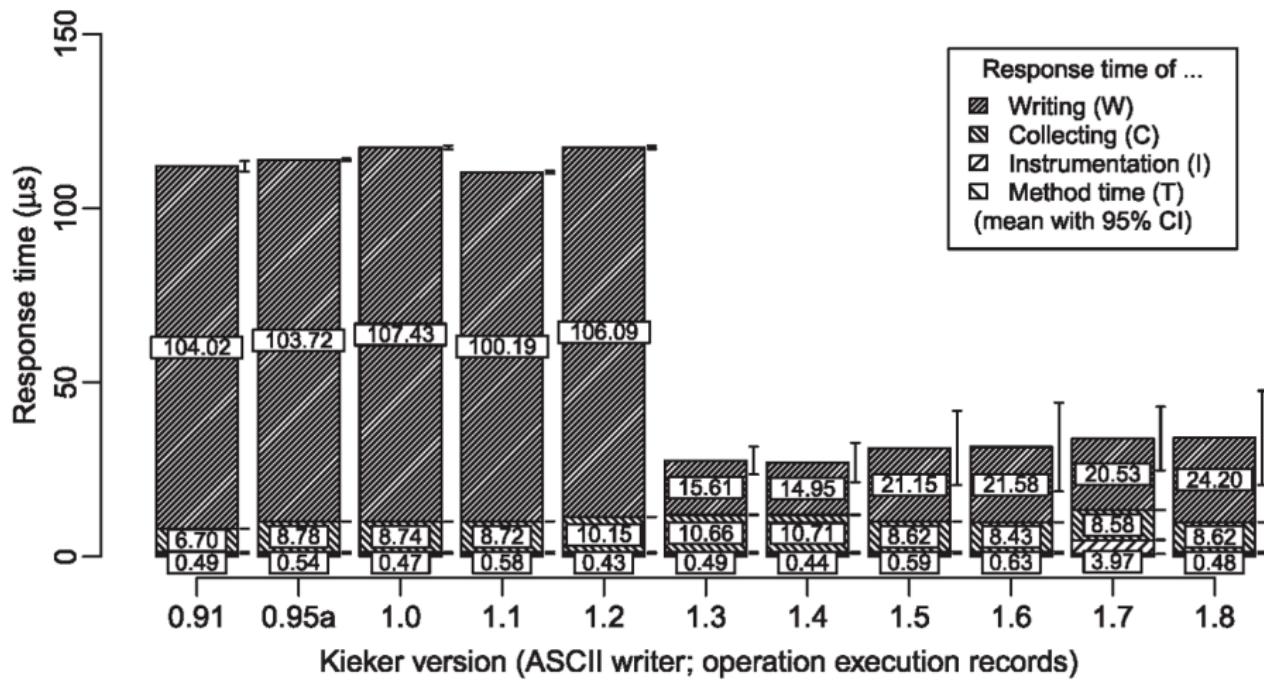
```
$ java -javaagent:lib/kieker-1.9_aspectj.jar BookstoreStarter
```

Monitoring Overhead

[Waller and Hasselbring 2013]

Kieker's Monitoring Component

Kieker



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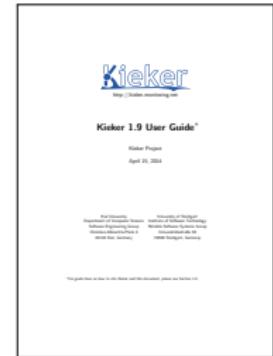
Details on the Analysis Component



Kieker's Analysis Component & WebGUI

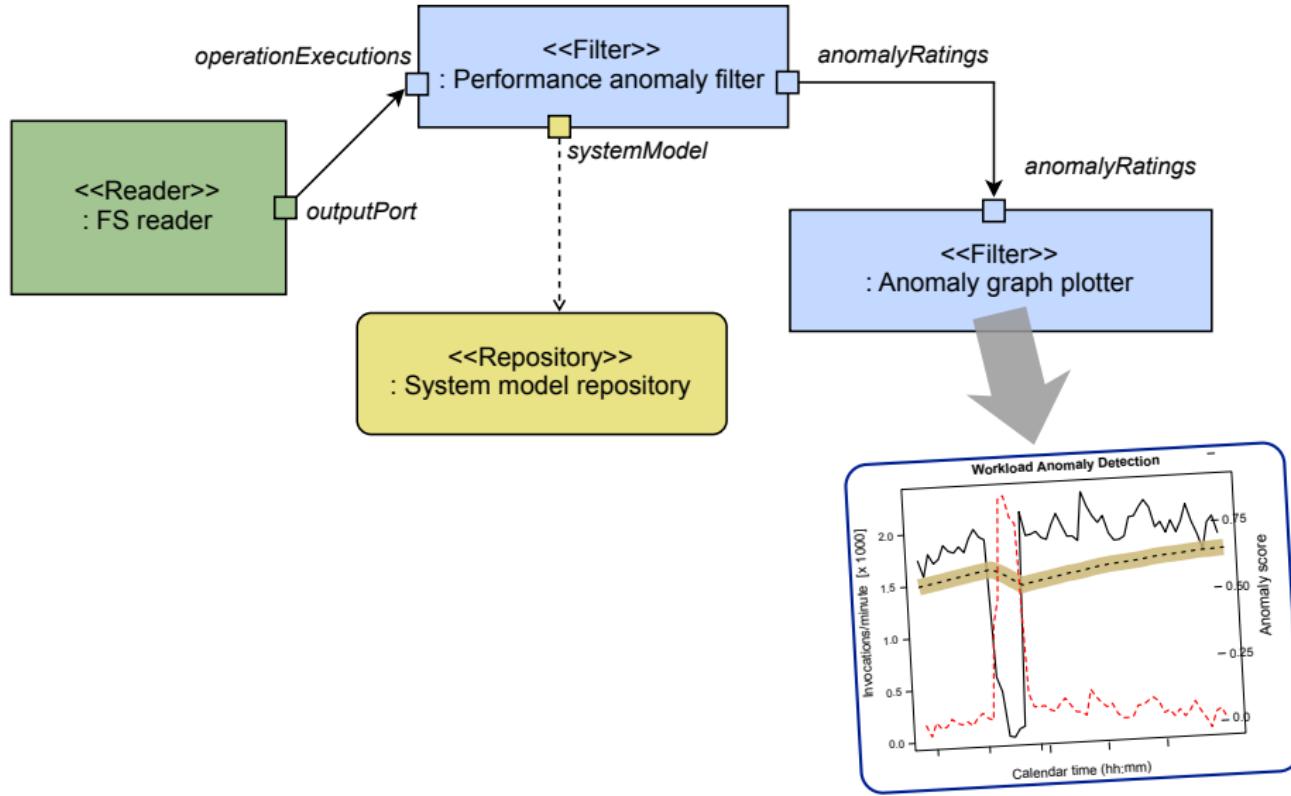
Also refer to the Kieker User Guide

- ① Ch. 2 (Quick start analysis)
- ② Ch. 4 (Details on the Analysis component)
- ③ Ch. 4 (Custom readers, filters, repositories)



Example Pipe-and-Filter Configuration

Kieker's Analysis Component & WebGUI



Programmatic Analysis Creation



Kieker's Analysis Component & WebGUI

```
/* 1. Create analysis controller for our response time analysis. */
final AnalysisController analysisController
    = new AnalysisController();
```

```
/* 2. Configure and register the reader */
final Configuration readerConfig = new Configuration();

readerConfig.setProperty(
    MyPipeReader.CONFIG_PROPERTY_NAME_PIPE_NAME, "somePipe");

final MyPipeReader reader =
    new MyPipeReader(readerConfig, analysisController);
```

```
/* 3. Configure, register, and connect the response time filter */
final Configuration filterConfig = new Configuration();

final long rtThresholdNanos =
    TimeUnit.NANOSECONDS.convert(1900, TimeUnit.MICROSECONDS);

filterConfig.setProperty( // configure threshold of 1.9 milliseconds:
    MyResponseTimeFilter.CONFIG_PROPERTY_NAME_TS_NANOS,
    Long.toString(rtThresholdNanos));

final MyResponseTimeFilter filter =
    new MyResponseTimeFilter(filterConfig, analysisController);

analysisController.connect(reader, MyPipeReader.OUTPUT_PORT_NAME,
    filter, MyResponseTimeFilter.INPUT_PORT_NAME_RESPONSE_TIMES);
```

```
/* 4. Save configuration to file (optional) */  
analysisController.saveToFile(new File("out.kax"));
```

```
/* 5. Start the analysis. */  
analysisController.run();
```

Own Analysis Components



Kieker's Analysis Component & WebGUI

```
public final class CountingFilter extends AbstractFilterPlugin {  
}
```

```
@Plugin(outputPorts = {  
    @OutputPort(name = "eventCount", eventTypes = { Long.class })})  
public final class CountingFilter extends AbstractFilterPlugin {  
}
```

Own Analysis Components (cont'd)



Kieker's Analysis Component & WebGUI

```
@Plugin(outputPorts = {  
    @OutputPort(name = "eventCount", eventTypes = { Long.class })})  
public final class CountingFilter extends AbstractFilterPlugin {  
  
    private final AtomicLong counter = new AtomicLong();  
  
}
```

```
@Plugin(outputPorts = {  
    @OutputPort(name = "eventCount", eventTypes = { Long.class })})  
public final class CountingFilter extends AbstractFilterPlugin {  
  
    private final AtomicLong counter = new AtomicLong();  
  
    public CountingFilter(Configuration conf, IProjectContext context) {  
        super(conf, context);  
    }  
  
}
```

Own Analysis Components (cont'd)



Kieker's Analysis Component & WebGUI

```
@Plugin(outputPorts = {  
    @OutputPort(name = "eventCount", eventTypes = { Long.class })})  
public final class CountingFilter extends AbstractFilterPlugin {  
  
    private final AtomicLong counter = new AtomicLong();  
  
    public CountingFilter(Configuration conf, IProjectContext context) {  
        super(conf, context);  
    }  
  
    @Override  
    public final Configuration getCurrentConfiguration() {  
        return new Configuration();  
    }  
}
```

Own Analysis Components (cont'd)



Kieker's Analysis Component & WebGUI

```
@Plugin(outputPorts = {  
    @OutputPort(name = "eventCount", eventTypes = { Long.class })})  
public final class CountingFilter extends AbstractFilterPlugin {  
  
    ...  
  
    @InputPort(name = "inputEvents", eventTypes = { Object.class })  
    public final void inputEvent(final Object event) {  
        final Long count = this.counter.incrementAndGet();  
  
        super.deliver("eventCount", count);  
    }  
}
```

AnalysisController

► **Instantiation:**

- + **AnalysisController()**
- + **AnalysisController(File)**

► **Persistence:**

- + **void: saveToFile(File)**

► **Pipes-and-Filters Configuration:**

- + **void: connect(AbstractPlugin, String, AbstractPlugin, String)**
- + **void: connect(AbstractPlugin, String, AbstractRepository)**

Controller State:

- + **STATE: getState()**
- + **void: run()**
- + **void: terminate(boolean)**



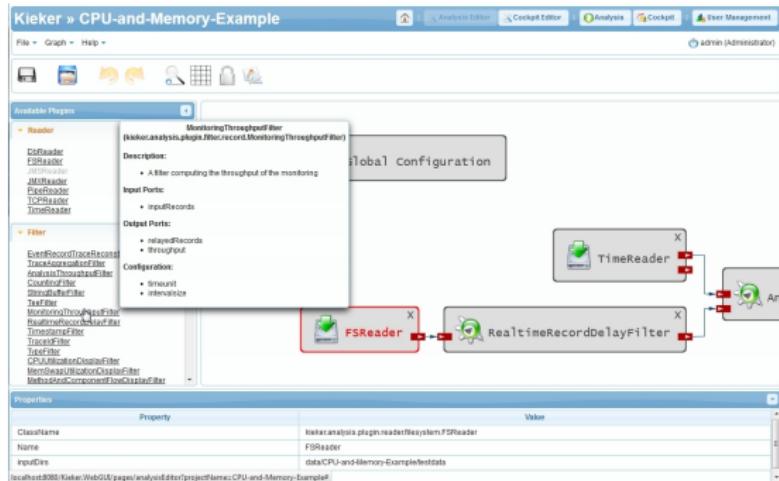
Also refer to:

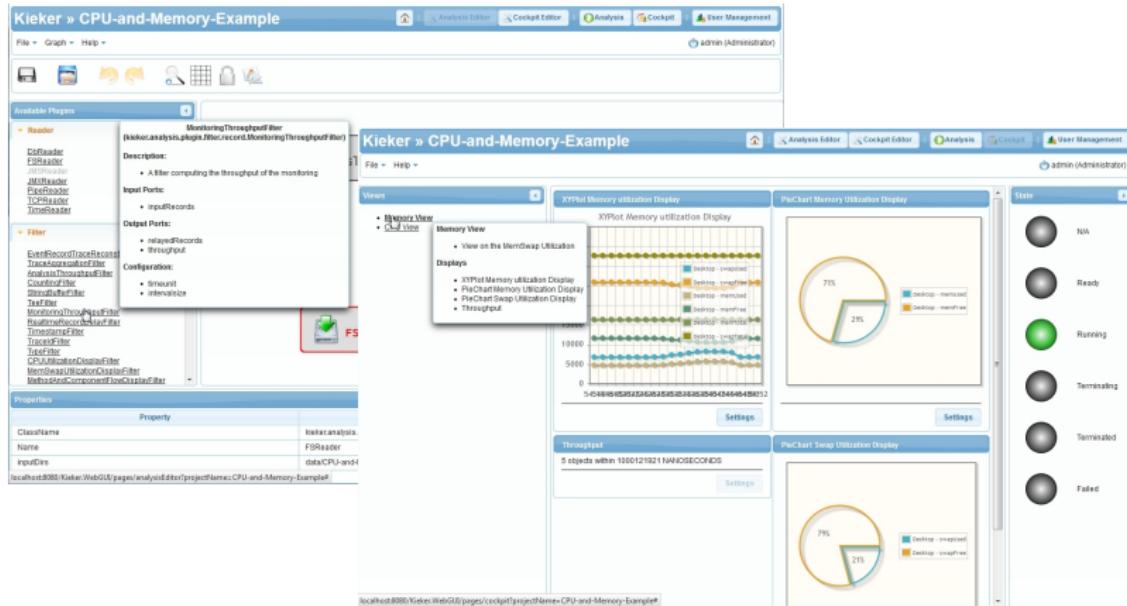
- ① Example projects included in the WebGUI
- ② Tutorial paper: Ehmke [2013]
- ③ Blog article

<http://kieker-monitoring.net/blog/>

[everything-in-sight-kiekers-webgui-in-action/](http://kieker-monitoring.net/blog/everything-in-sight-kiekers-webgui-in-action/)







The screenshot displays the Kieker WebGUI interface for a project named "CPU-and-Memory-Example".

Left Panel (Project Overview):

- Available Plugins:**
 - Reader**: FSEReader, FileRecord, Counter, TCPReader, FileWriter, TextFile, MonitoringProcessor, Reader, AnalysisProcessor, Counter, Writer, TextFile, MonitoringProcessor, Reader, AnalysisProcessor, Counter, Writer, TextFile, TracesFilter, TypeFilter, GZIPCompressorFilter, MessageUtilizationFilter, MethodAndComponentFilter.
 - Filter**: EventRecordFilter, RecordAnalyzerFilter, AnalysisProcessorFilter, CounterFilter, WriterFilter, TextFileFilter, MonitoringProcessorFilter, ReaderFilter, AnalysisProcessorFilter, CounterFilter, WriterFilter, TextFileFilter, TracesFilter, TypeFilter, GZIPCompressorFilter, MessageUtilizationFilter, MethodAndComponentFilter.
- MonitoringThroughputBar**: A filter computing the throughput of the monitoring.
- Input Ports:** inputRecords.
- Output Ports:** relatedRecords, throughput.
- Configuration:** timeout, interval.

Properties:

Property	Value
ClassName	IoMonitor
Name	FSEReader
InputPorts	data/CPUs-and-Memory-Example

URL: localhost:8080/Kieker/WebGUI/pages/analysiseditor/projectName=CPU-and-Memory-Example

Right Panel (Monitoring Dashboard):

- Memory View**: Shows memory utilization across desktop, swap, and memory components. A pie chart indicates 71% for desktop-memory and 21% for desktop-swap.
- XYPlot Memory utilization Display**: A line chart showing memory utilization over time (5-10 hours).
- PieChart Memory Utilization Display**: A pie chart showing the distribution of memory utilization between desktop and cockpit.
- Throughput**: Displays 5 objects within 1000/121021 nanoseconds.
- XYPlot Swap Utilization Display**: A line chart showing swap utilization over time.
- PieChart Swap Utilization Display**: A pie chart showing the distribution of swap utilization between desktop and cockpit.

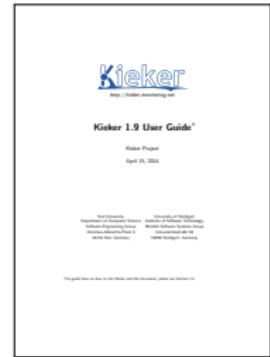
Status Legend:

- N/A
- Ready
- Running
- Terminating
- Terminated
- Failed

- 1 Introduction and Overview of Approach
 - Interactive: Quick Start
- 2 Use Cases in Research and Practice
- 3 Kieker's Monitoring Component
- 4 Kieker's Analysis Component & WebGUI
 - Interactive: WebGUI
- 5 Interactive: Java EE Monitoring with Kieker
- 6 A Detailed Look at Selected Use Cases

Also refer to the Kieker User Guide

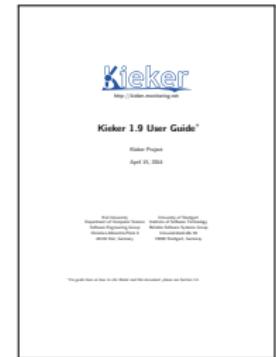
- ① Chapter 5 (AspectJ-based instrumentation)
- ② Chapter 5 (TraceAnalysis tool)
- ③ Appendix B (Java EE example)
- ④ Appendix C (Continuous analysis with JMS)
- ⑤ Appendix D (Monitoring of system metrics)

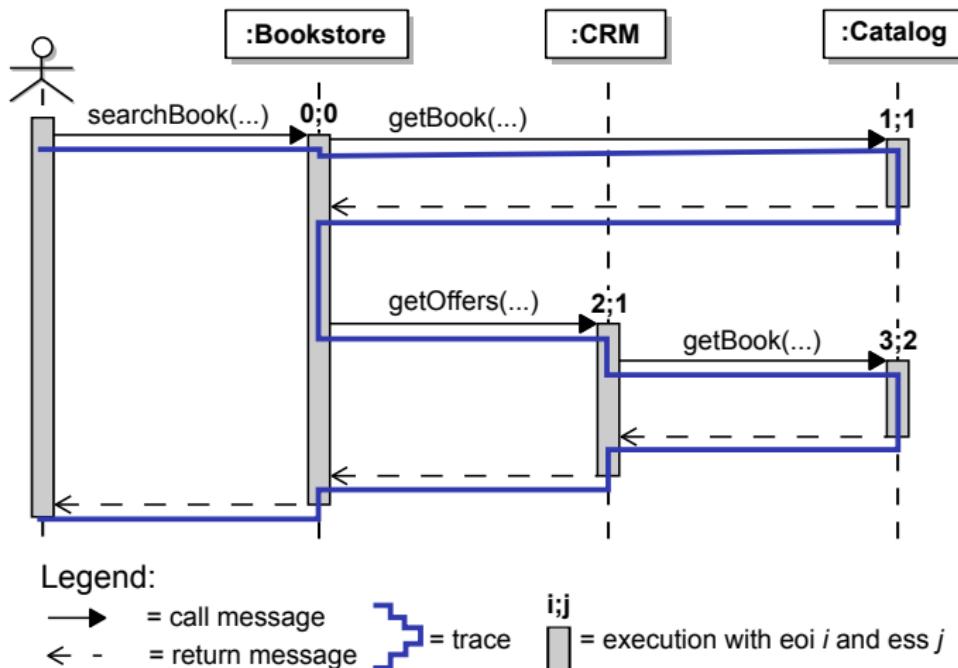


- 1 Introduction and Overview of Approach**
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Also refer to the Kieker User Guide

- ① Chapter 5 (AspectJ-based instrumentation)
- ② Chapter 5 (TraceAnalysis tool)
- ③ Paper [van Hoorn et al. 2009]
- ④ Paper [Rohr et al. 2008]





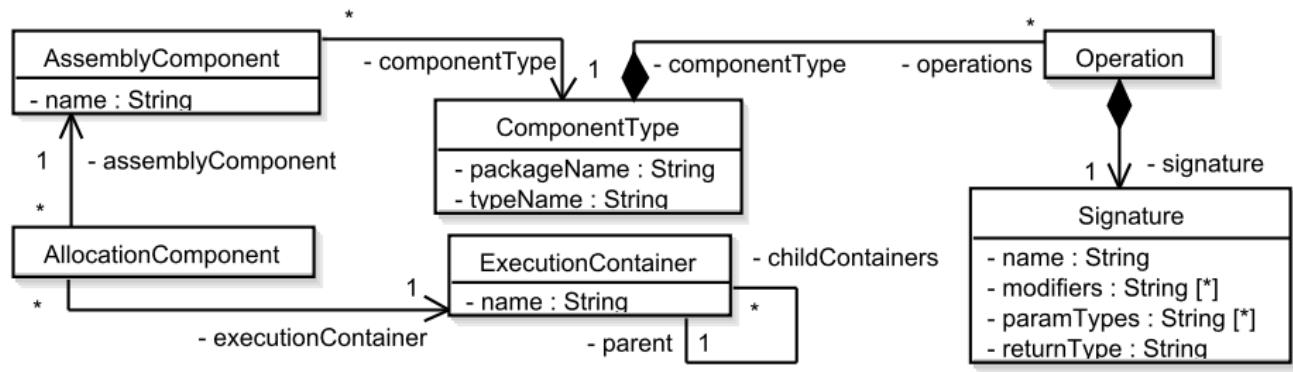
Execution order index (eoi) i : i -th started execution in a trace
Execution stack size (ess) j : execution started at stack depth j

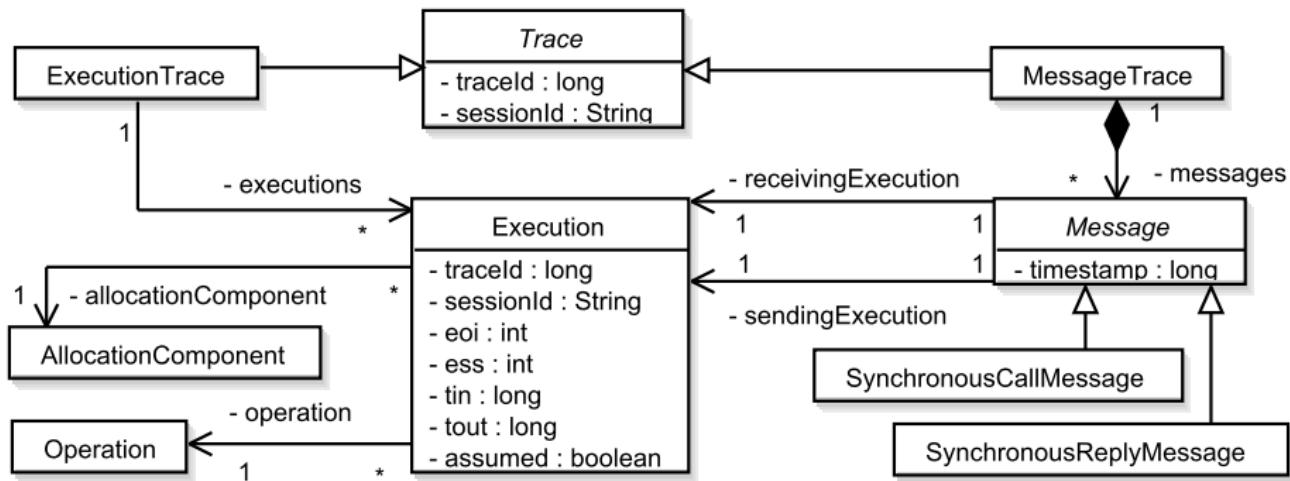
A single line of the monitoring log – a single *monitoring record*

```
$0; 1283156545623365608; public void kieker.examples..CRM.getOffers();  
<no-session-id>; 6488138950668976129; 1283156498817823953;  
1283156498820007367; Osterinsel; 2; 1
```

The meaning of this record:

- ① Type of monitoring record (see `kieker.map`; here: `OperationExecutionRecord`)
- ② Logging timestamp (time in ns)
- ③ Operation signature (fully qualified)
- ④ Session id (only with web applications)
- ⑤ Trace id (unique id of the trace)
- ⑥ t_{in} (start time of execution)
- ⑦ t_{out} (end time of execution)
- ⑧ Hostname (name of the computer)
- ⑨ eoi (execution order index)
- ⑩ ess (execution stack size)





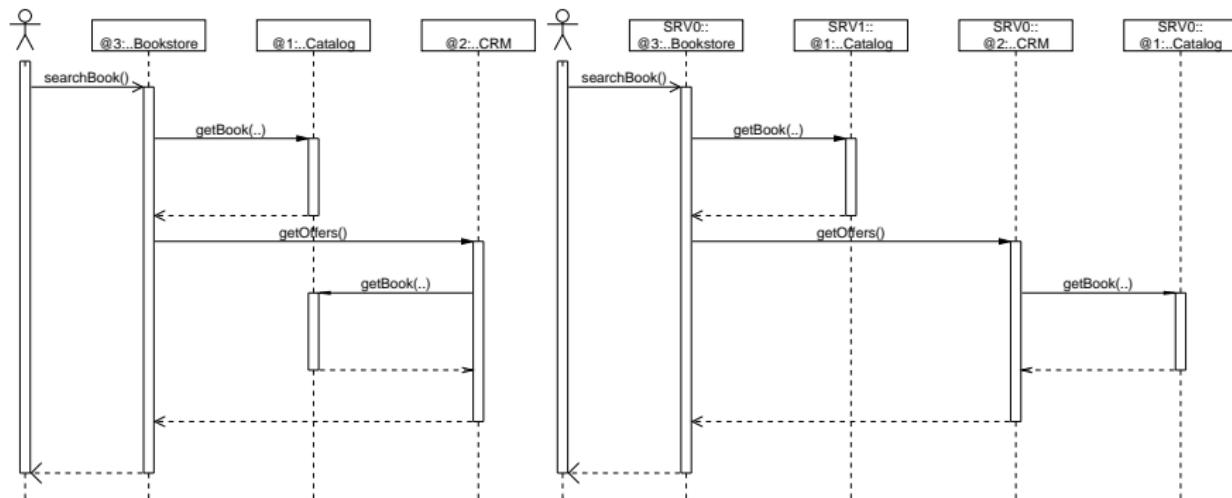
Sequence Diagrams

Kieker. TraceAnalysis Tool



A Detailed Look at Selected Use Cases ▷ Trace Analysis

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



(a) Assembly-level view

(b) Deployment-level view

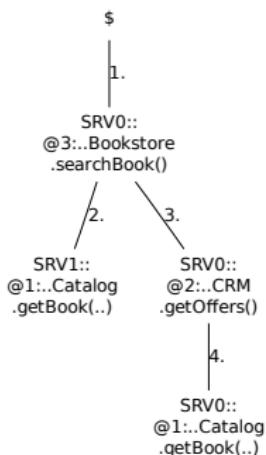
Dynamic Call Trees

Kieker. TraceAnalysis Tool (cont'd)

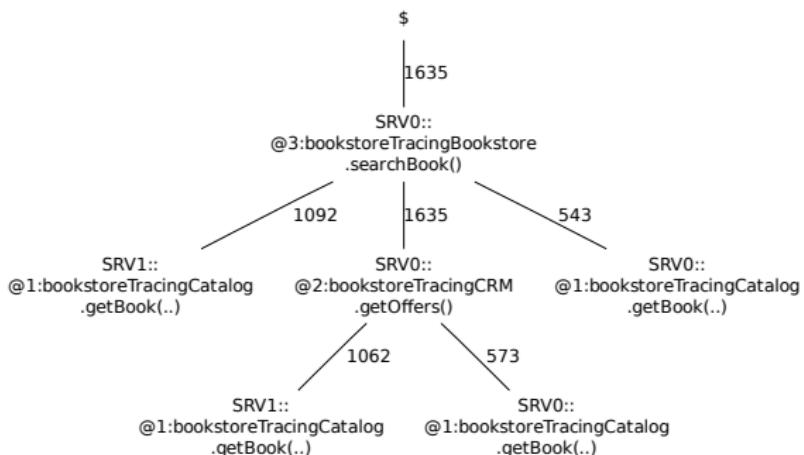
Kieker

A Detailed Look at Selected Use Cases ▷ Trace Analysis

- 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

Hierarchical Calling Dependency Graphs



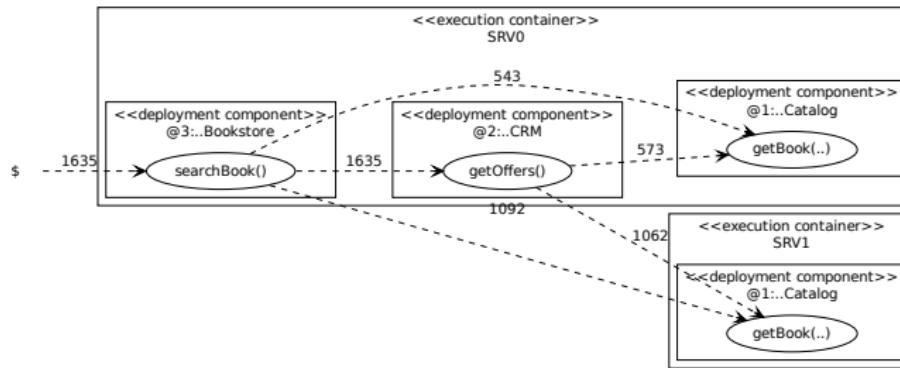
Kieker. TraceAnalysis Tool (cont'd)

A Detailed Look at Selected Use Cases > Trace Analysis

- 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)

A Detailed Look at Selected Use Cases ▷ Trace Analysis



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

The screenshot shows a Mozilla Firefox browser window with the title "System Model Reconstructed by Kieker.TraceAnalysis - Mozilla Firefox". The page content consists of five tables:

- Component Types**

ID	Package	Name	Operations
3	bookstoreTracing	Bookstore	• searchBook()
2	bookstoreTracing	CRM	• getOffers()
1	bookstoreTracing	Catalog	• getBook(boolean)
- Operations**

ID	Component type	Name	Parameter types	Return type
3	bookstoreTracing.Bookstore	searchBook		
2	bookstoreTracing.CRM	getOffers		
1	bookstoreTracing.Catalog	getBook	• boolean	
- Assembly Components**

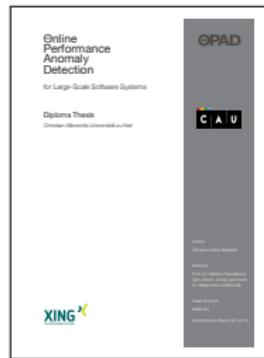
ID	Name	Component type
3	@3	bookstoreTracing.Bookstore
2	@2	bookstoreTracing.CRM
1	@1	bookstoreTracing.Catalog
- Execution Containers**

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

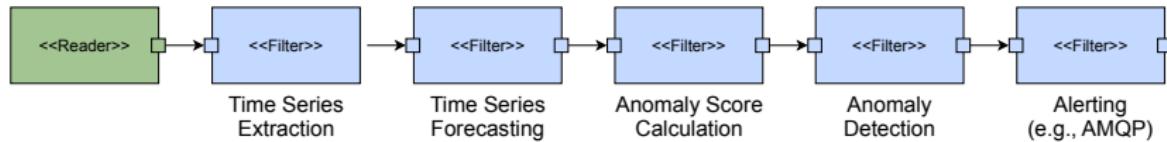
Details to be found in

- ① Master's Thesis by Bielefeld [2012]
- ② Master's Thesis by Frotscher [2013]



ΘPAD Processing Steps

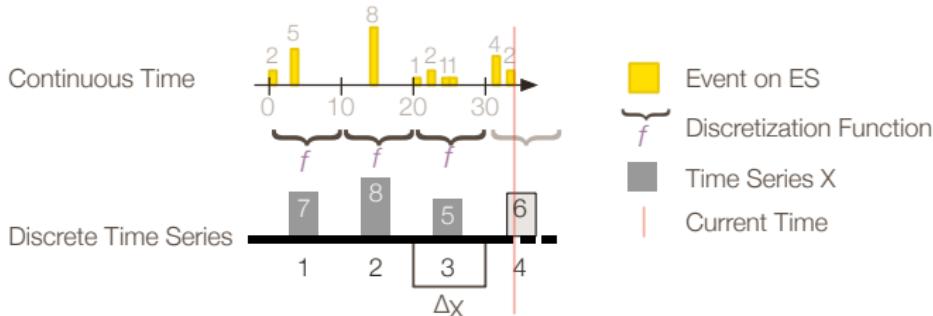
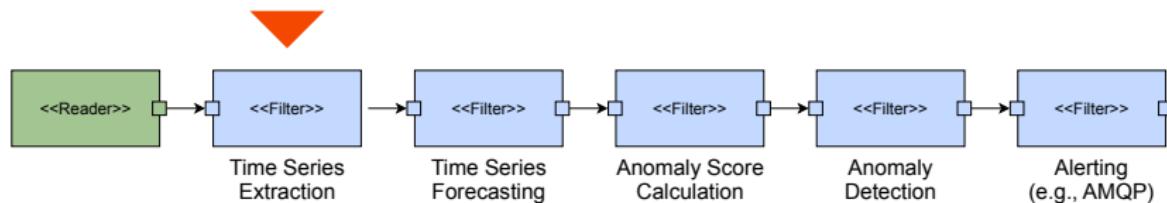
A Detailed Look at Selected Use Cases ▷ ΘPAD



Step 1: Time Series Extraction

ΘPAD Processing Steps (cont'd)

A Detailed Look at Selected Use Cases ▷ ΘPAD

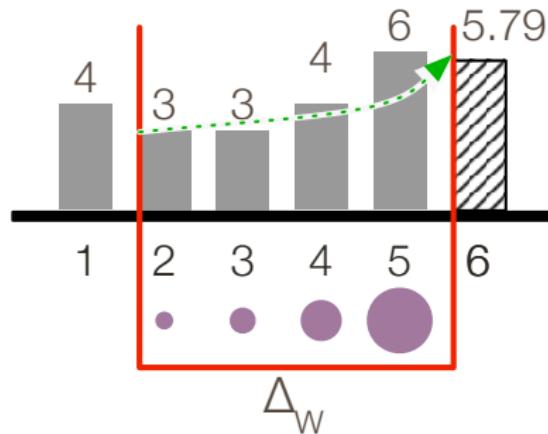
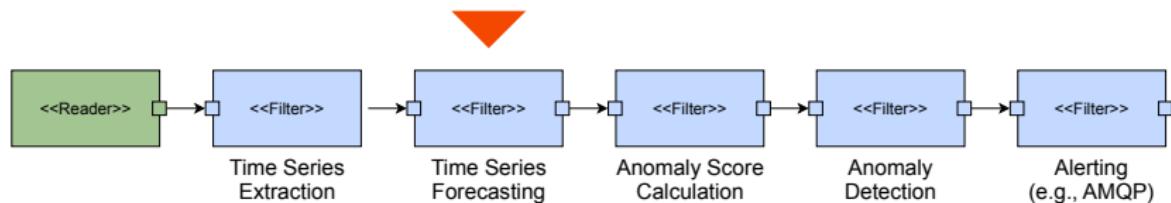


```
select sum(value) as aggregation  
from MeasureEvent.win:time_batch( 1000 msec )
```

Step 2: Time Series Forecasting

ΘPAD Processing Steps (cont'd)

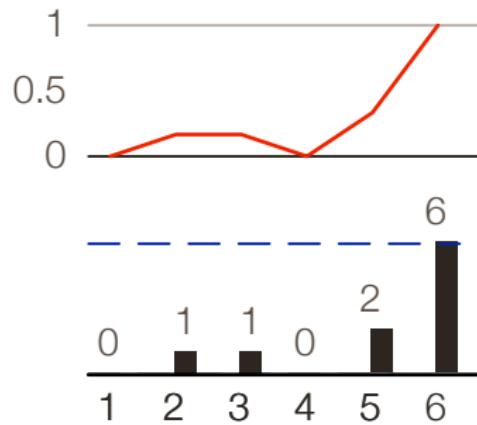
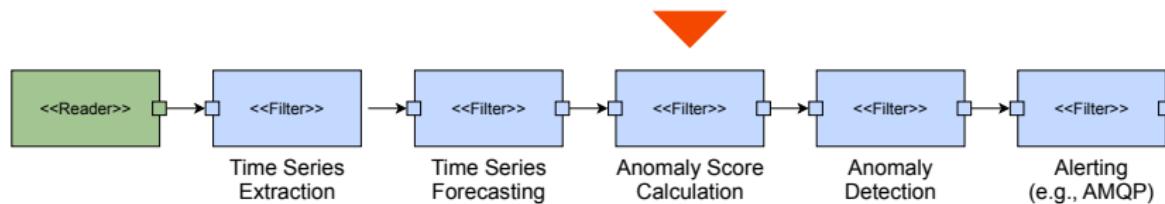
A Detailed Look at Selected Use Cases ▷ ΘPAD



Step 3: Anomaly Score Calculation

ΘPAD Processing Steps (cont'd)

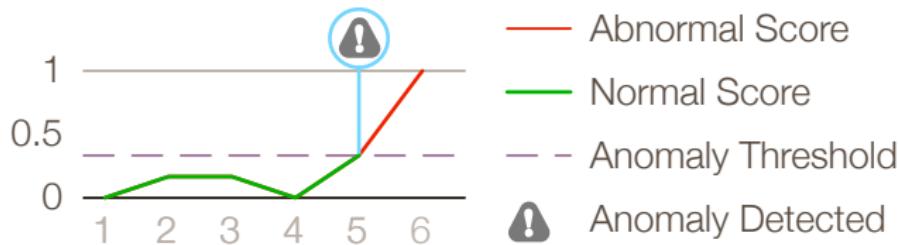
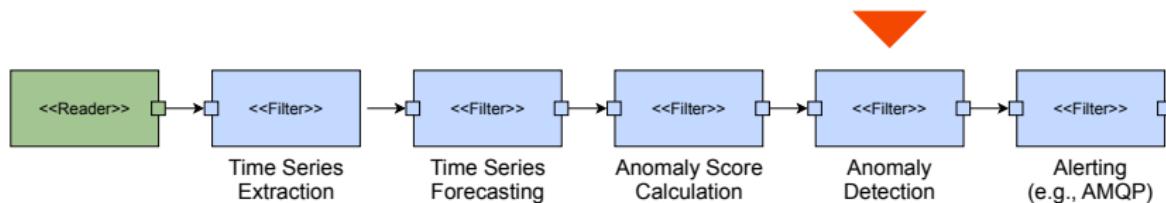
A Detailed Look at Selected Use Cases ▷ ΘPAD



Step 4: Anomaly Detection

ΘPAD Processing Steps (cont'd)

A Detailed Look at Selected Use Cases ▷ ΘPAD





- 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



cewe color

dataport



HSH
NORDBANK

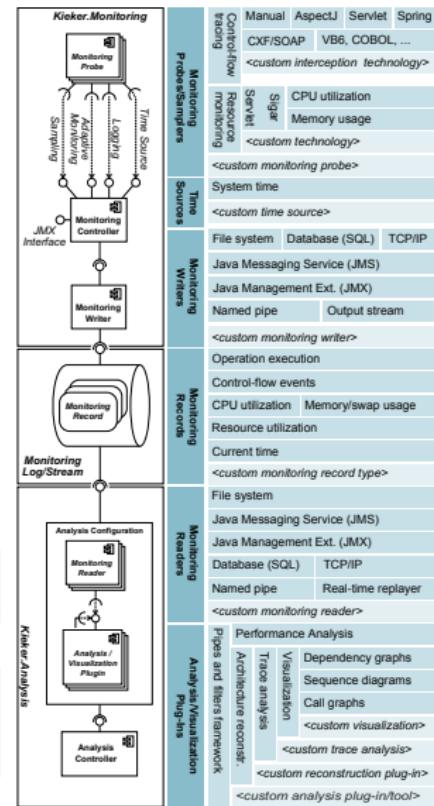


Kieker is open-source software (Apache License, V. 2.0)

<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>



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For a comprehensive list of publications, talks, and theses about Kieker, visit:

<http://kieker-monitoring.net/research/>