

Architecture-based Online Capacity Management: Modeling, Monitoring, and Adaptation

D3S Seminar/Department Meeting
Department of Distributed and Dependable Systems
Charles University, Prague

André van Hoorn

Software Engineering Group
University of Kiel, Germany

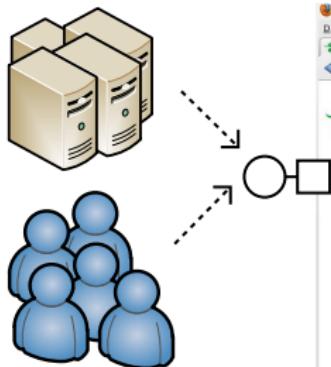
avh@informatik.uni-kiel.de

June 20, 2012 @ Prague



Motivation & Overall Goal

Introduction



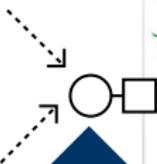
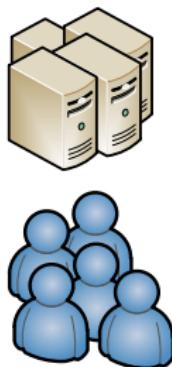
The screenshot shows the homepage of Thalia.de, a German online bookstore. At the top, there's a navigation bar with links for "Bücher", "eBooks", "OYO", "Hörbücher", "Filme", "Musik", "Spielwaren", "Games", and "Software". A search bar is prominently displayed. Below the navigation, a large banner features a young boy holding books and the text "Schulbücher und Lernhilfen". To the right of the banner is a sidebar with sections for "Aktuelle Themen" (including "Die ZEIT Polit-Thriller-Box" and "Tribute von Panem"), "Thalia in Ihrer Nähe", and a "Filiale suchen" button. The main content area includes a "Top-Empfehlungen" section with five book covers and their details:

Buch	Buch	Buch	Buch	Buch
Der Knochenbrecher von Chris Carter € 9,99	Todesmelodie von Daniel Knauf € 9,99	House of Night 09... von P.C. Cast € 16,99	Das Lied von Eis... von George R.R. Ma € 16,99	Die Tribute von... von Suzanne Collins € 18,99
+ mehr				

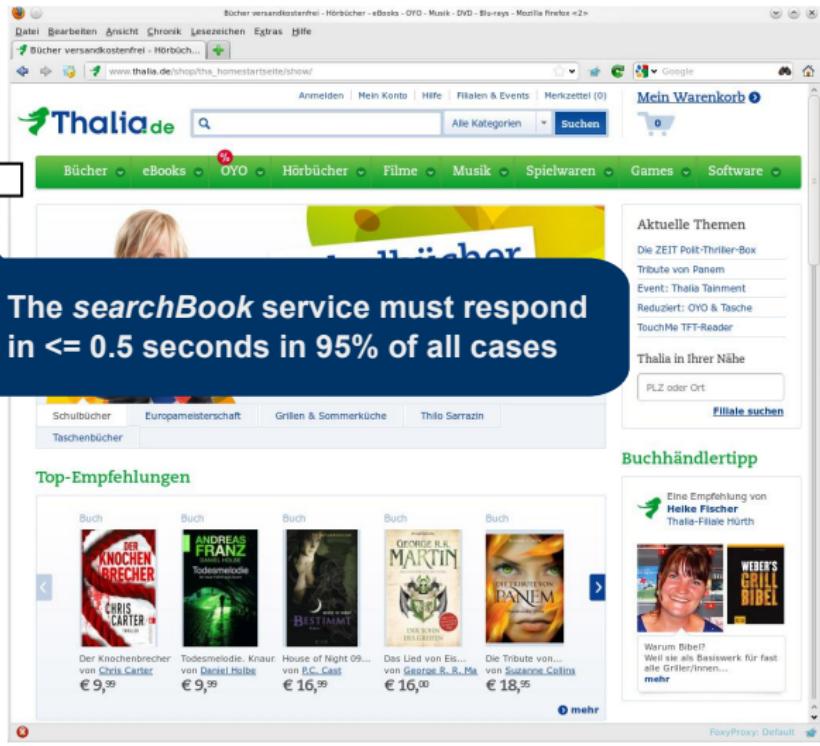
On the right side of the main content area, there's a "Buchhändlertipp" section featuring a photo of a woman and the text "Eine Empfehlung von Heike Fischer Thalia-Filiale Hürth". Below this, there's another section with a photo of a woman and the text "Wer ist Bibi? Weil sie als Basiswerk für fast alle Grillen/Innen... mehr".

Motivation & Overall Goal

Introduction



! The **searchBook** service must respond in ≤ 0.5 seconds in 95% of all cases



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

Daten Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe

Blücher versandkostenfrei - Hörbüch... +

www.thalia.de/shop/tha_homesite/seite/show/

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

Alle Kategorien Suchen

Thalia.de

Bücher eBooks OYO Hörbücher Filme Musik Spielwaren Games Software

Aktuelle Themen

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

Thalia in Ihrer Nähe

PLZ oder Ort

Filiale suchen

Schulbücher Europameisterschaft Grillen & Sommerküche Thilo Sarrasin

Taschenbücher

Top-Empfehlungen

Buch

Der Knochenbrecher von Chris Carter € 9,99

Buch

Todesmelodie von Daniel Hohne € 9,99

Buch

House of Night 09... von P.C. Cast € 16,99

Buch

Das Lied von Eis... von George R.R. Martin € 16,99

Buch

Die Tribute von Panem von Suzanne Collins € 18,99

mehr

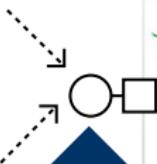
Eine Empfehlung von Helke Fischer Thalia-Filiale Hürth

Wer ist Bibi? Weil sie als Basiswerk für fast alle Grillen/Innen... mehr

Weber's Grillbibel

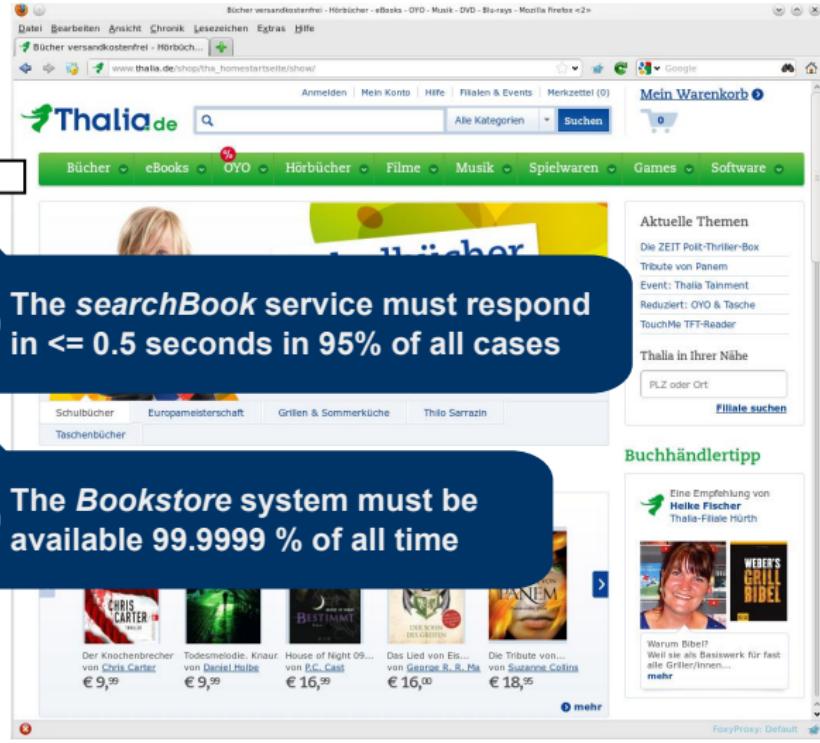
Motivation & Overall Goal

Introduction



The searchBook service must respond in ≤ 0.5 seconds in 95% of all cases

The Bookstore system must be available 99.9999 % of all time



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

Datei Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe

Blücher versandkostenfrei - Hörbüch...

www.thalia.de/shop/tha_homestartseite/show/ Anmelden Mein Konto Hilfe Filialen & Events Merkzettel (0)

Alle Kategorien Suchen

Thalia.de Suchen

Bücher eBooks OYO Hörbücher Filme Musik Spielwaren Games Software

Aktuelle Themen

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

Thalia in Ihrer Nähe

PLZ oder Ort Filiale suchen

Buchhändlertipp

Elke Fischer Thalia-Filiale Hürth

Ein Empfehlung von Helke Fischer

Wer ein Bibel? Weil sie als Basiswerk für fast alle Grüter/Innen... mehr

Das Knochenbrecher von Chris Carter € 9,99

Todesmelodie von Daniel Hohls € 9,99

House of Night 09... von P.C. Cast € 16,99

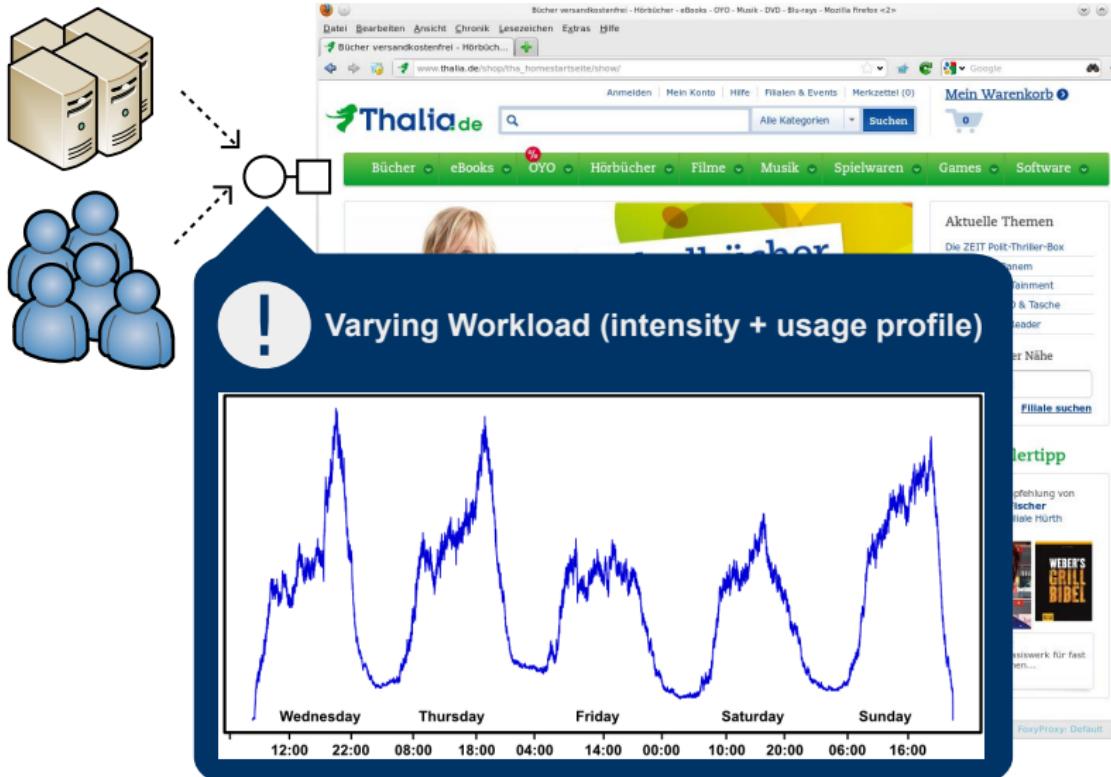
Das Lied von Eis... von George R. R. Martin € 16,00

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FoxyProxy: Default

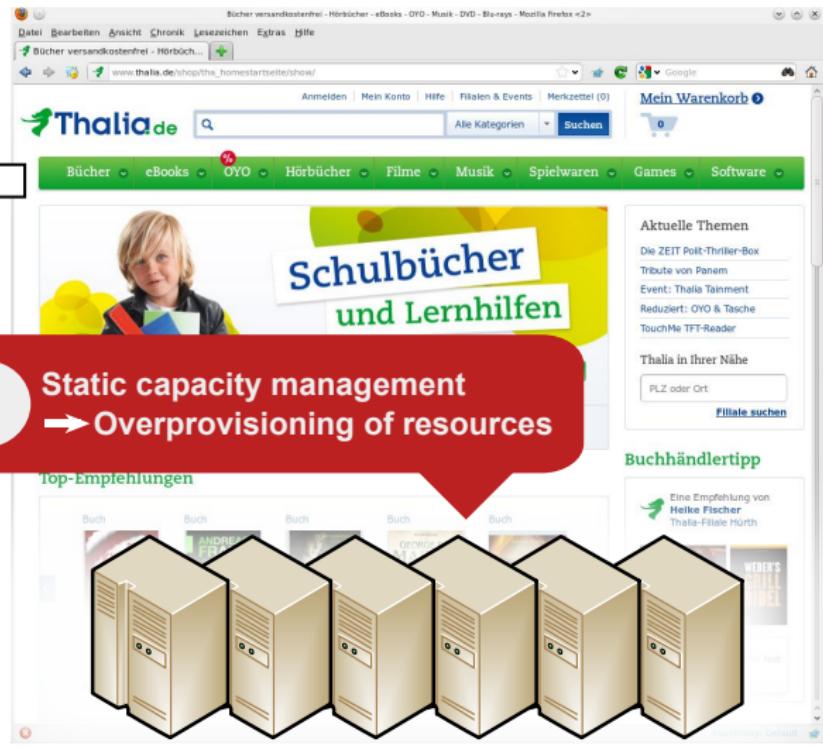
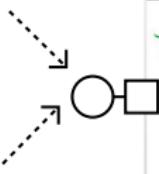
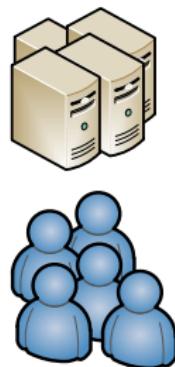
Motivation & Overall Goal

Introduction



Motivation & Overall Goal

Introduction



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

Datei Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe

☰ Bücher versandkostenfrei - Hörbüch... +

www.thalia.de/shop/tha_homestartseite/show/ Anmelden Mein Konto Hilfe Filialen & Events Merkzettel (0)

Mein Warenkorb 0

Alle Kategorien Suchen

Bücher eBooks OYO Hörbücher Filme Musik Spiele Games Software

Schulbücher und Lernhilfen

Aktuelle Themen

- Die ZEIT Polit-Thriller-Box
- Tribute von Panem
- Event: Thalia Tainment
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- TouchMe TFT-Reader

Thalia in Ihrer Nähe

PLZ oder Ort Filiale suchen

! Static capacity management
→ Overprovisioning of resources

top-Empfehlungen

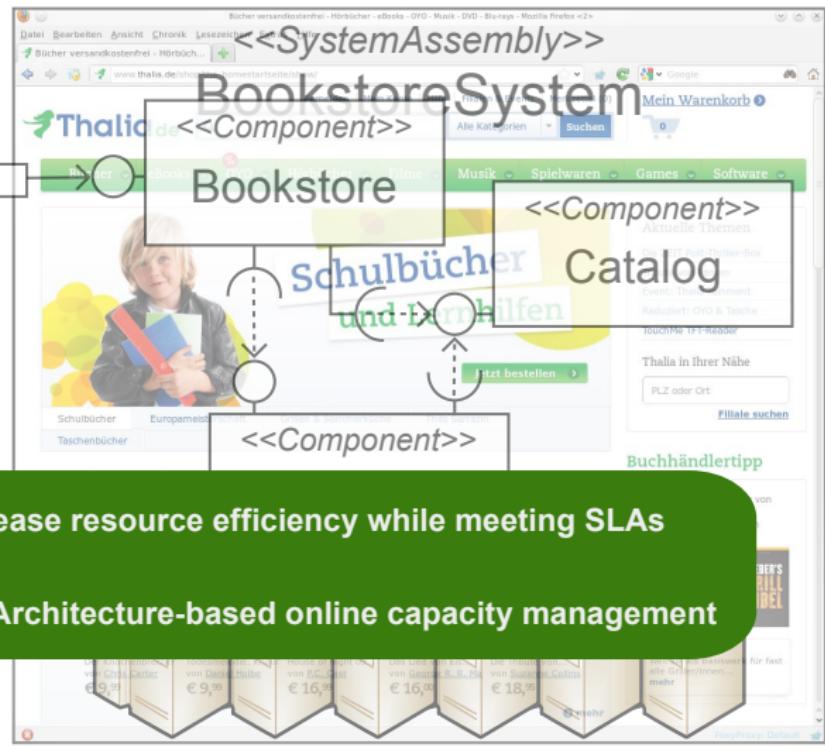
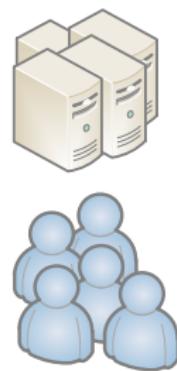
Buch Buch Buch Buch Buch Buch Buch

ANDREAS FRANZ GEORGES GODEFROY

Weber's Grillbibel

Motivation & Overall Goal

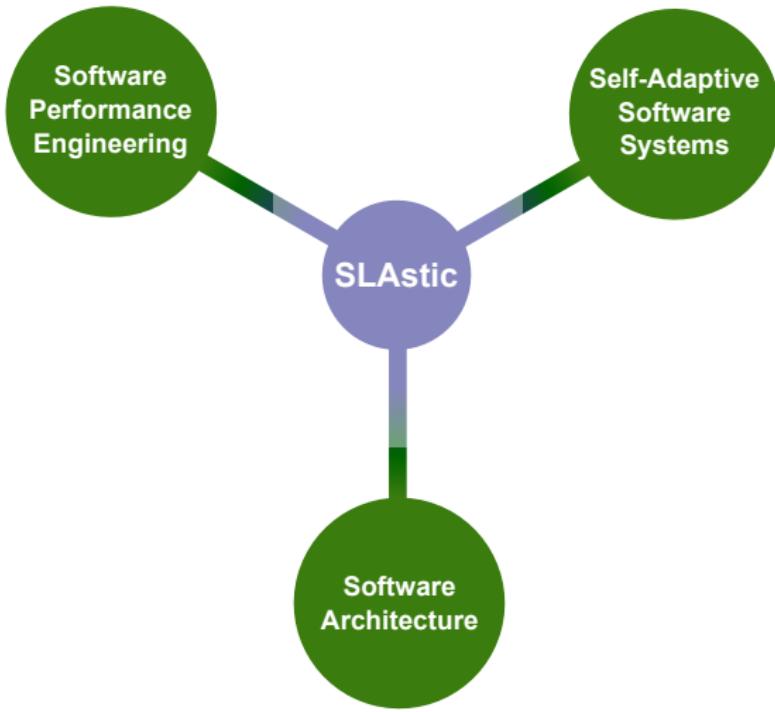
Introduction



Goal: Increase resource efficiency while meeting SLAs

SLAastic: Architecture-based online capacity management

Scientific Context



Affiliation

- **University of Kiel, Software Engineering Group**
- Before: University of Oldenburg (DFG RTG TrustSoft)



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Research Interests

1 Software performance engineering & self-*

- {Model,Architecture}-{based,driven} SPE techniques (+ tools)
- Online performance management (monitoring, analysis)
- (Architectural) performance models @ runtime

2 Software architecture

- Component- & service-based software systems, MDSD
- QoS (particularly, performance and resource efficiency)
- Runtime reconfiguration/adaptation, self-*



Current Projects

- 1 **SLAStic** — Model-Driven Online Capacity Management for C-B Software Systems
- 2 **Kieker** — Application Performance Management and Dynamic Software Analysis

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- Component- & service-based software systems, MDSD
- QoS (particularly, performance and resource efficiency)
- Runtime reconfiguration/adaptation, self-*

3 Software re(verse)-engineering

- Dynamic and hybrid (legacy) software analysis
- Extraction of architectural models and usage profiles
- Architecture-based software modernization

Current Projects

- 1 **SLAStic** — Model-Driven Online Capacity Management for C-B Software Systems
- 2 **Kieker** — Application Performance Management and Dynamic Software Analysis
- 3 **DynaMod** — Dynamic Analysis for Model-Driven Software Modernization



Architecture-based Online Capacity Management: Modeling, Monitoring, and Adaptation

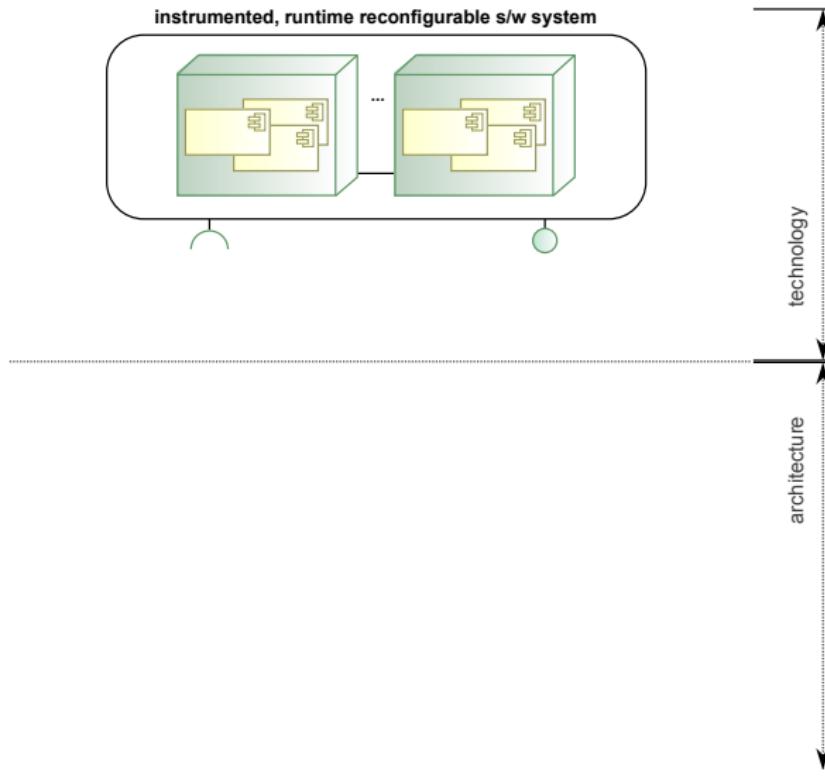
- 1 Introduction
- 2 SLAastic — Architecture-Based Online Capacity Management
- 3 Kieker — Application Performance Monitoring and Dynamic Analysis
- 4 Conclusion

SLAastic Framework



SLAastic — Architecture-Based Online Capacity Management

Christian-Albrechts-Universität zu Kiel

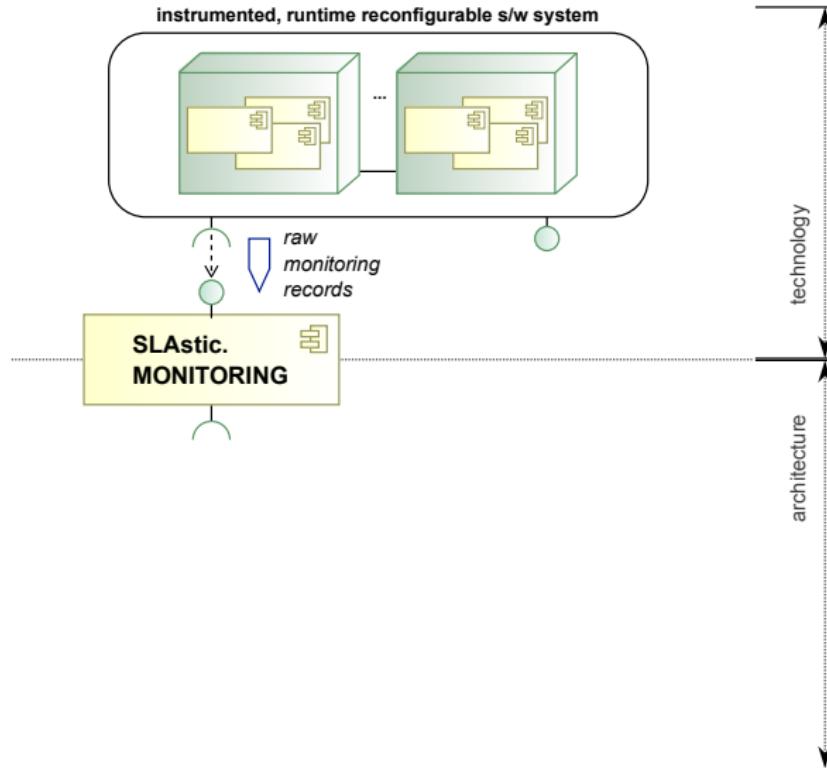


SLAastic Framework

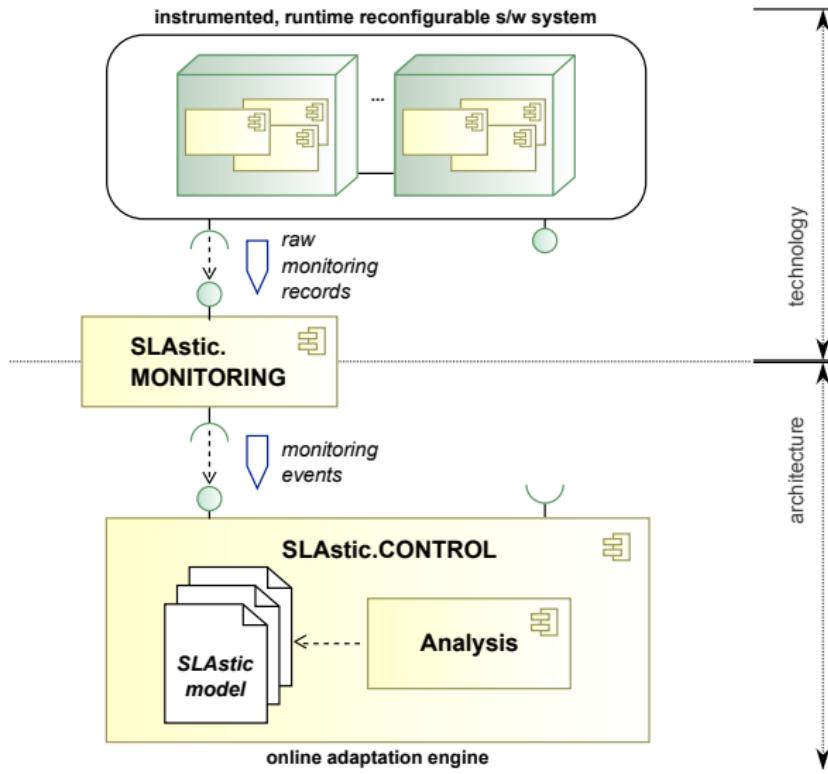


SLAastic — Architecture-Based Online Capacity Management

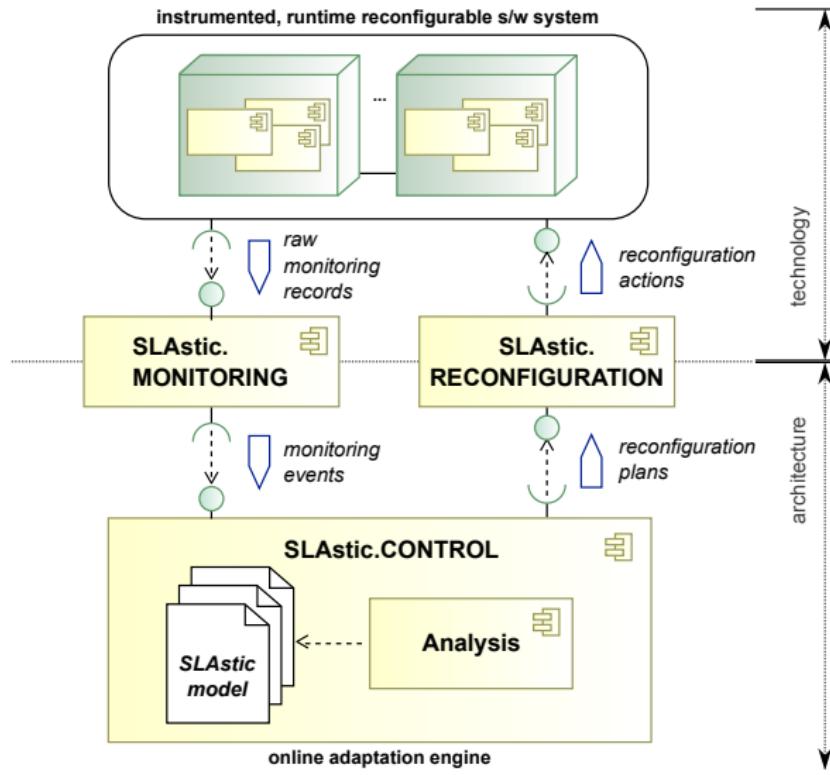
Christian-Albrechts-Universität zu Kiel



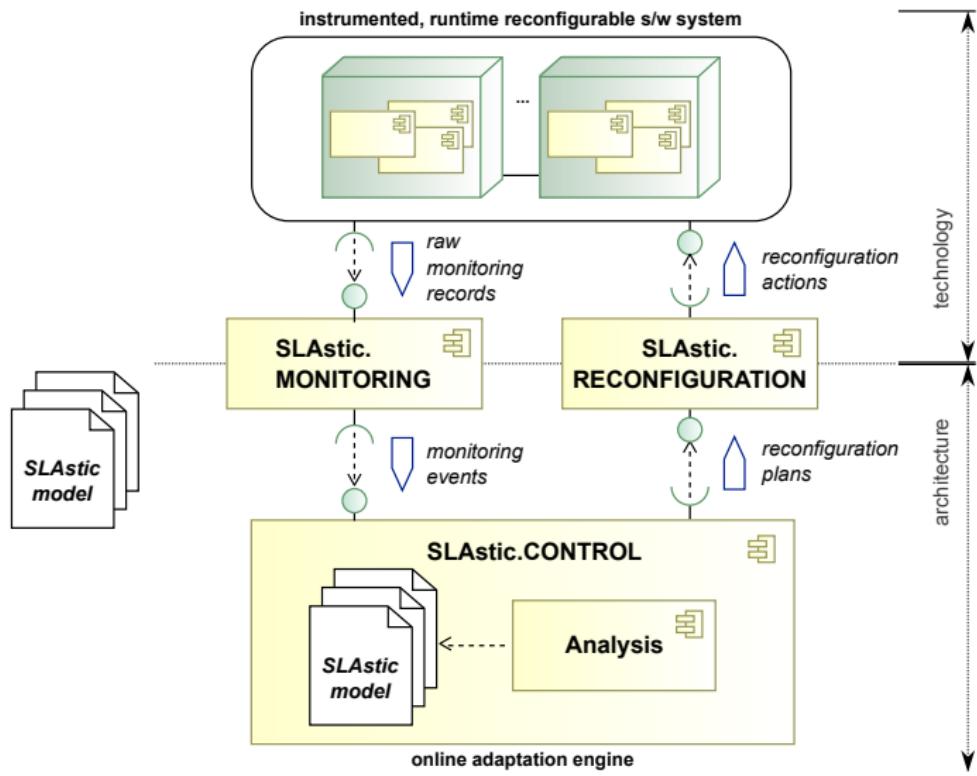
SLAastic Framework



SLAastic Framework

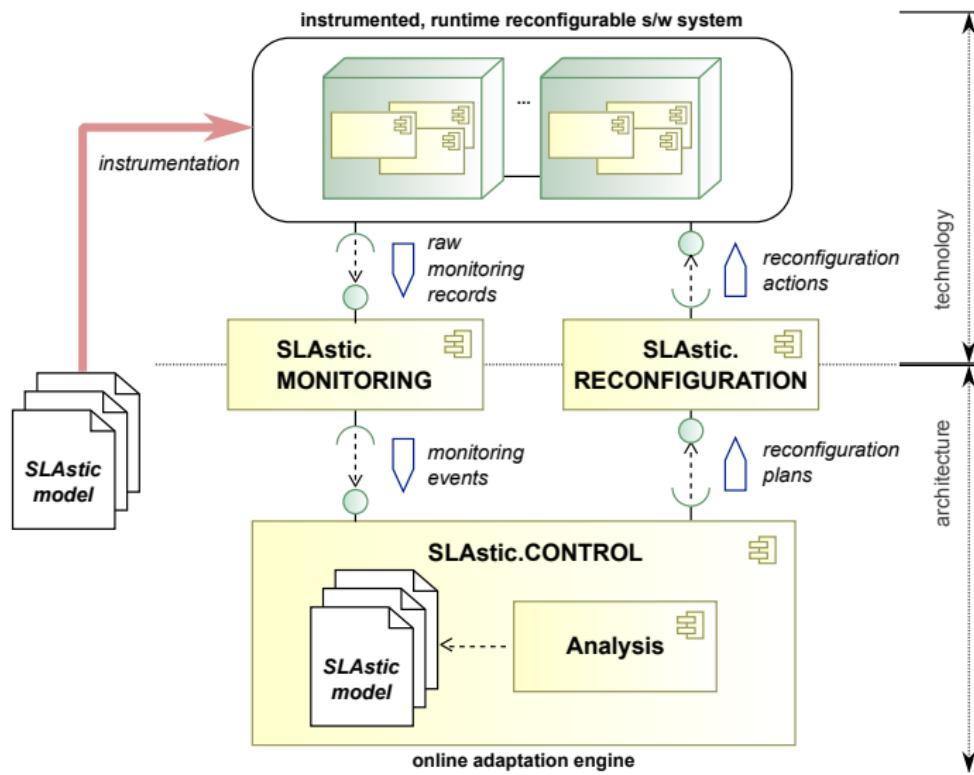


SLAastic Framework



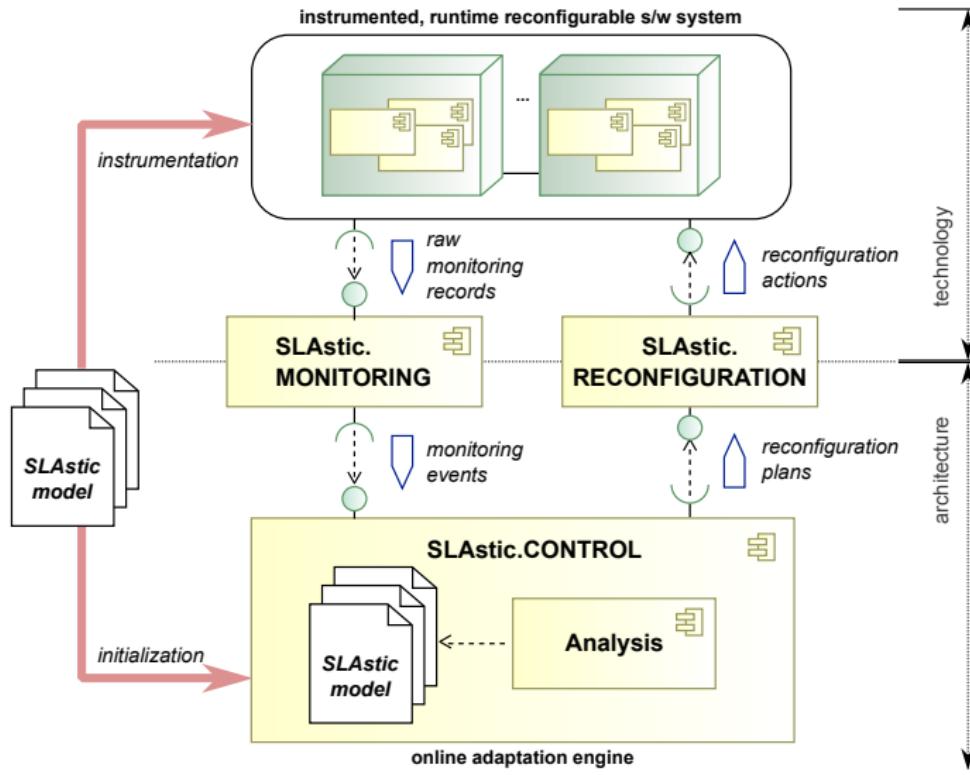
Model-Driven Instrumentation

SLAastic — Architecture-Based Online Capacity Management



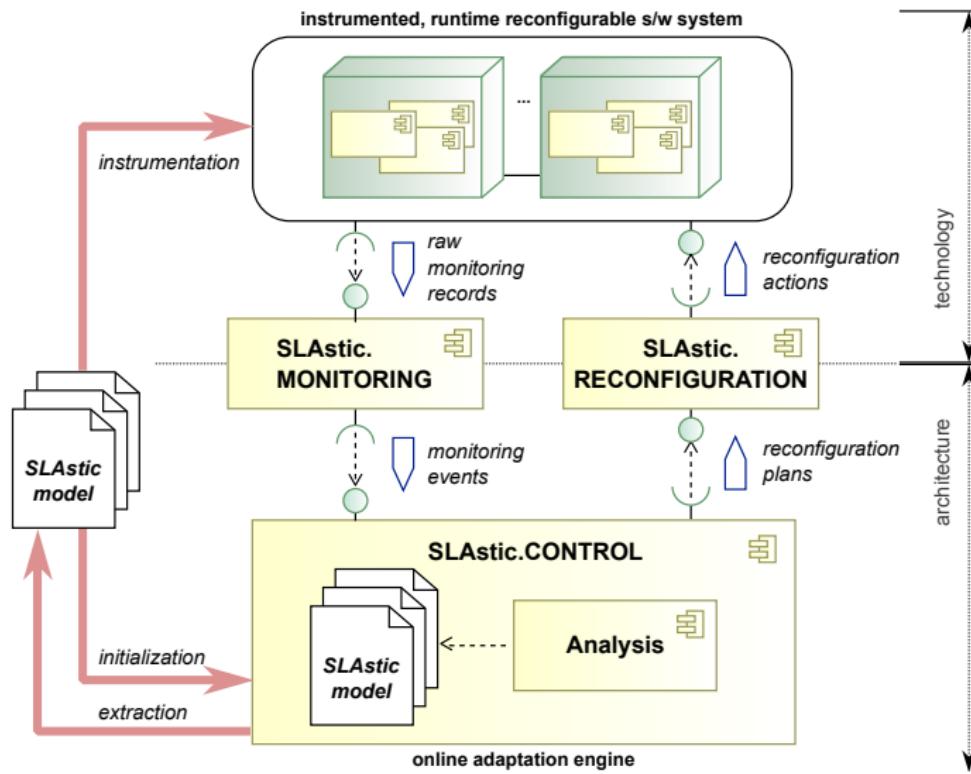
Initialization of Framework & Runtime Models

SLAastic — Architecture-Based Online Capacity Management

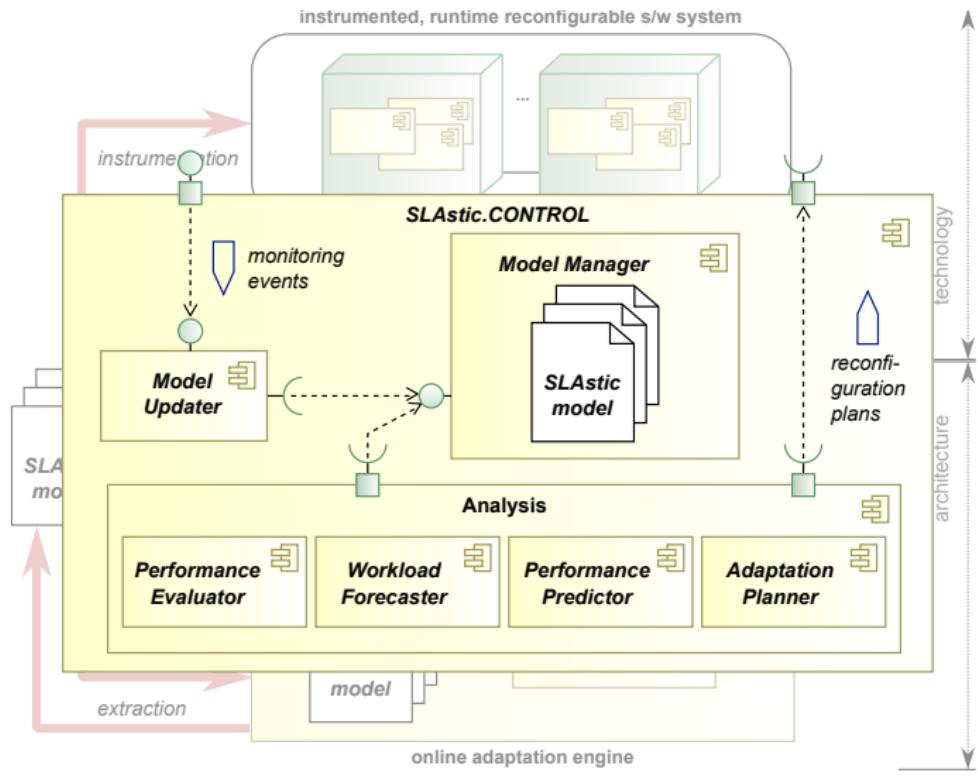


Extraction of Architectural Models (Dyn. Analysis)

SLAStic — Architecture-Based Online Capacity Management



SLAastic.CONTROL (zoom-in)

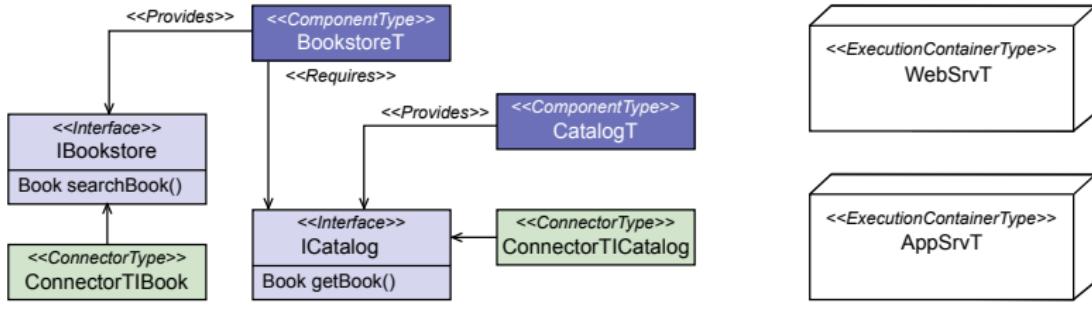


System Partition (also used as runtime model)

- ① Type repository (e.g., component types, interfaces, connector types, execution container types)
- ② Component assembly (e.g., assembly of components via connectors)
- ③ Execution environment (e.g., execution containers and interconnection via links)
- ④ Component deployment (mapping: assembly components → containers)

System Partition (also used as runtime model)

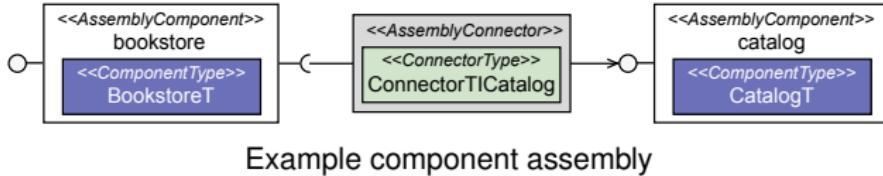
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Example type repository

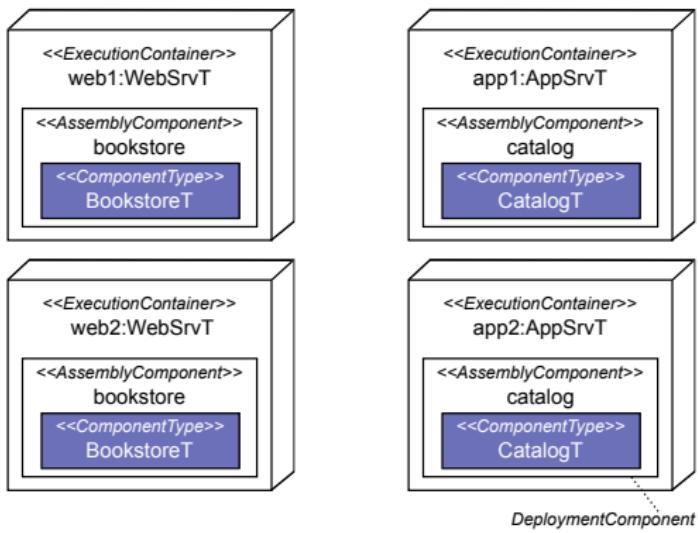
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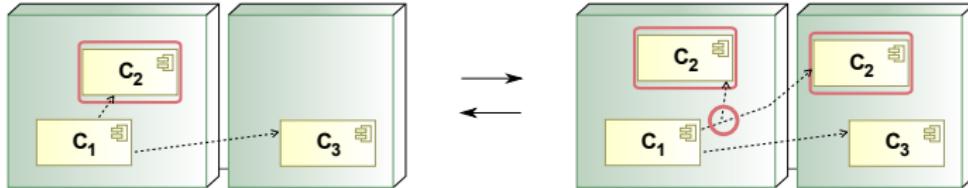
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Example component deployment

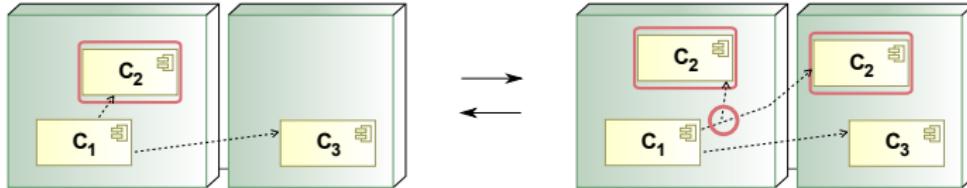
① (De-)Replication of Software Components



① (De-)Replication of Software Components

- replicate (component: `AssemblyComponent`, to: `ExecutionContainer`)
- derePLICATE (component: `DeploymentComponent`)

① (De-)Replication of Software Components



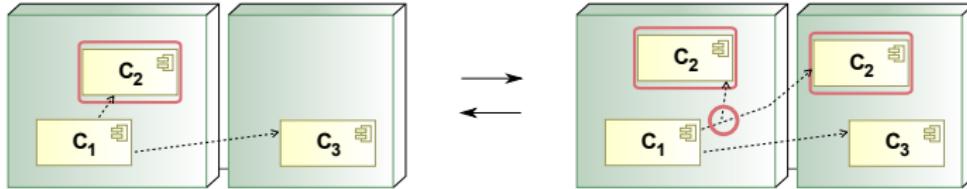
SLAastic Runtime Reconfiguration Operations



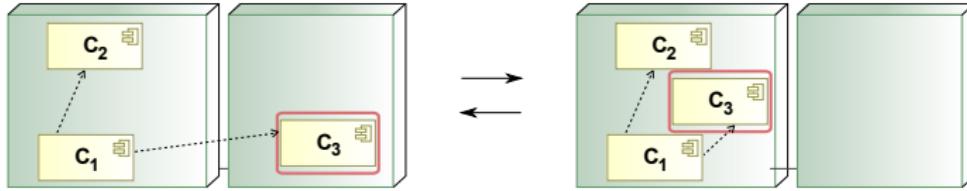
SLAastic — Architecture-Based Online Capacity Management

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① (De-)Replication of Software Components



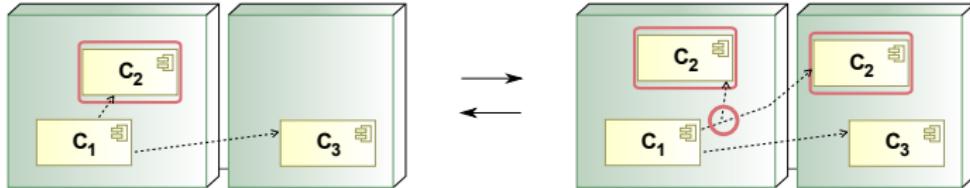
② Migration of Software Components



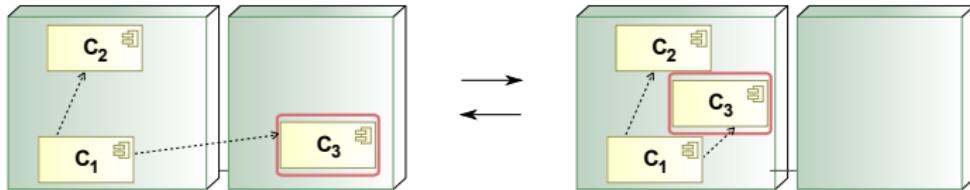
SLAastic Runtime Reconfiguration Operations

SLAastic — Architecture-Based Online Capacity Management

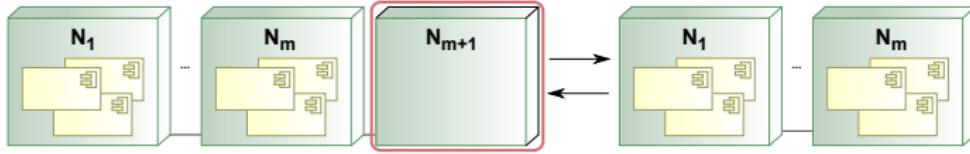
① (De-)Replication of Software Components



② Migration of Software Components



③ (De-)Allocation of Execution Containers



Completions/Decorations

SLAastic Meta-Model (cont'd)

SLAastic — Architecture-Based Online Capacity Management



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Completions/Decorations

- **Adaptation / Reconfiguration** (e.g., plans, operations, capabilities, properties)
- **Measurement** (e.g., workload, timing, utilization)
- **Usage** (e.g., operation call frequencies, calling relationships)
- ...

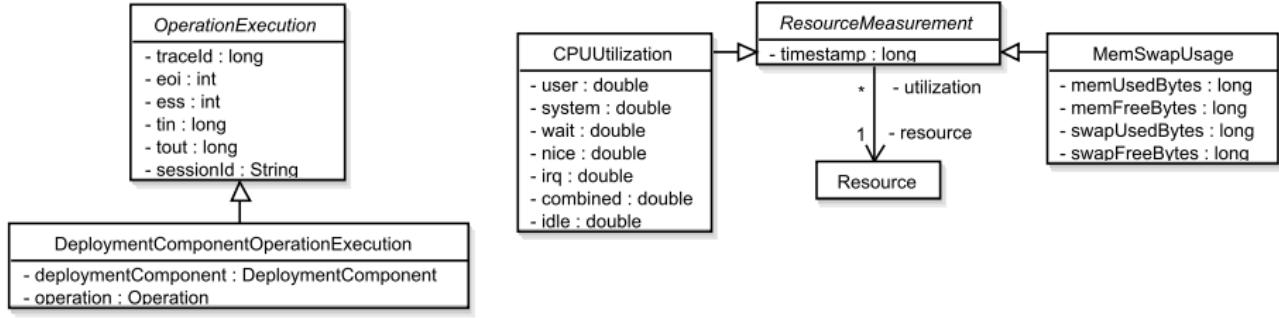
Completions/Decorations

SLAStic Meta-Model (cont'd)

SLAStic — Architecture-Based Online Capacity Management

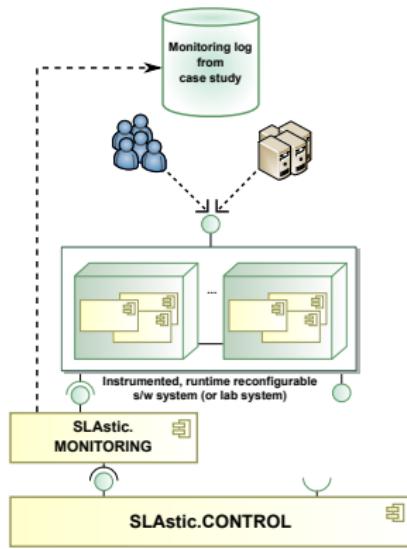
Completions/Decorations

- Adaptation / Reconfiguration (e.g., plans, operations, capabilities, properties)
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- ...



Measurement event types

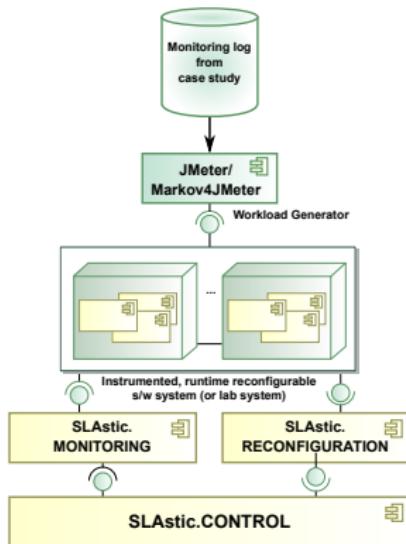
Evaluation Methodology



- ① Online analysis (production/lab system)

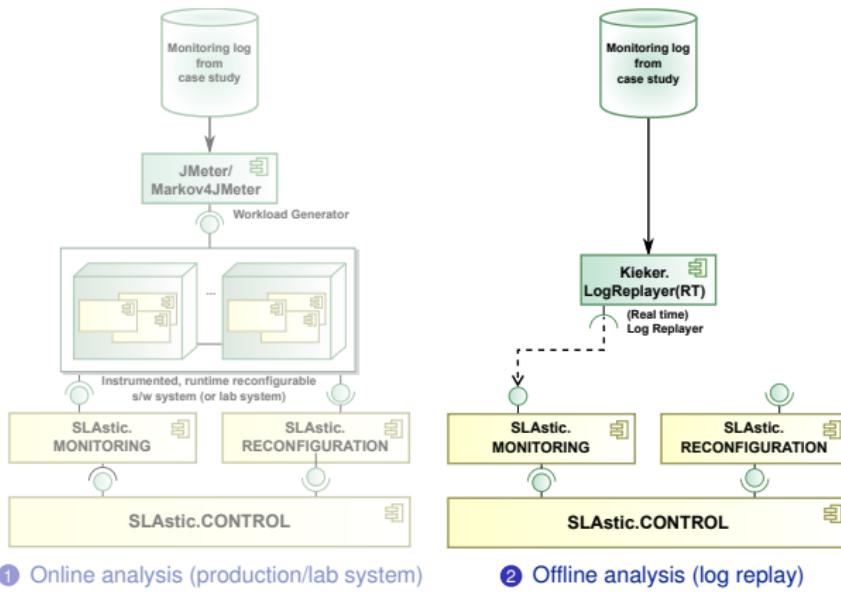
Evaluation Methodology

SLAastic — Architecture-Based Online Capacity Management

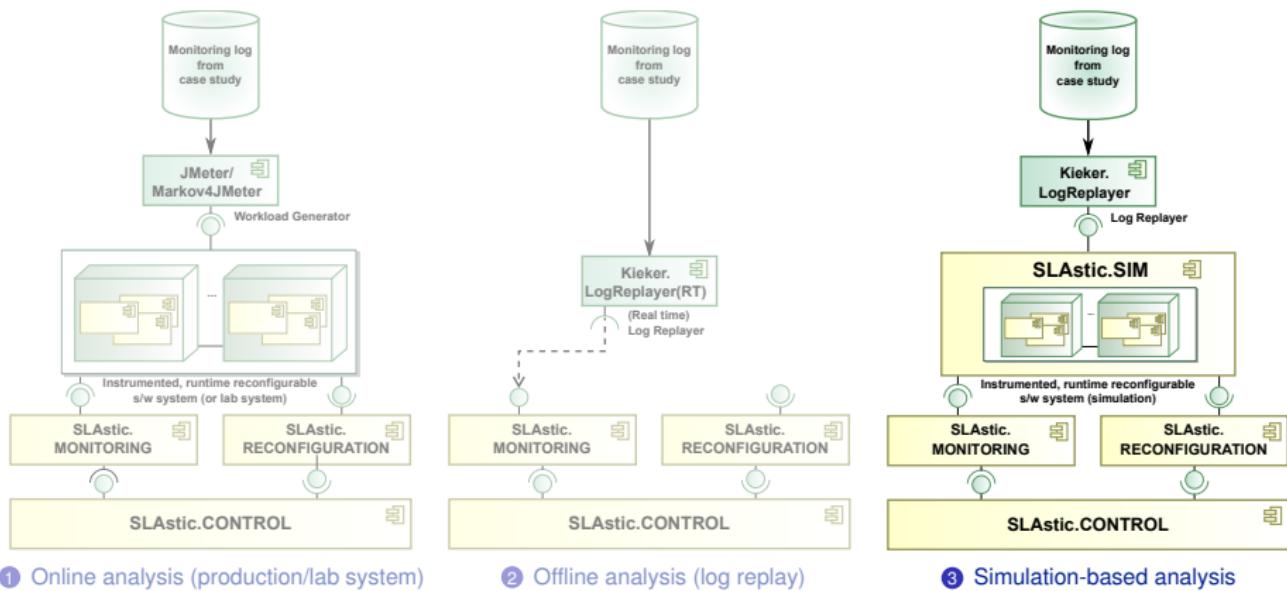


- ① Online analysis (production/lab system)

Evaluation Methodology



Evaluation Methodology



Agenda

Kieker — Application Performance Monitoring and Dynamic Software Analysis



- 1 Introduction
- 2 SLAastic — Architecture-Based Online Capacity Management
- 3 Kieker — Application Performance Monitoring and Dynamic Analysis
- 4 Conclusion

Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

Kieker — Application Performance Monitoring and Dynamic Software Analysis

The screenshot shows the Eclipse IDE interface with two open files:

- Catalog.java:** Contains Java code with a monitoring probe annotation:

```
26     @OperationExecutionMonitoringProbe
27     try {
28         Thread.sleep(3);
29     } else {
30         Thread.sleep(3);
31     }
32     } catch (InterruptedException ex) {}
```
- axop.xml:** Shows the generated aspect code:

Node	Content
concrete-aspe	kieker.monitoring.probe.aspectj.operation.
name	kieker.monitoring.probe.aspectj.operation.
extends	kieker.monitoring.probe.aspects.operation.
pointcut	monitoredOperation
express	execution(int com.ibatis.jdbcstorage.service.

Software system with monitoring instrumentation



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

Kieker — Application Performance Monitoring and Dynamic Software Analysis

The screenshot shows two windows in the Eclipse IDE. On the left, the 'Catalog.java' file contains Java code with a red box highlighting a 'Monitoring probe'. The code includes annotations like '@OperationExecutionMonitoringProbe'. On the right, the 'aop.xml' configuration file shows a 'Monitoring Probe/Sampler' tab selected, listing various monitoring technologies and their configurations.

Java code snippet:

```
26     @OperationExecutionMonitoringProbe
27     public void someMethod() {
28         try {
29             ...
30         } catch (InterruptedException ex) {}
31     }
32 }
```

Kieker configuration interface:

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

Software system with monitoring instrumentation

Java probes/samplers:

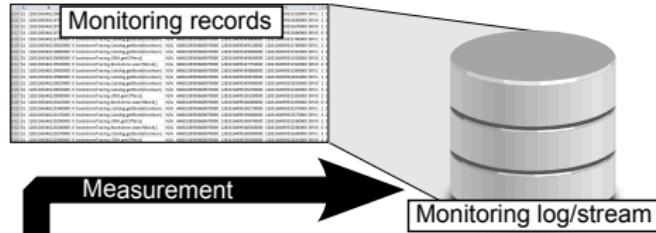
- + basic adapters for
- C#/.NET
- Visual Basic 6/COM
- COBOL



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

Kieker — Application Performance Monitoring and Dynamic Software Analysis



A screenshot of the Eclipse IDE interface. The top bar shows "java ch2-trace-monitoring aspectj/ac/BookstoreTracing/Catalog.java - Eclipse". The Catalog.java editor shows Java code with annotations. A red box highlights the annotation "@GenerationExecutionMonitoringProbe" on line 27. The code includes a try-catch block and a sleep operation. To the right of the code editor is a "AspectJ" tool window showing a tree structure of aspects and their concrete operations.

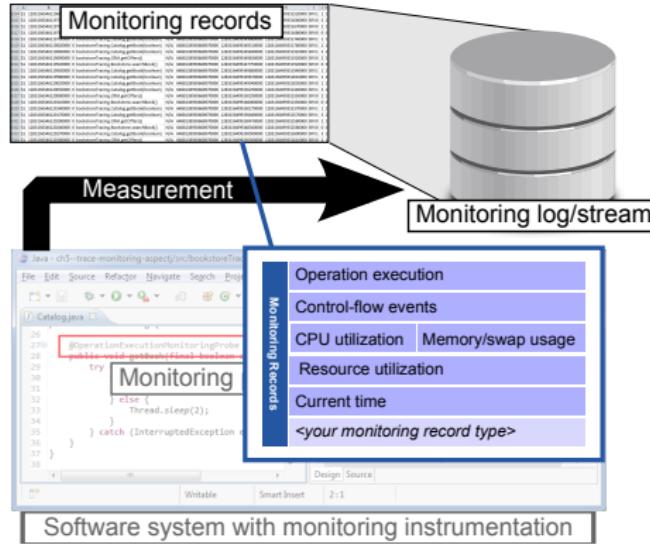
Software system with monitoring instrumentation



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

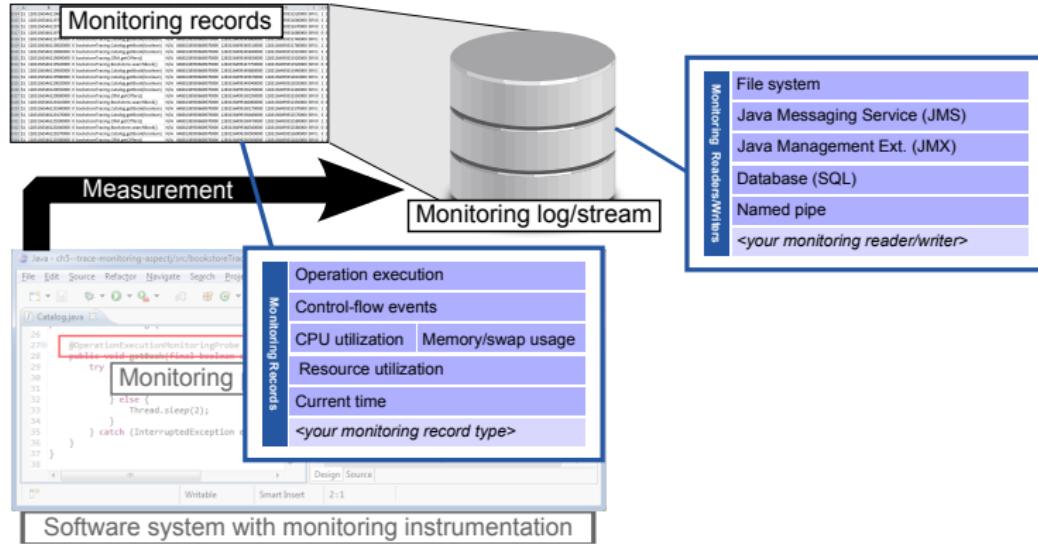
Kieker — Application Performance Monitoring and Dynamic Software Analysis



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

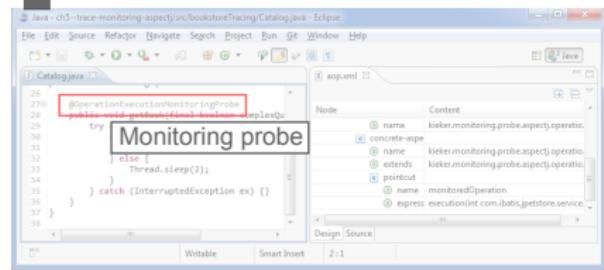
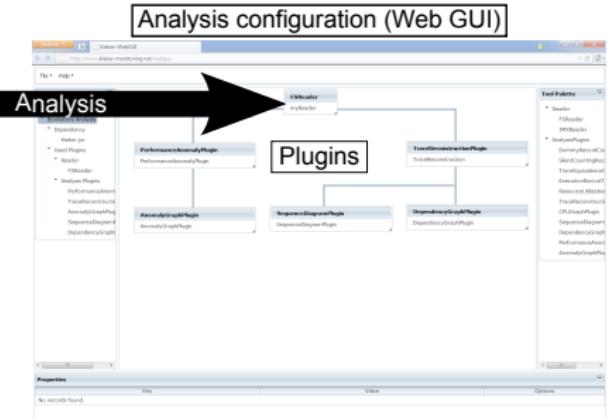
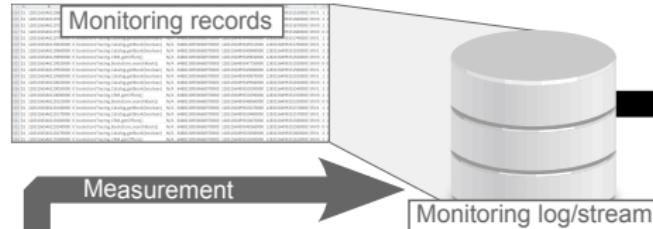
Kieker — Application Performance Monitoring and Dynamic Software Analysis



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

Kieker — Application Performance Monitoring and Dynamic Software Analysis



A screenshot of an Eclipse IDE showing a Java code editor. The code is annotated with Kieker monitoring annotations. A red box highlights the annotation "@GenerationExecutionMonitoringProbe" on line 27. The code is as follows:

```
26
27 @GenerationExecutionMonitoringProbe
28     try {
29         Thread.sleep(3);
30     } catch (InterruptedException ex) {}
31     }
32     else {
33         Thread.sleep(3);
34     }
35 }
```

The code editor has tabs for "Catalog.java" and "aspects1". The properties panel on the right shows the annotation details.

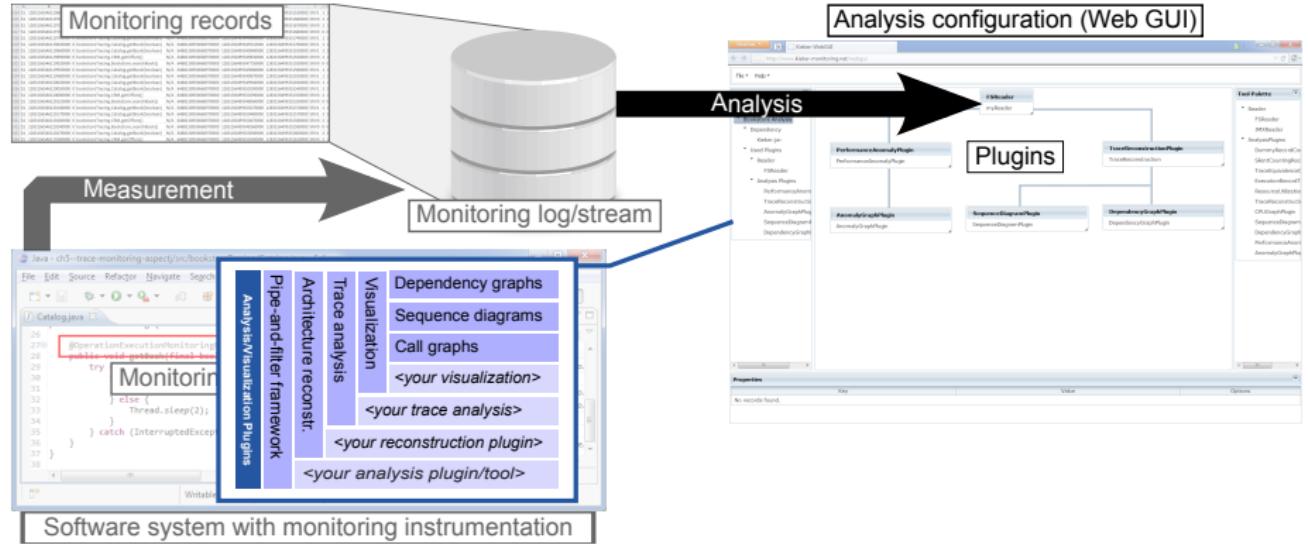
Software system with monitoring instrumentation



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

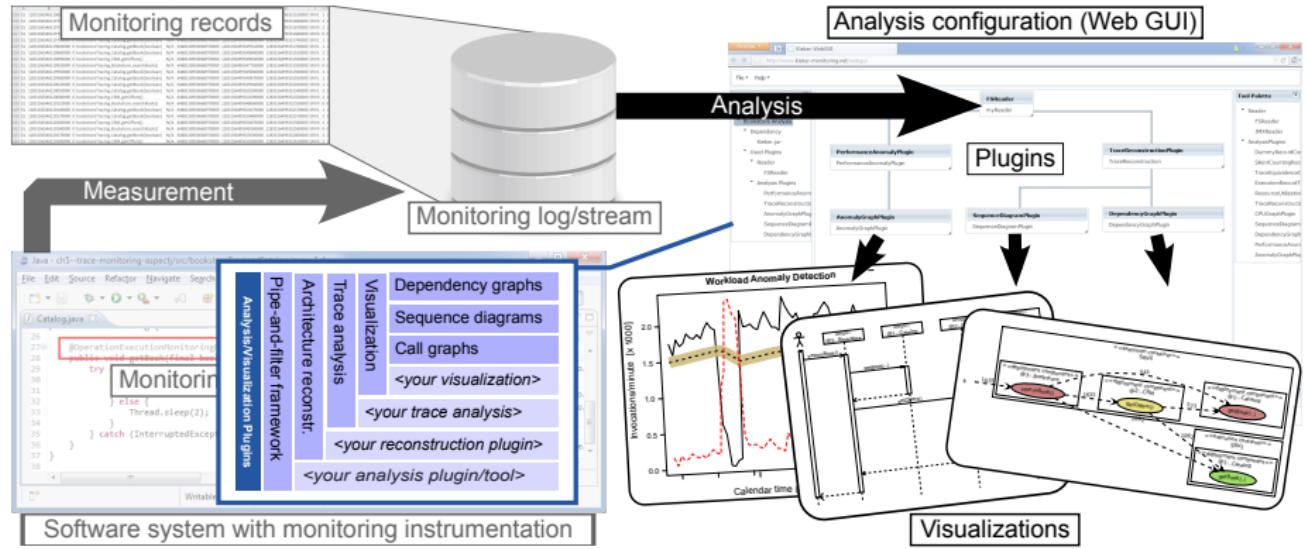
Kieker — Application Performance Monitoring and Dynamic Software Analysis



Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

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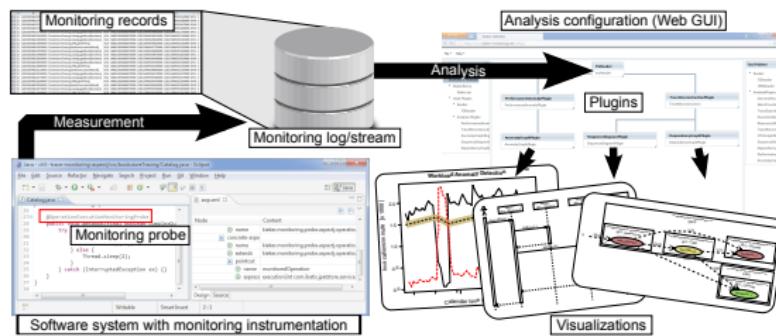


Kieker

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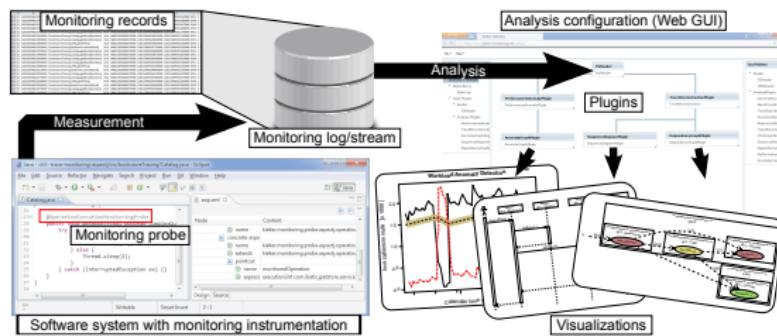


Selected use cases in research and industrial practice (+ teaching):

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Kieker — Application Performance Monitoring and Dynamic Software Analysis



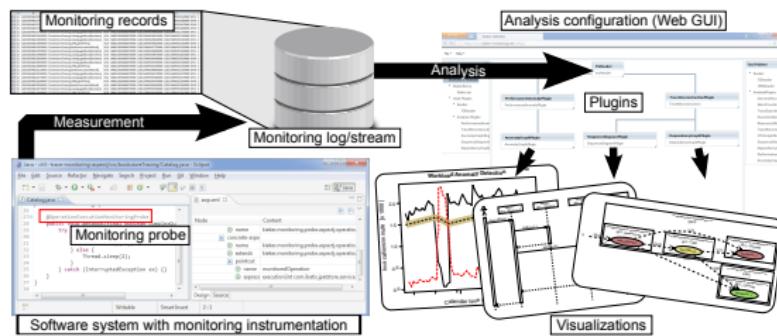
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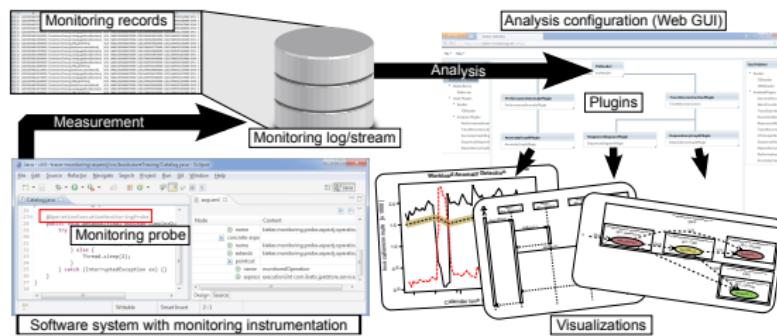
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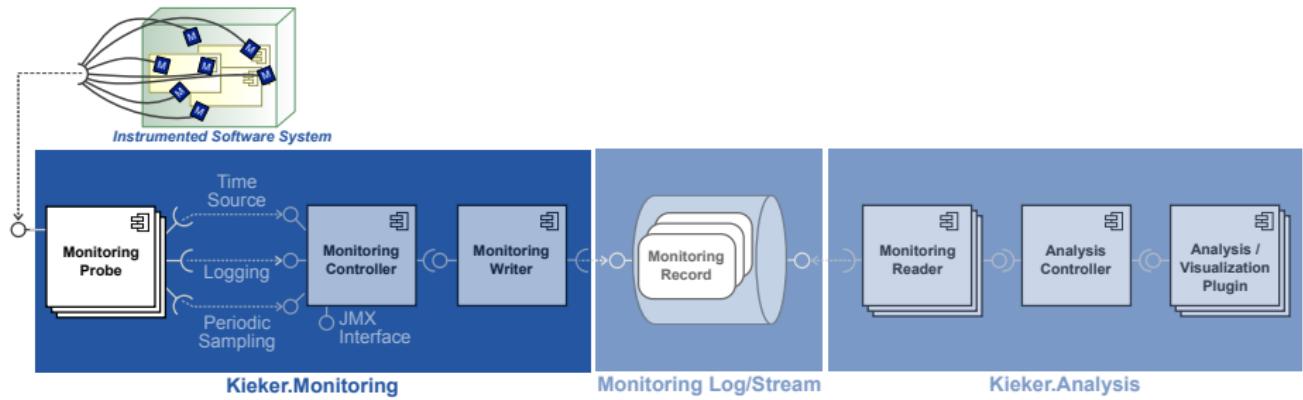


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- Extraction of software architectural (performance) models and visualizations
- Simulation (replaying previously monitored stimuli; measurement, logging, and analysis)

Core Kieker Framework Components

Kieker — Application Performance Monitoring and Dynamic Software Analysis

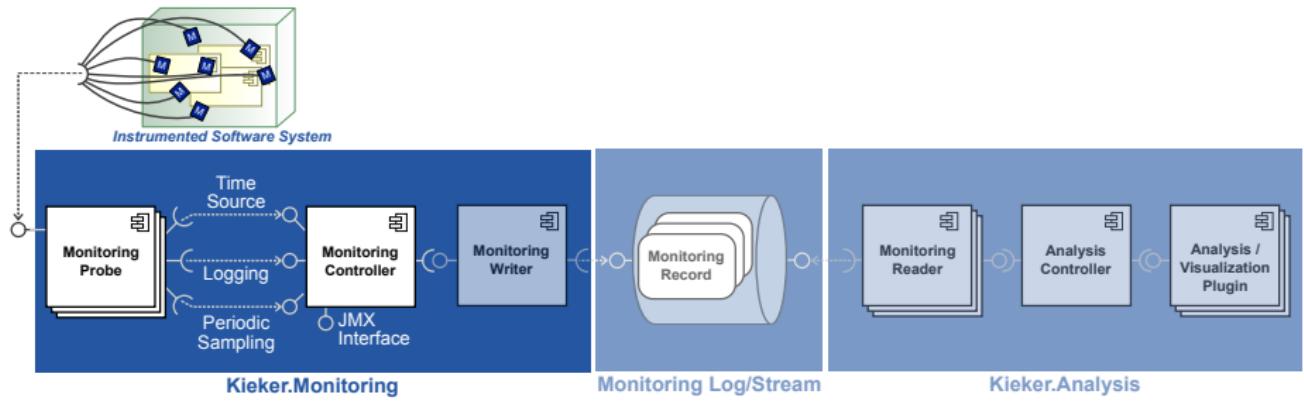


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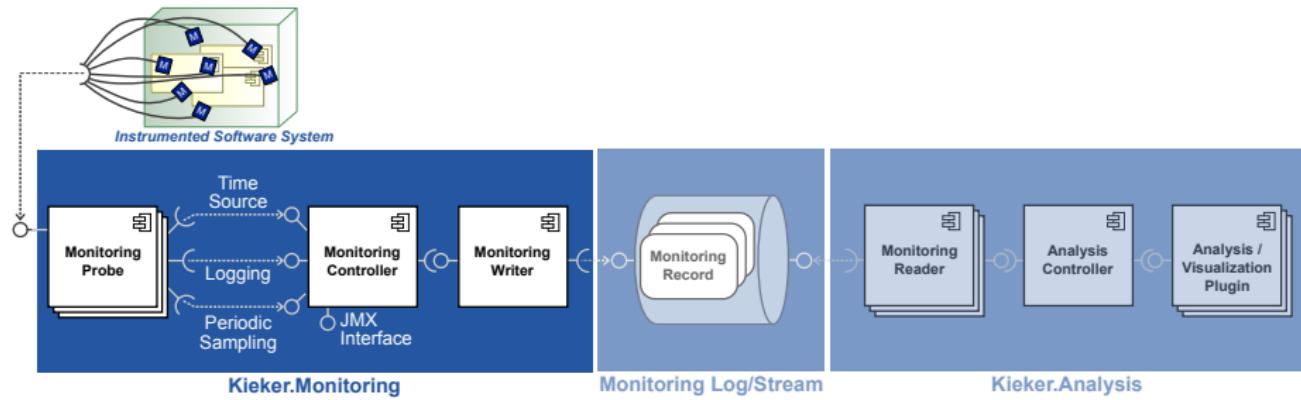


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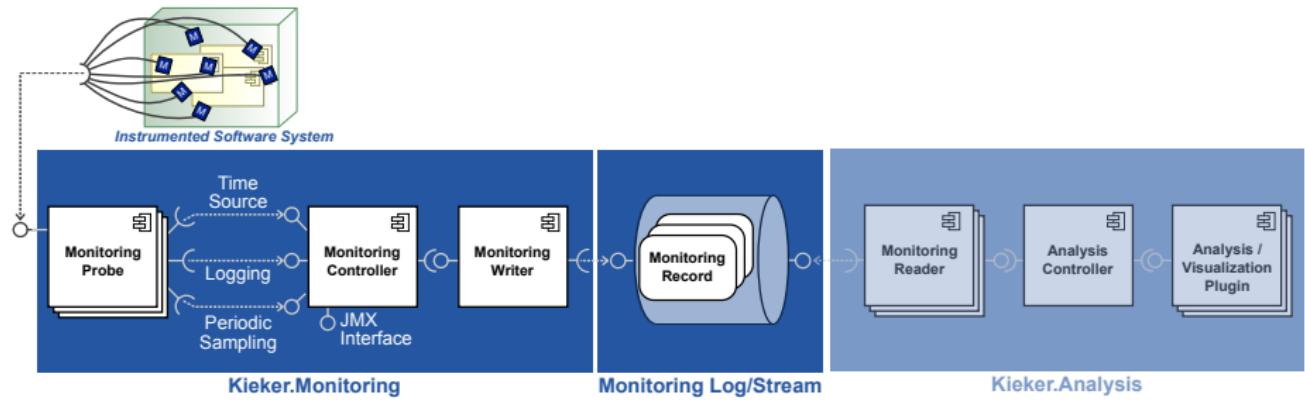


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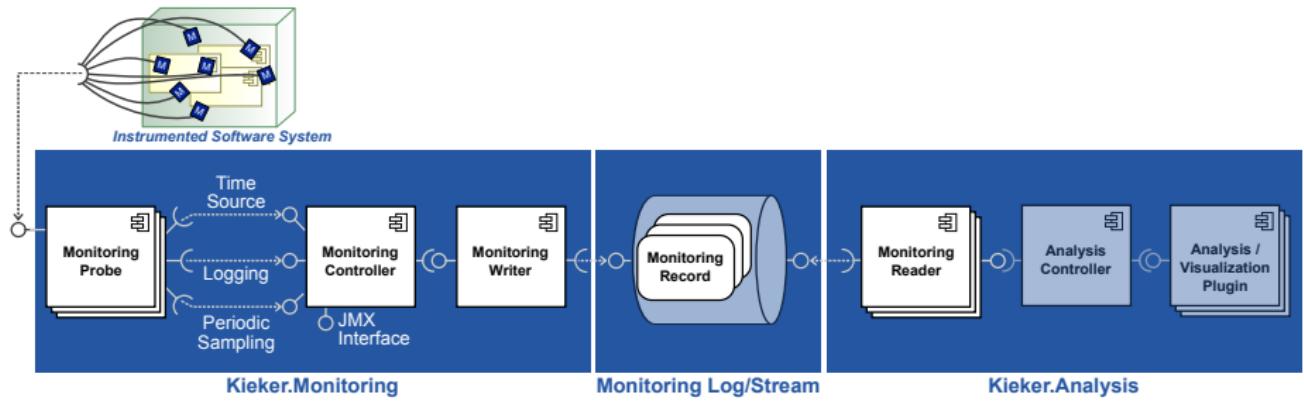


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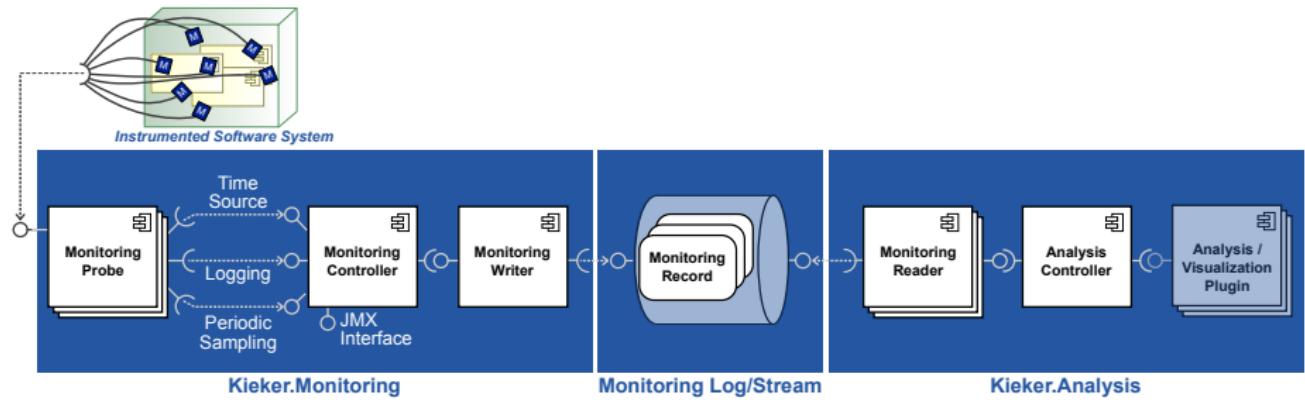


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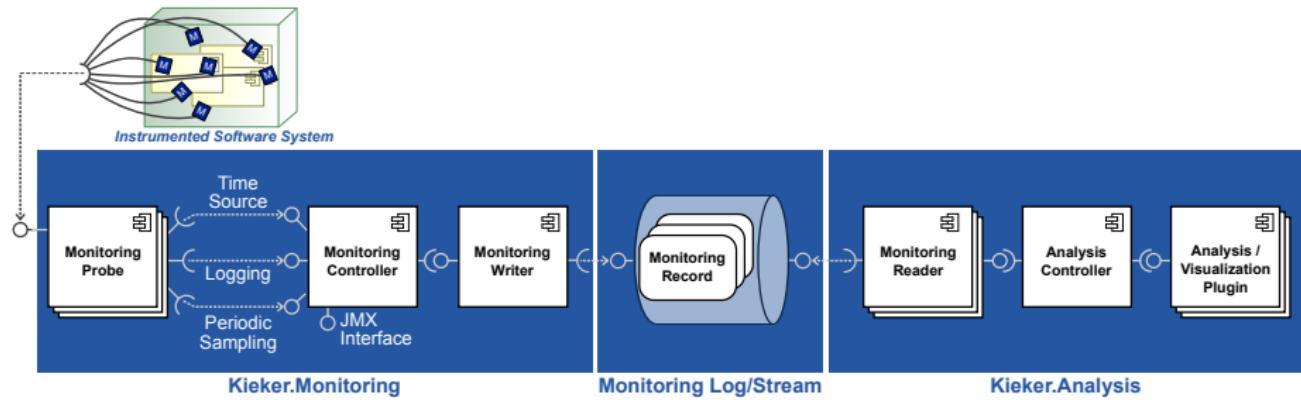
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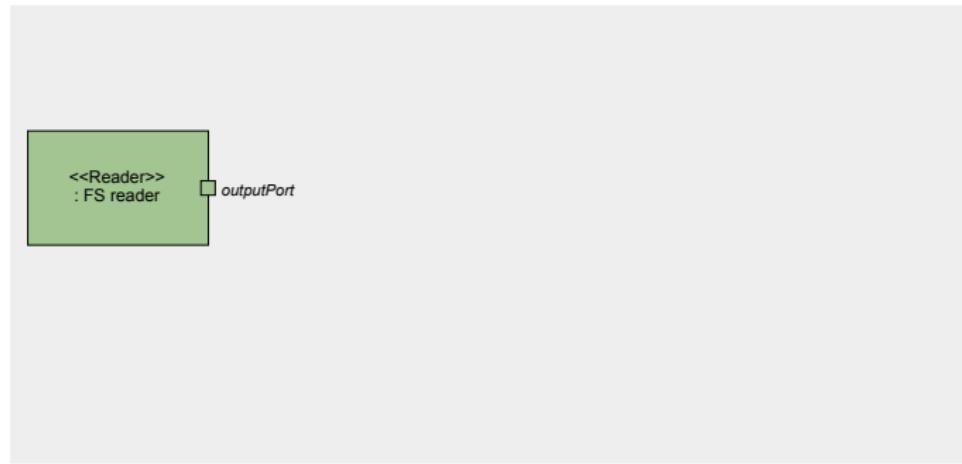
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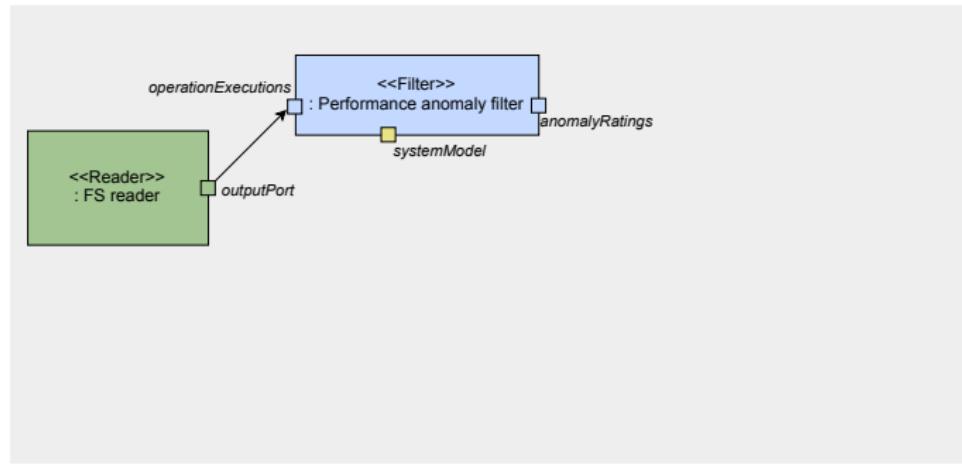
Example Pipe-and-Filter Configuration



Kieker.Analysis example pipes-and-filters configuration

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

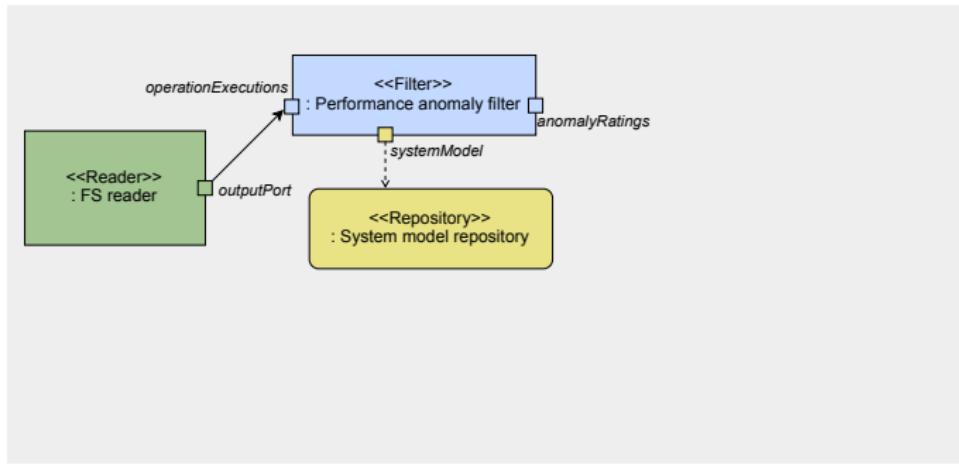
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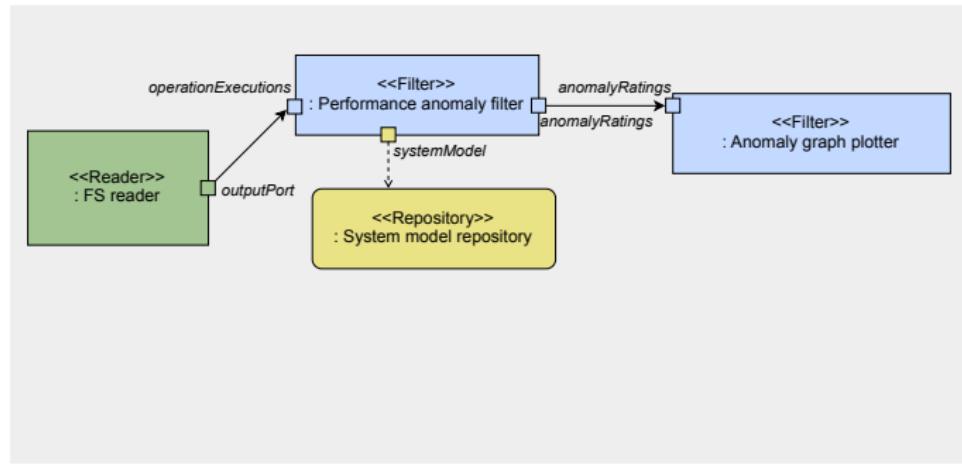
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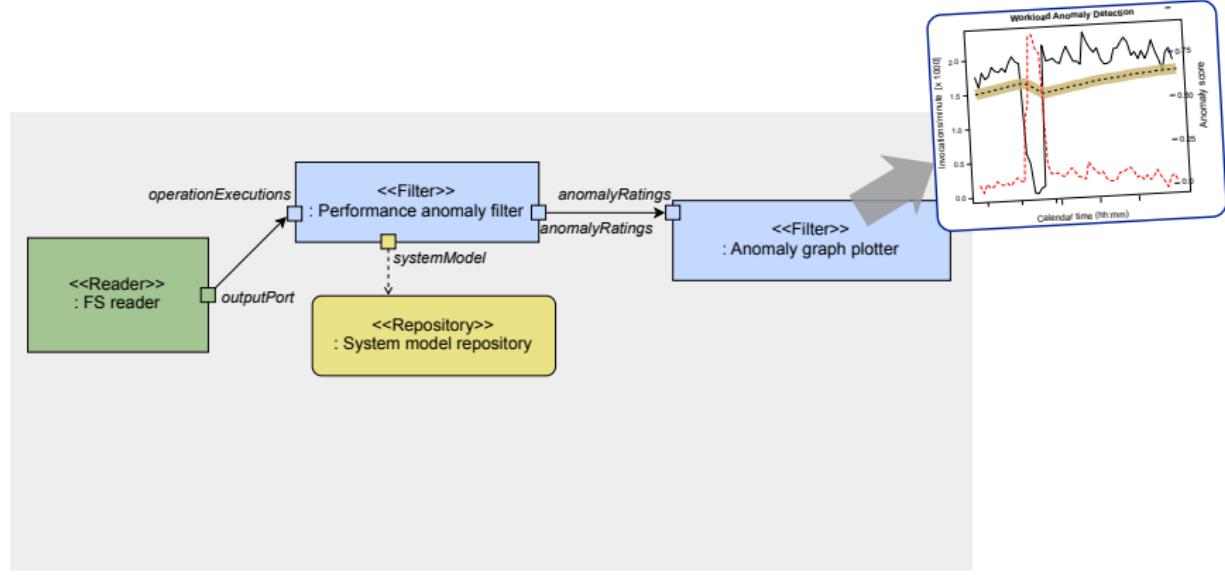
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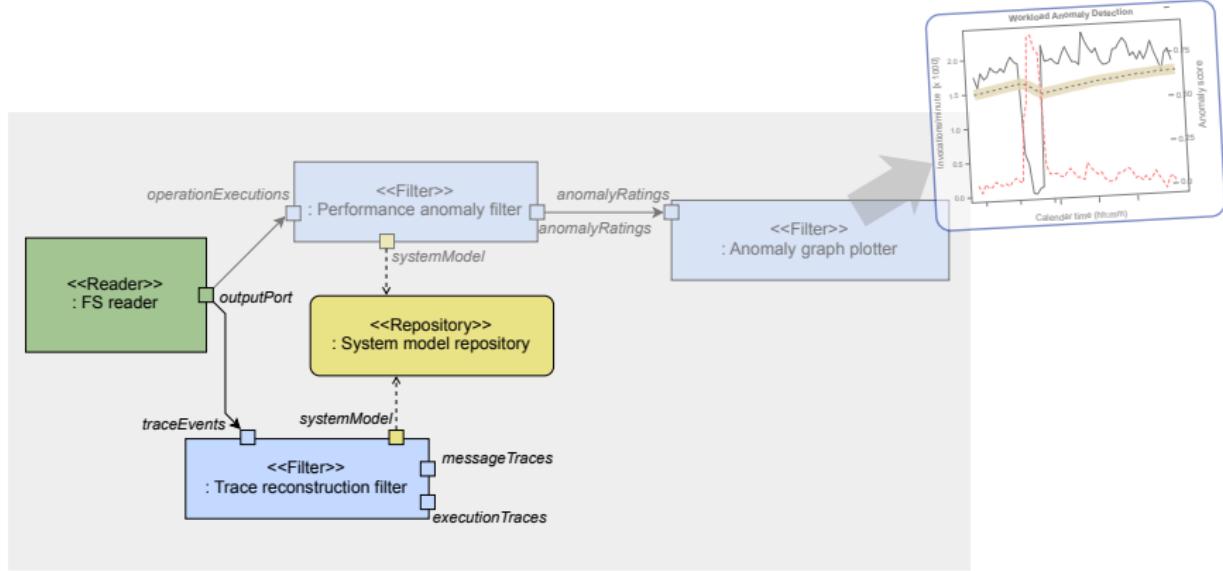
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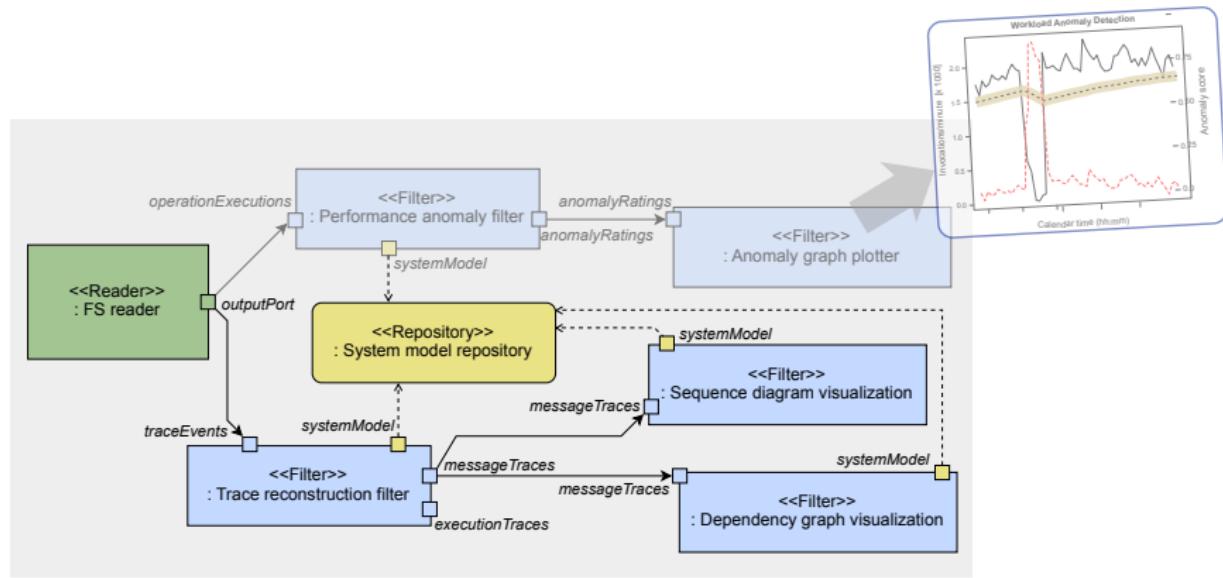
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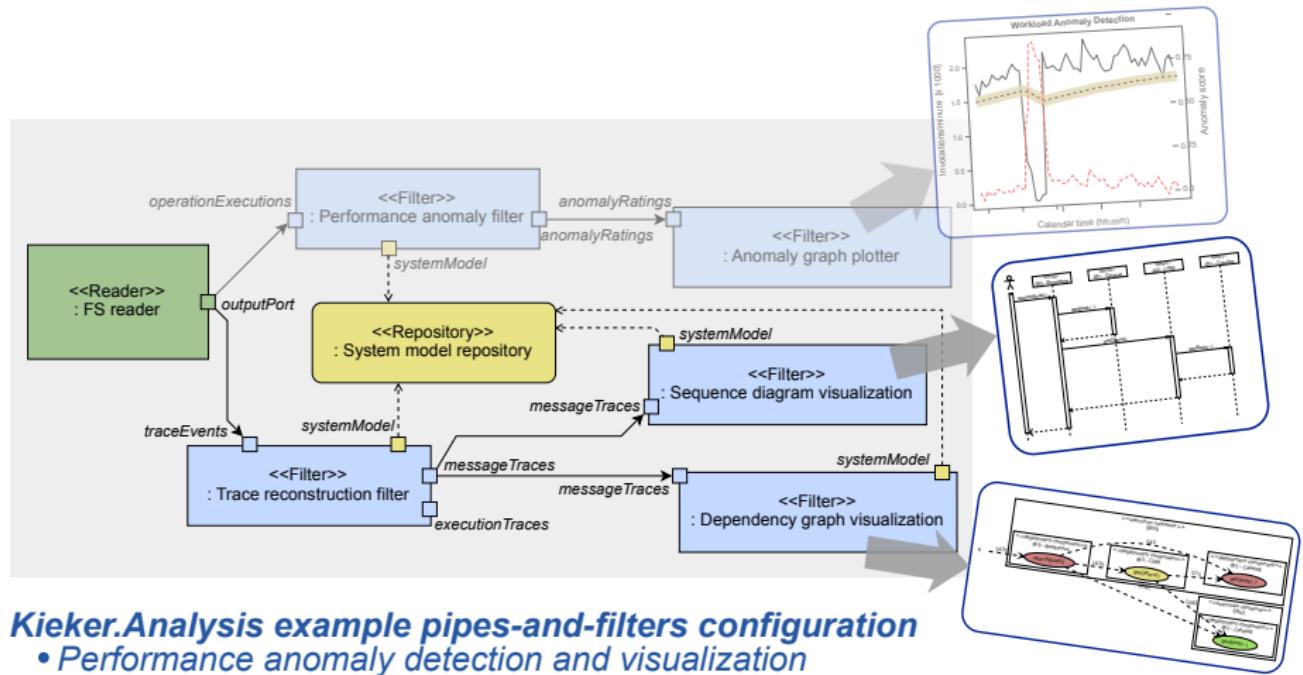
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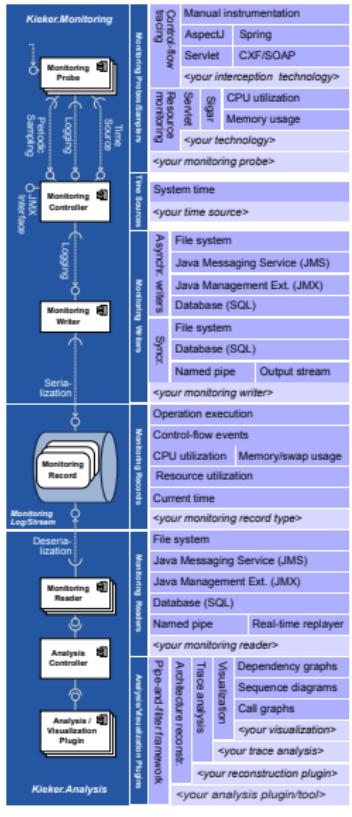
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Framework Features & Extension Points

Kieker — Application Performance Monitoring and Dynamic Software Analysis



- 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



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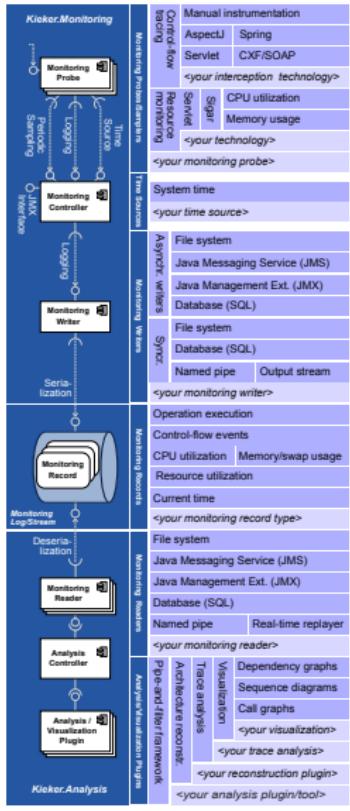


Kieker is open-source software (Apache License, V. 2.0)

<http://kieker-monitoring.net>

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

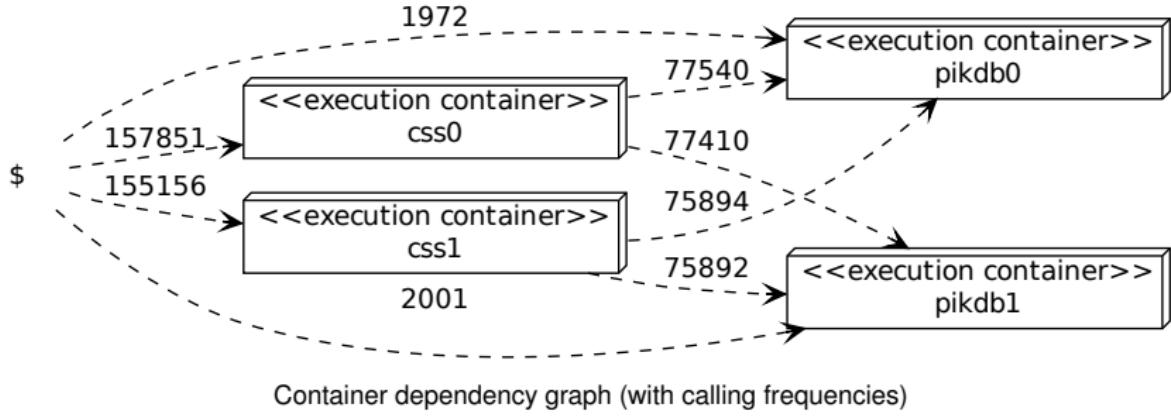
<http://research.spec.org/projects/tools.html>





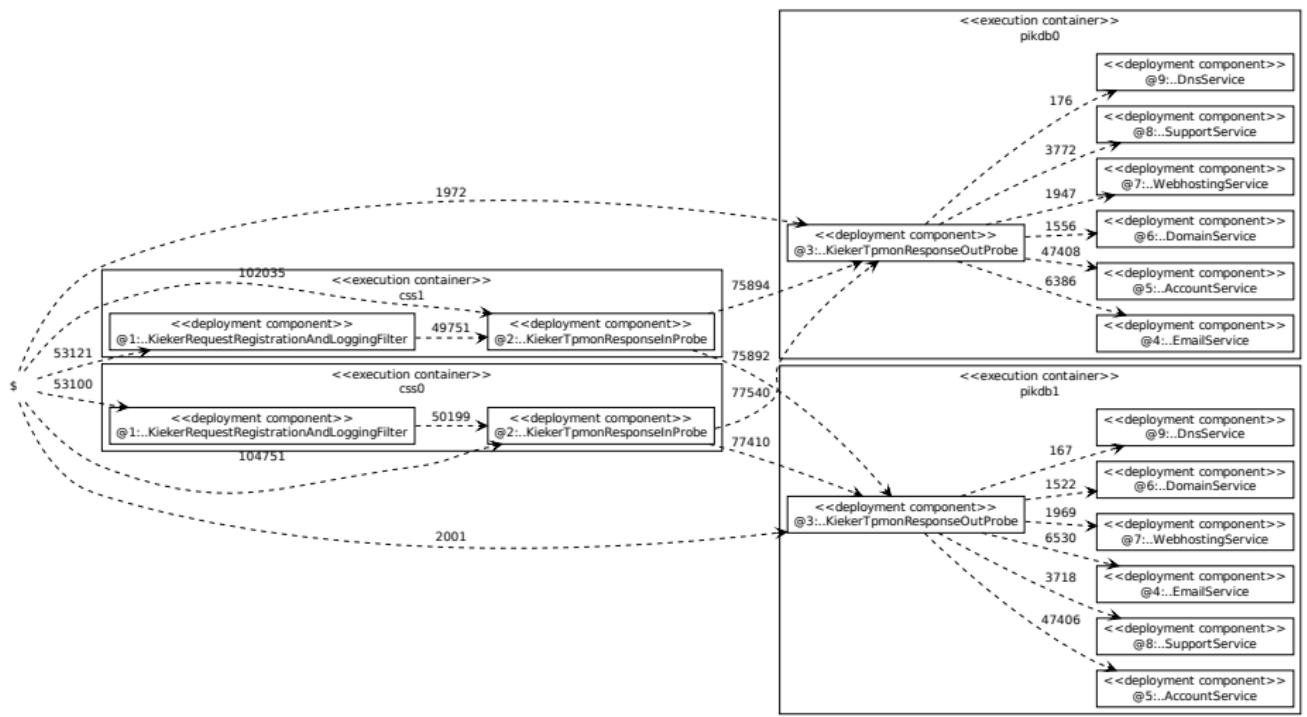
Telecommunication provider, distributed setting

- **Goal:** Workload characterization and performance evaluation
- Java-based **technology:** Servlet, Spring, and CXF/SOAP
- **Continuous Monitoring** (utilizing Kieker):
 - Probes for collecting **distributed application-level trace and performance data**
 - Continuous monitoring **in production use since 12/2009**
- **Model extraction examples** (316,980 traces):



Case Study: Model Extraction Examples (cont'd)

Deployment-level component dependency graph (with calling frequencies):



SLAastic

- Self-adaptive capacity management based on application-level workload
- Adaptation goal: Increased resource efficiency while meeting SLAs
- Means for adaptation: Architectural runtime reconfiguration
- Use of architectural (performance) models at development & runtime
- Domain: Business-critical distributed component-based software systems

Kieker

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Feel free to contact me: avh@informatik.uni-kiel.de

Conclusion

- N. Günther. Modellbasierte Laufzeit-Performance-Vorhersage für komponentenbasierte Softwarearchitekturen ("Model-based online performance prediction for component-based software architectures", in german), Nov. 2011. Diploma Thesis, University of Kiel.
- A. van Hoorn. *Model-Driven Online Capacity Management for Resource Efficient Component-Based Software Systems*. PhD thesis, Department of Computer Science, University of Kiel, Kiel, Germany, 2012. work in progress.
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