

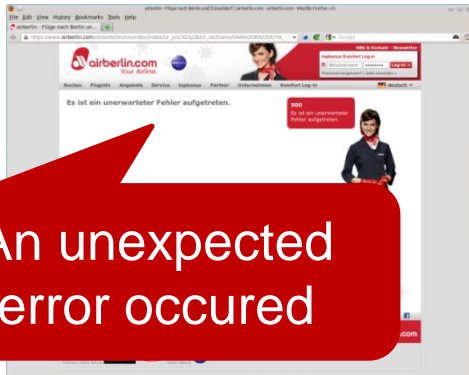
Measurement-Based Application Performance Problem Detection and Diagnosis

André van Hoorn

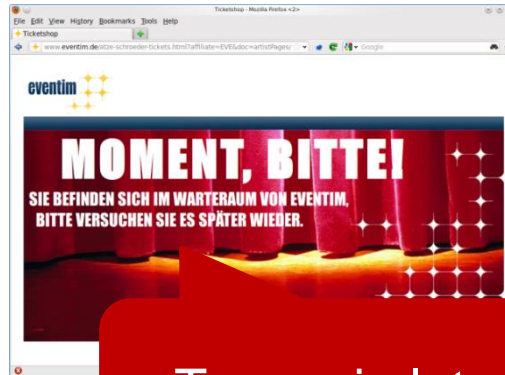
April 21, 2015 @  **GRAN SASSO
SCIENCE INSTITUTE**
CENTER FOR ADVANCED STUDIES
Istituto Nazionale di Fisica Nucleare, L'Aquila, Italy



Performance (QoS) Problems are Omnipresent



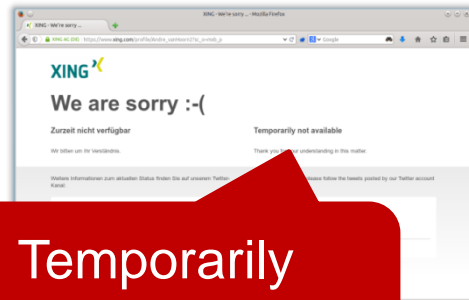
An unexpected error occurred



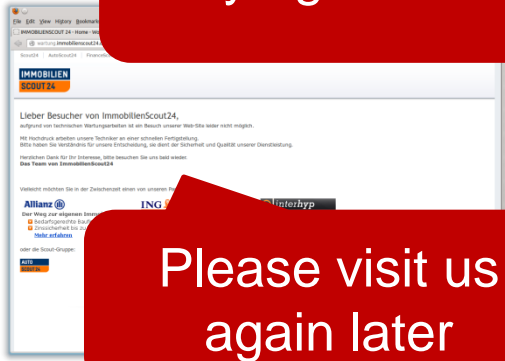
Try again later



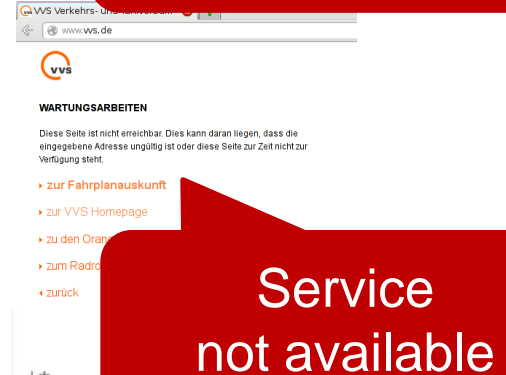
Temporarily unavailable



Temporarily not available



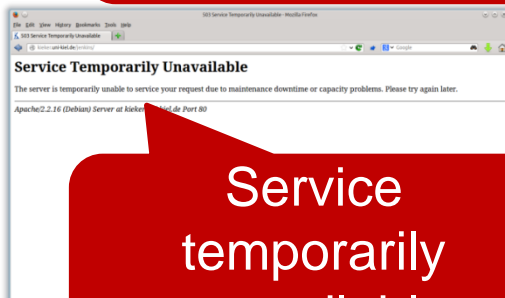
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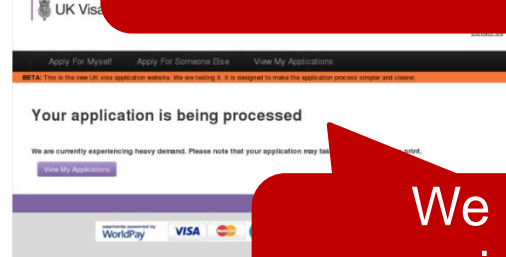
Service not available



... more capacity is on the way

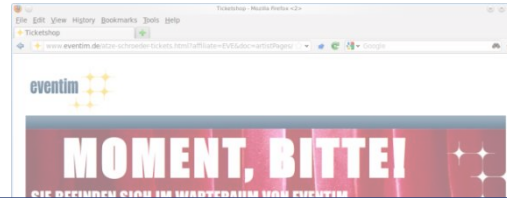
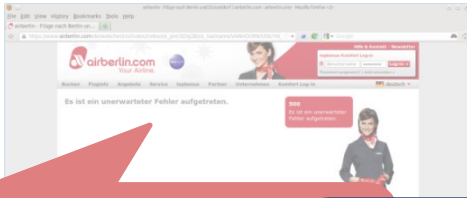


Service temporarily unavailable



We are experiencing heavy demand

Performance (QoS) Problems are Omnipresent



An unexpected
occure

How to (semi-)automate

1. the detection of performance problems?
2. pinpointing the root cause (i.e., diagnosis)
3. the proactive detection and diagnosis?

Temporarily
not available

Please visit us
again later

Service
not available

... more capacity
is on the way

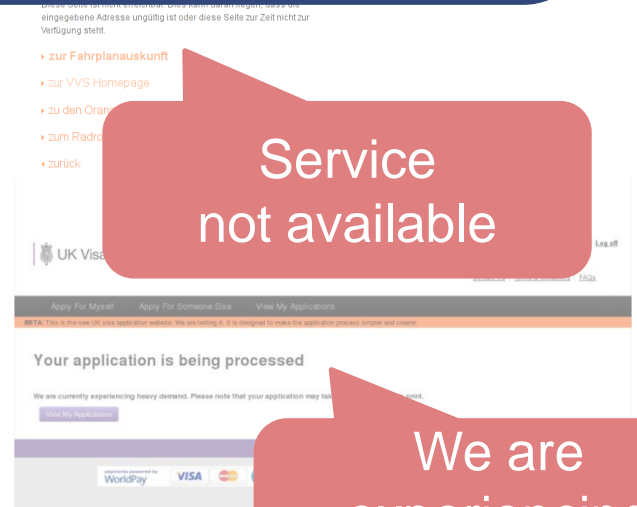
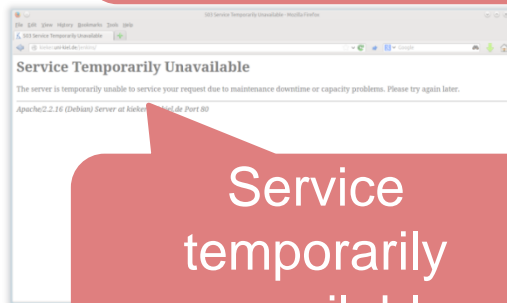
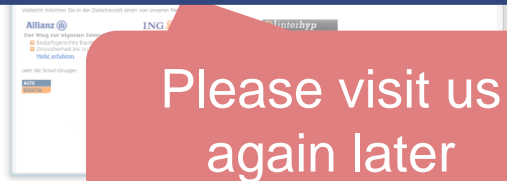
Service
temporarily
unavailable

We are
experiencing
heavy demand

mozilla services

The Firefox Sync service is operating properly for most users.

There may be intermittent problems for some through the weekend. More capacity is on the way. If you're having problems with Mozilla Services infrastructure, please contact us via Twitter. Follow these instructions to help us resolve your issue. Please refer to the Twitter stream below for the latest status.



Application Performance Management

- APM dimensions according to Gartner (2014)

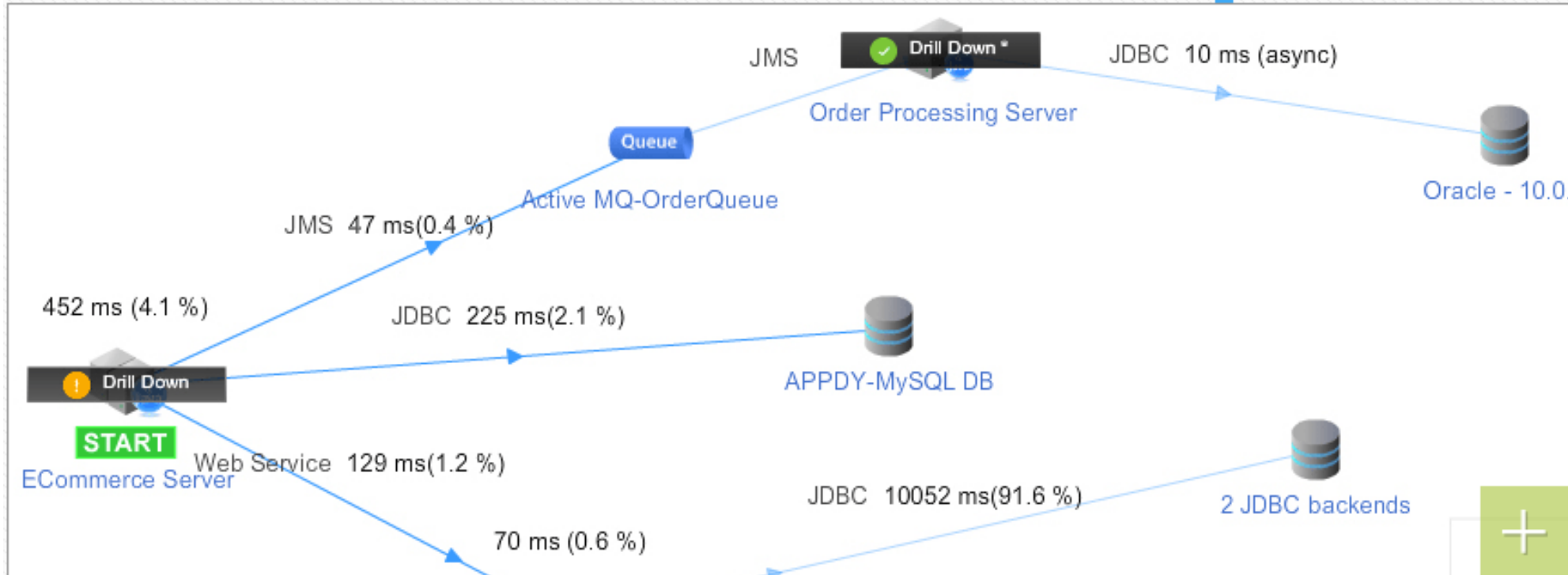
1. End-user experience monitoring

<https://www.gartner.com/doc/288942>

2. Application topology discovery and visualization



Example: Application Topology Discovery and Visualization



© AppDynamics

Application Performance Management

- APM dimensions according to Gartner (2014)

1. End-user experience monitoring
2. Application topology discovery and visualization
3. User-defined transaction profiling
4. Application component deep-dive

<https://www.gartner.com/doc/288942>



Example: Application Component Deep-Dive

Call Drill Down. Exe Time: 10975 ms Timestamp: 10/10/12 4:26:14 PM BT: Checkout GUID: d3036e58-022b-436f-bd5b-70416ece72ed

Execution Time: 10975 ms. Node Node_8003. Timestamp: 10/10/12 4:26:14 PM.

Set as Root Reset Root (?) Show Filters

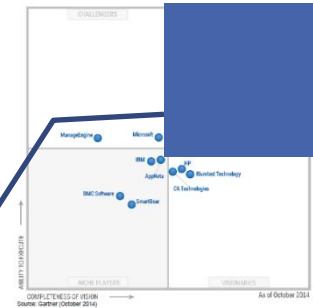
Name	Time (ms)	Exit Calls / Threads
StrutsActionProxy:execute	51 ms (self) 0.5 %	
Struts Action - ViewCart:sendItems:164	0 ms (self) 0 %	
Proxy For Spring Bean - cartServiceTarget:checkOut	0 ms (self) 0 %	
Proxy For Spring Bean - cartServiceTarget:invoke	0 ms (self) 0 %	
Spring Bean - cartServiceTarget:checkOut:40	0 ms (self) 0 %	
Spring Bean - soapUtil:raisePO:22	0 ms (self) 0 %	
Constructor of com.appdynamics.inventory.OrderServicePortTypeProxy:12	0 ms (self) 0 %	
com.appdynamics.inventory.OrderServicePortTypeProxy:_initOrderServicePortTypeProxy:22	0 ms (self) 0 %	
Constructor of com.appdynamics.inventory.OrderServiceLocator:12	140 ms (self) 1.3 %	
com.appdynamics.inventory.OrderServicePortTypeProxy:createOrder:54	0 ms (self) 0 %	
com.appdynamics.inventory.OrderServiceSOAP11BindingStub:createOrder:158	199 ms (self) 1.8 %	Web Service
Spring Bean - itemPersistence:getItemById:24	5 ms (self) 0 %	
Spring Bean - soapUtil:raisePO:26	0 ms (self) 0 %	
com.appdynamics.inventory.OrderServicePortTypeProxy:createOrder:54	0 ms (self) 0 %	
com.appdynamics.inventory.OrderServiceSOAP11BindingStub:createOrder:158	10026 ms (self) 91.4 %	Web Service
Spring Bean - transactionManager:doCommit:578	8 ms (self) 0.1 %	
Proxy For Spring Bean - cartServiceTarget:invoke	0 ms (self) 0 %	
Spring Bean - cartServiceTarget:checkOut:38	0 ms (self) 0 %	
Spring Bean - itemPersistence:getItemById:24	288 ms (self) 2.6 %	JDBC
Spring Bean - soapUtil:raisePO:26	0 ms (self) 0 %	
com.appdynamics.inventory.OrderServicePortTypeProxy:createOrder:54	0 ms (self) 0 %	
com.appdynamics.inventory.OrderServiceSOAP11BindingStub:createOrder:158	197 ms (self) 1.8 %	Web Service (3)
com.appdynamics.inventory.OrderServiceSOAP11BindingStub:createCall:91	11 ms (self) 0.1 %	
Spring Bean - messageProducer:sendMessageWithOrderId:30	0 ms (self) 0 %	
Spring Bean - proucerJmsTemplate:send:469	0 ms (self) 0 %	

Export to PDF

Application Performance Management

- APM dimensions according to Gartner (2014)

1. End-user experience monitoring <https://www.gartner.com/doc/288942>
2. Application topology discovery and visualization
3. User-defined transaction profiling
4. Application component deep-dive
5. IT operations analytics based on, e.g.,
 - Complex operations event processing
 - Statistical pattern discovery and recognition
 - Unstructured text indexing, search and inference
 - Multidimensional database search and analysis



- APM tools (selection)

- Commercial:

APPDYNAMICS

 **dynatrace**

 **New Relic®**

- Free/open-source:

inspectIT
...because performance matters!

kieker

Application Performance Management

■ APM dimensions:

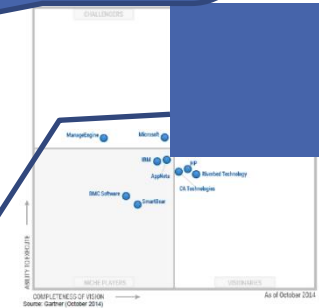
1. End-user experience
2. Application performance
3. User-defined metrics
4. Application health
5. IT operations analytics based on, e.g.,

Example ITOA activity:

Performance problem detection and diagnosis

- Reactive vs. proactive
- Manual vs. automatic (incl. recommendations)
- State-based vs. transaction-based

- Complex operations event processing
- Statistical pattern discovery and recognition
- Unstructured text indexing, search and inference
- Multidimensional database search and analysis



■ APM tools (selection)

■ Commercial:

APPDYNAMICS

 **dynatrace**

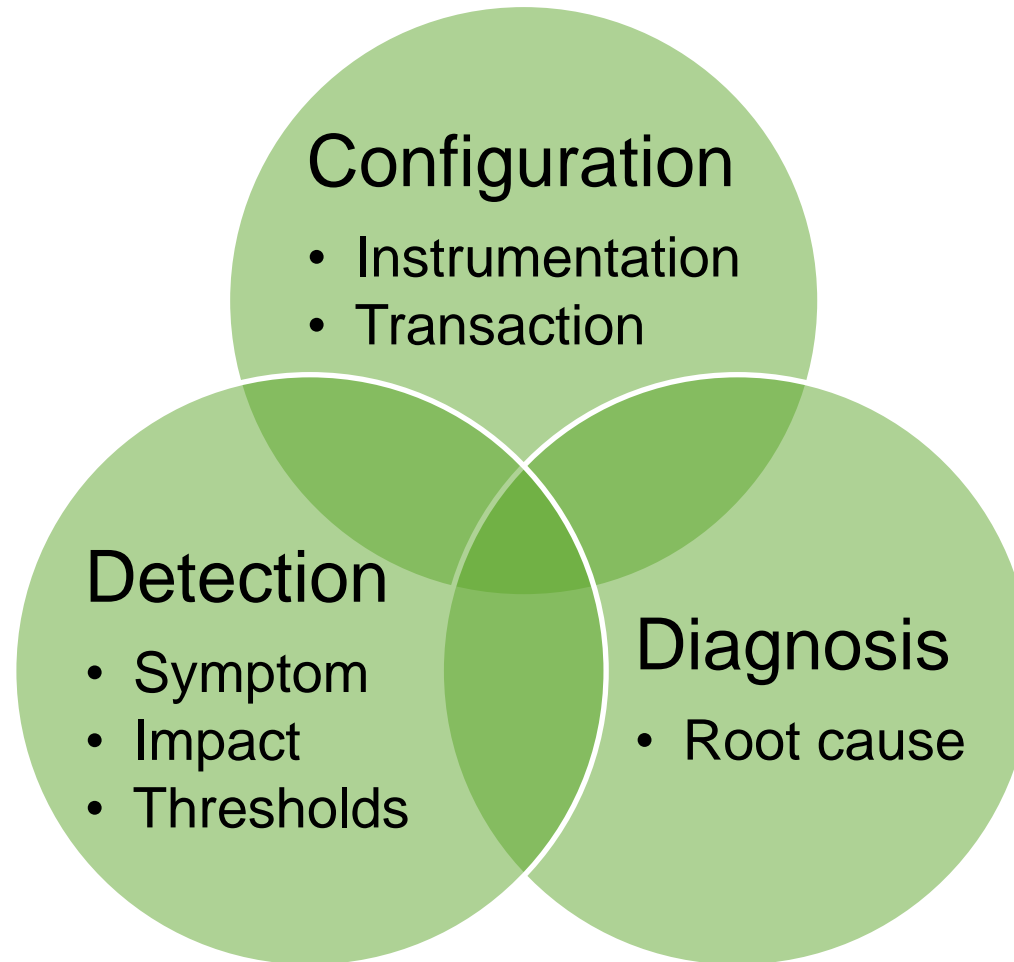
 **New Relic®**

■ Free/open-source:

 **inspectIT**
...because performance matters!

 **kieker**

APM Process: Common Activities (High-Level)



Agenda

1

- Introduction – Performance Problems

2

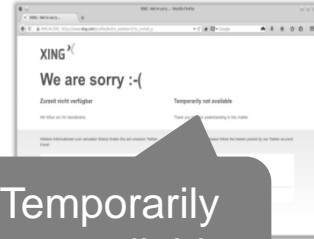
- Kieker – Open Source APM Framework

3

- Performance Problem Detection and Diagnosis with Kieker

4

- diagnoseIT Project – Vision and Approach

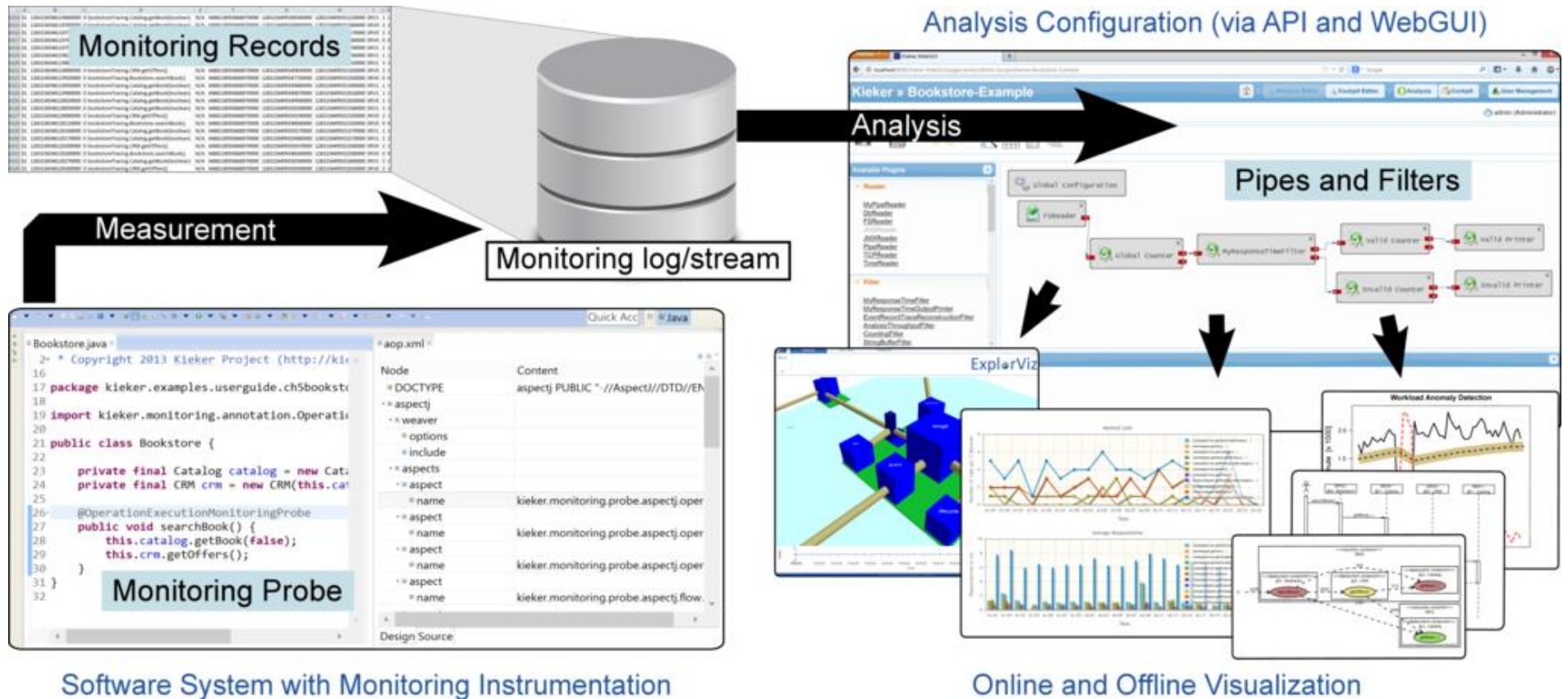


Temporarily not available





Open Source APM Framework

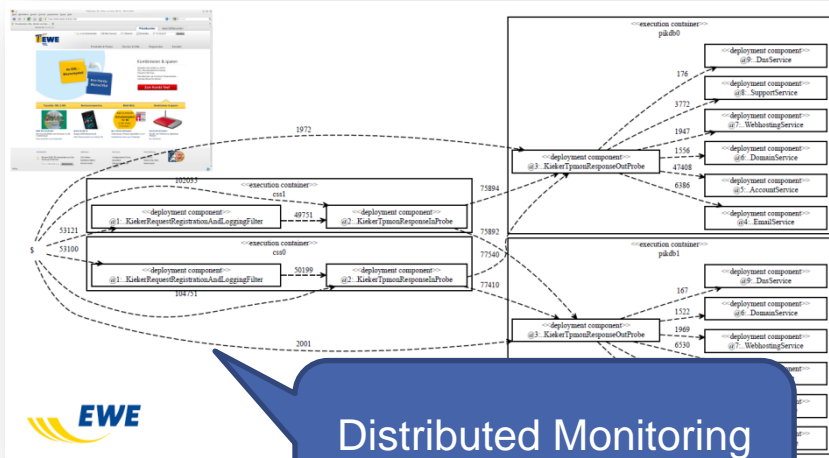


Download : <http://kieker-monitoring.net/>

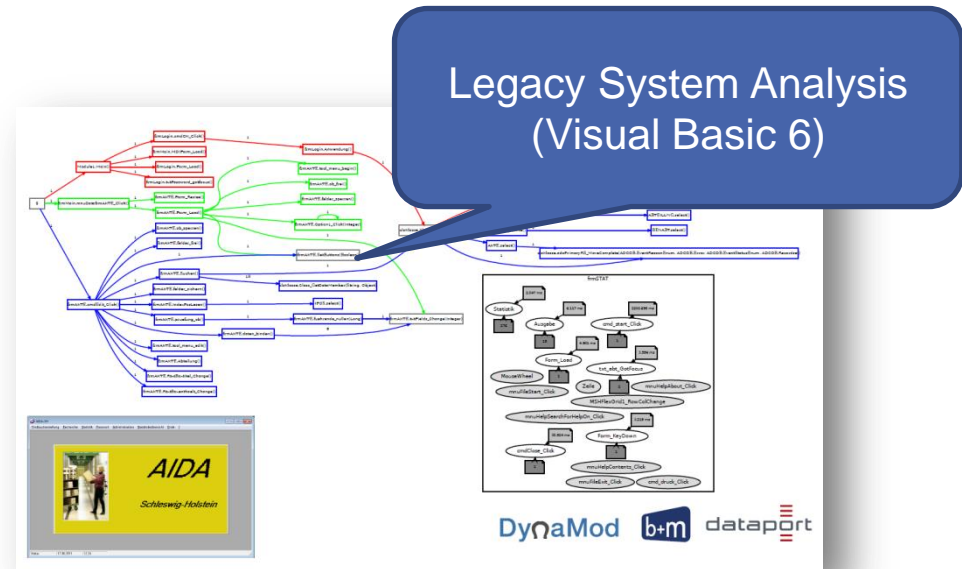
Kieker is distributed as part of SPEC® RG's repository of peer-reviewed tools for quantitative system evaluation and analysis



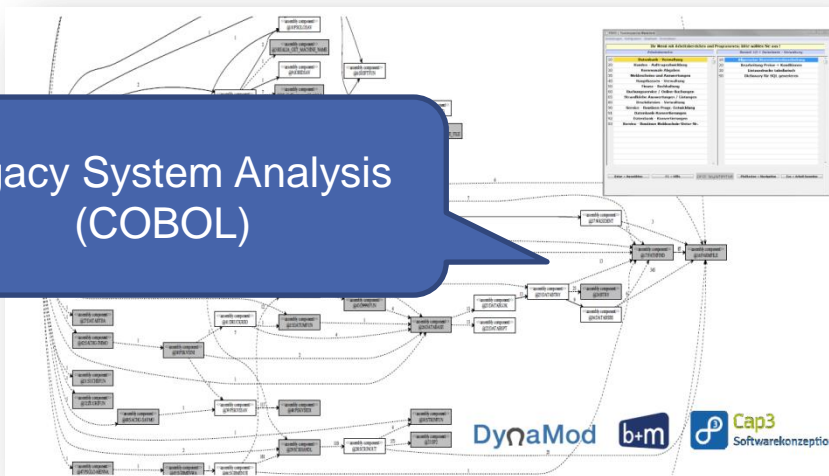
<http://research.spec.org/projects/tools.html>



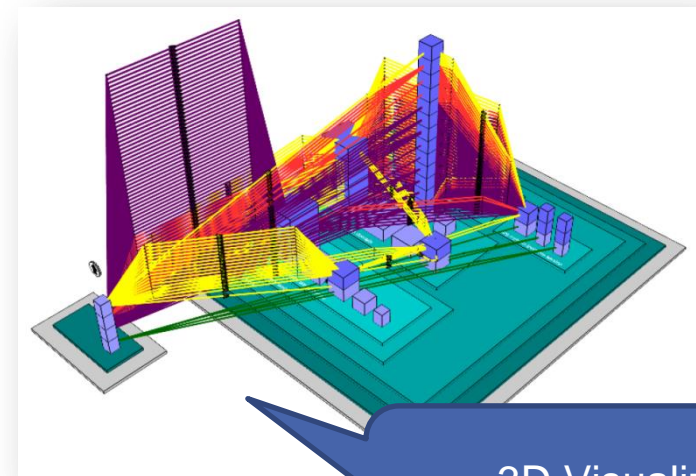
Distributed Monitoring
(Java EE/SOAP)



Legacy System Analysis
(Visual Basic 6)

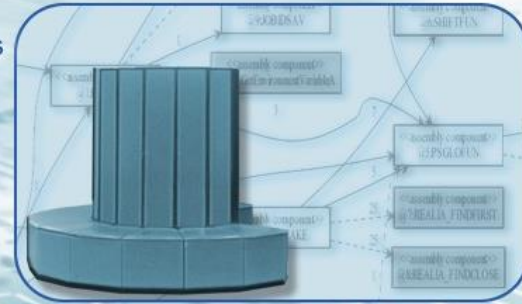


Legacy System Analysis
(COBOL)



3D Visualization
of Concurrency

analyzing legacy systems



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

KIEKER FRAMEWORK USE CASES RESEARCH AND CONSULTING

About Kieker

Projects, Publications, Talks, Tutorials

analyzing a software system's runtime behavior — enabling Application Performance Monitoring and Architecture Discovery.

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More than 60 Participants Attended SOSP '14 in Stuttgart

Posted on 14.12.2014 by André van Hoorn

User Guide

Issue Tracking



Agenda

1

- Introduction – Performance Problems

2

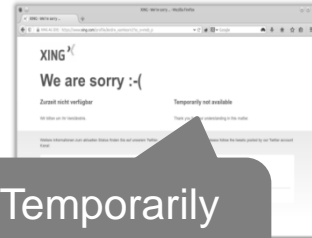
- Kieker – Open Source APM Framework

3

- Performance Problem Detection and Diagnosis (PPD&D) with Kieker

4

- diagnoseIT Project – Vision and Approach

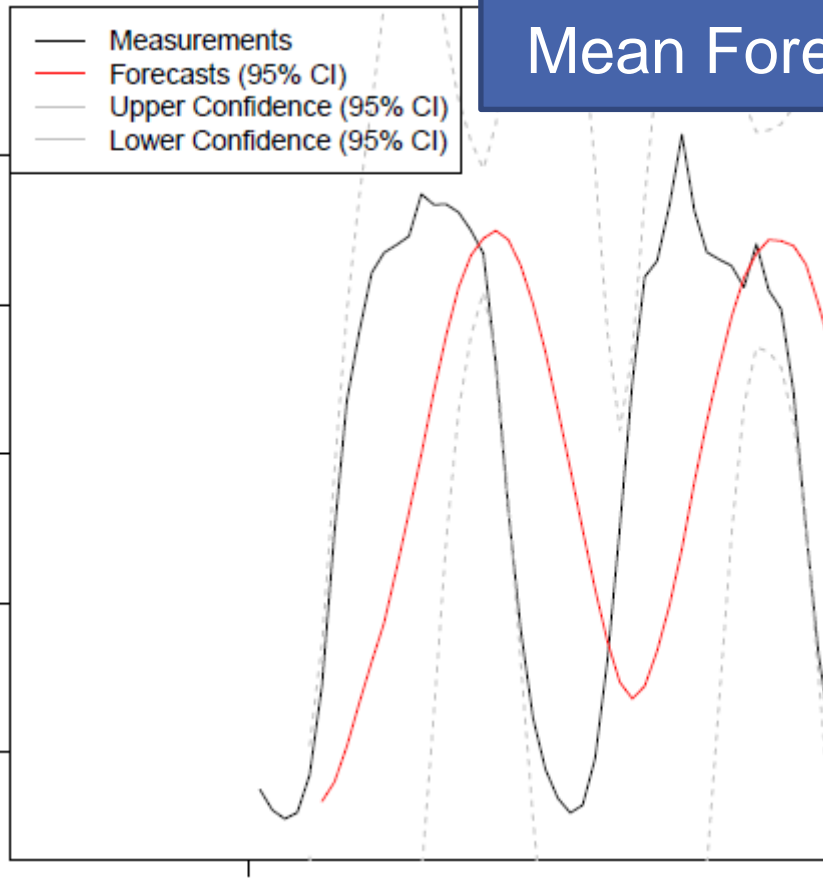


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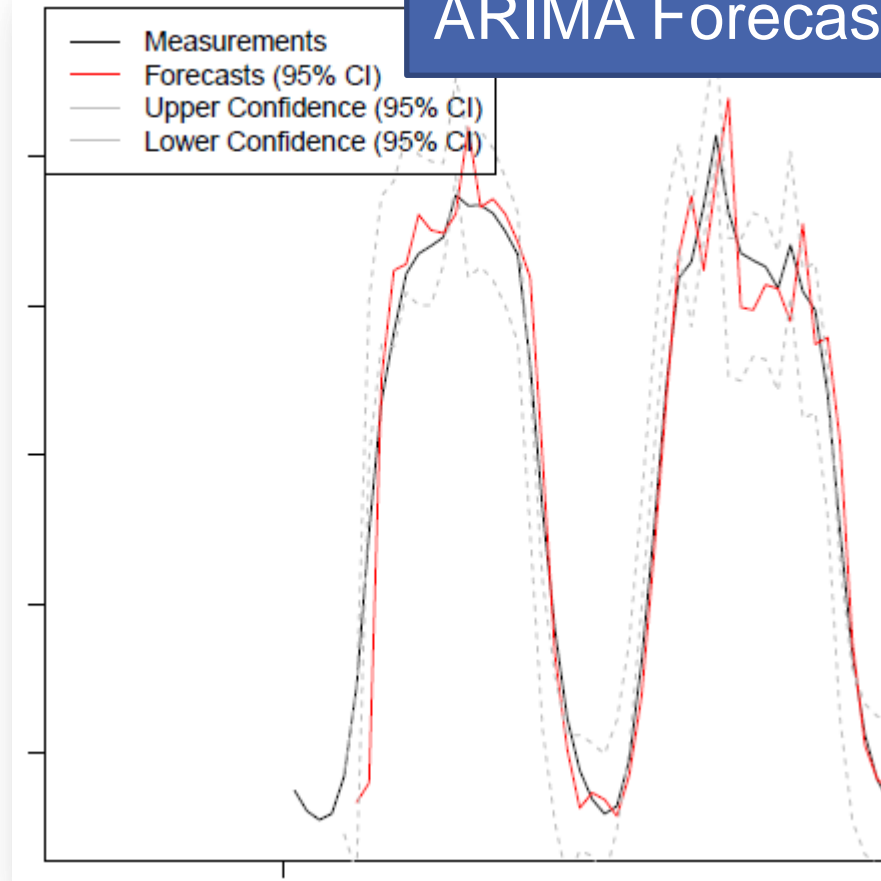


⊙PAD – Time Series Analysis Introduction

Mean Forecaster

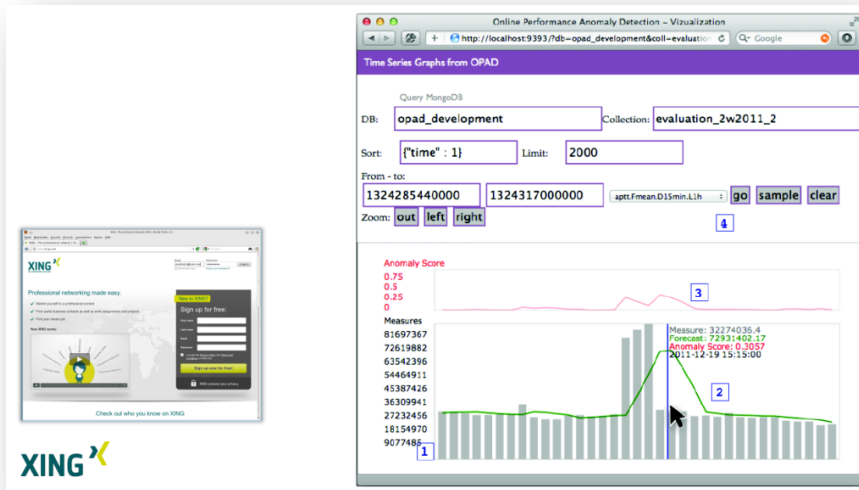


ARIMA Forecaster

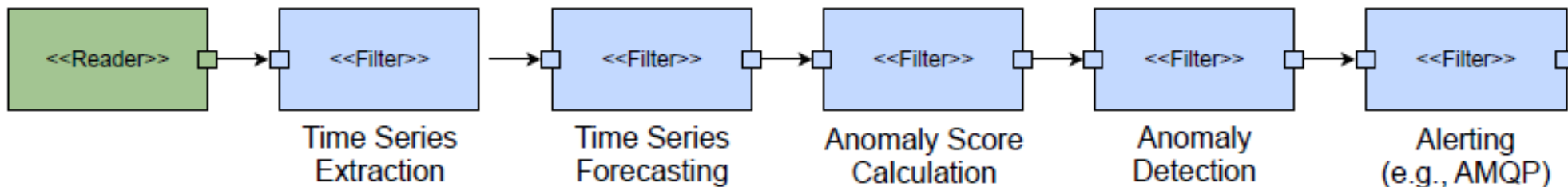


Forecasts for Wikipedia data (Kieker ⊙PAD example)

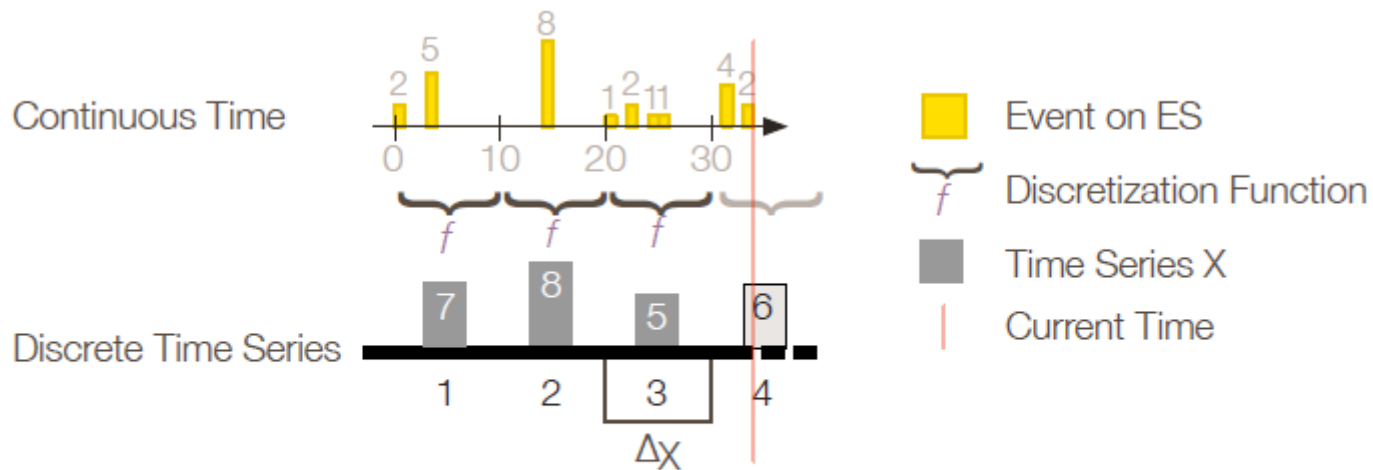
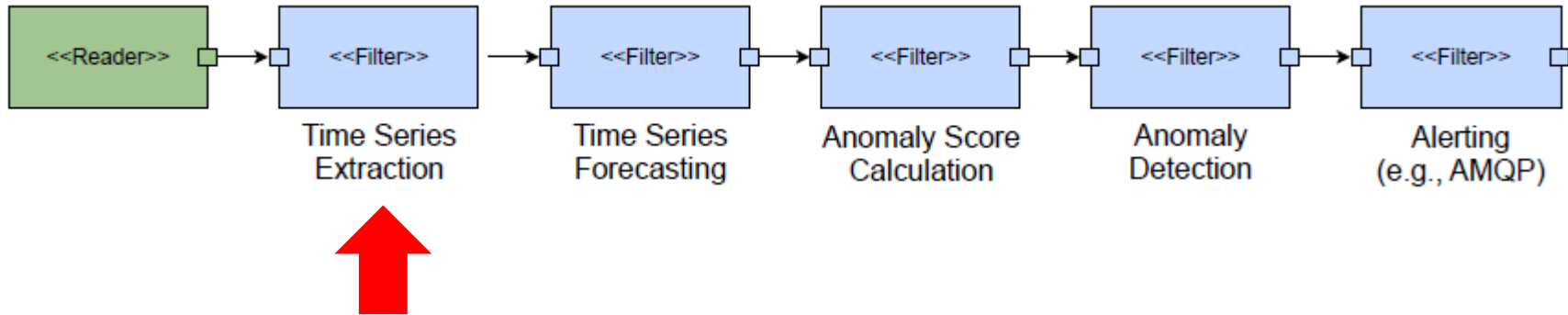
OPAD: Online Performance Anomaly Detection



(Bielefeld, 2012), (Frotscher, 2013)



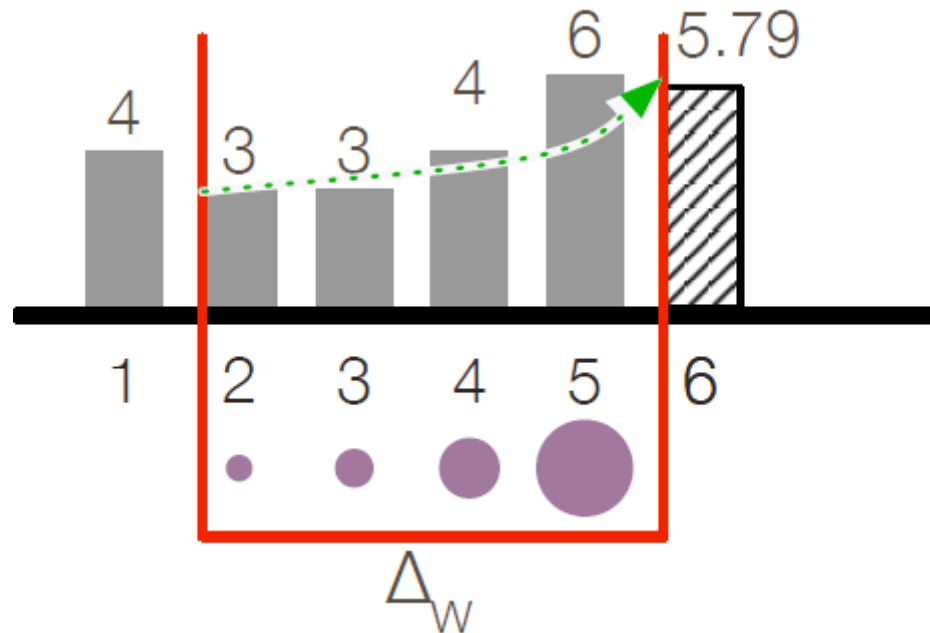
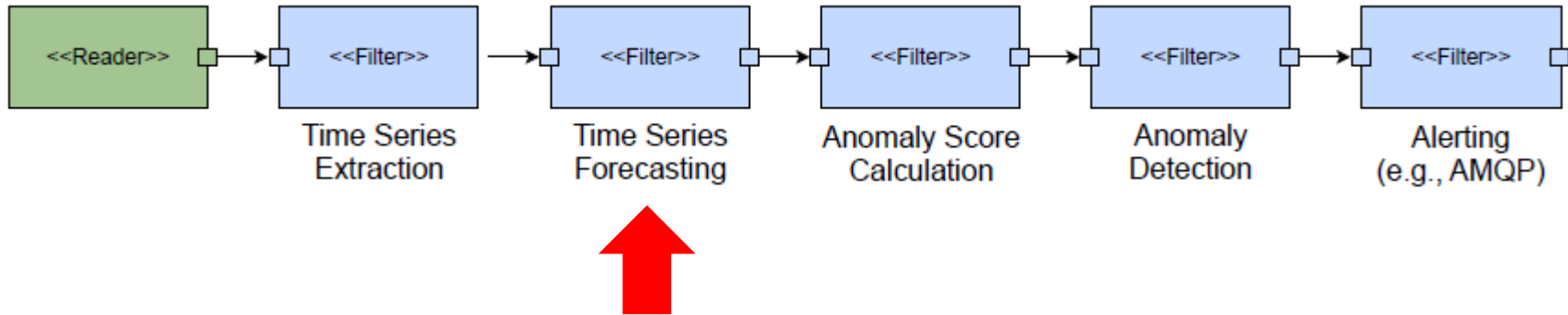
ⓂPAD (cont'd) – Time Series Extraction



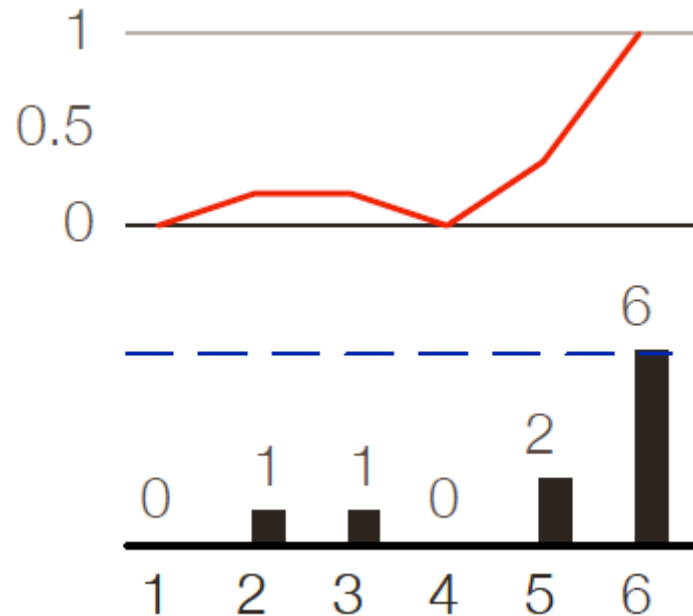
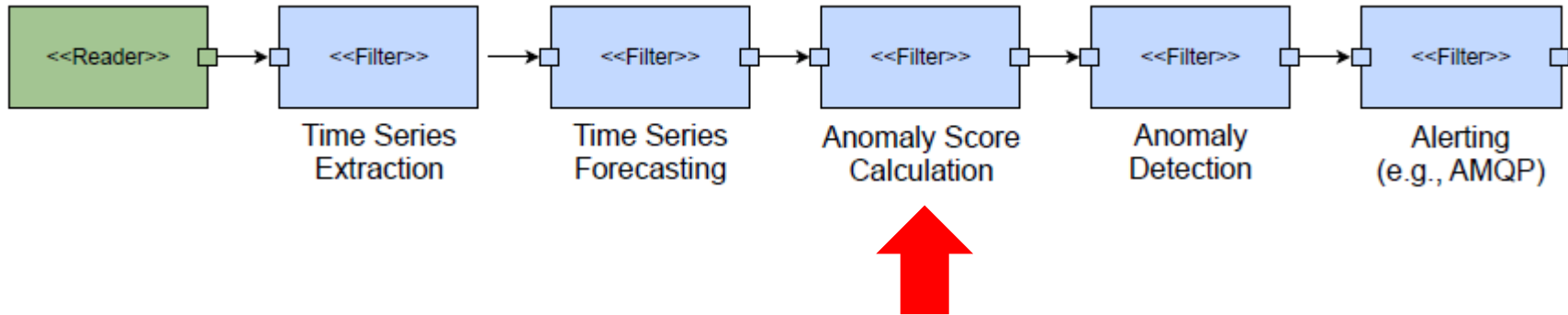
```

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

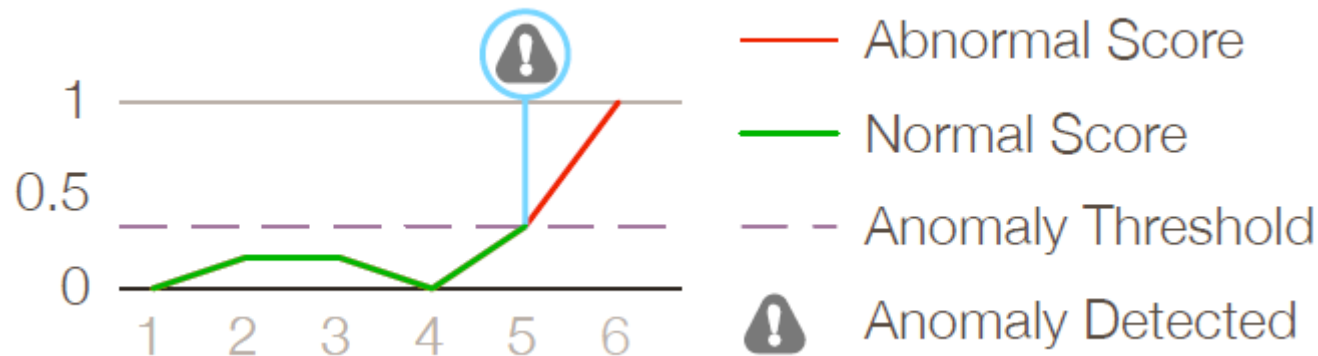
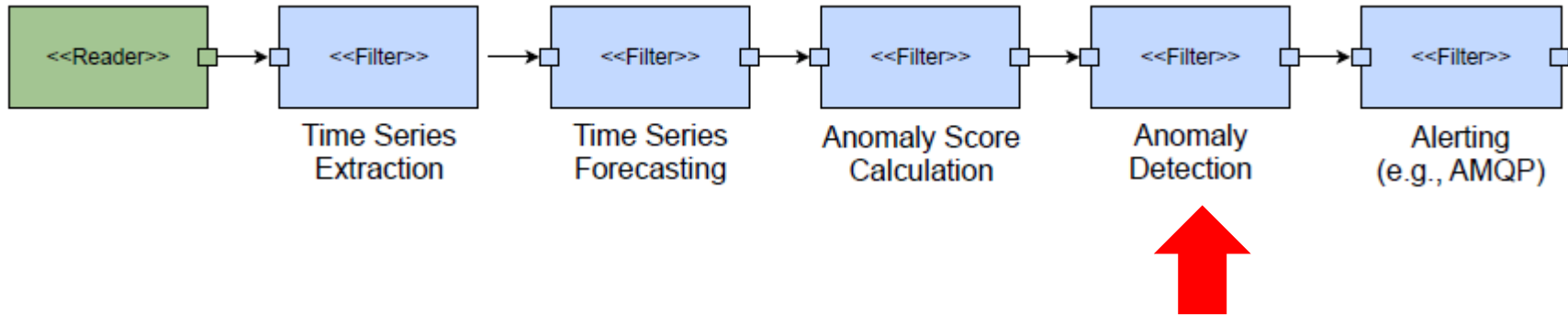
ⓂPAD (cont'd) – Time Series Forecasting



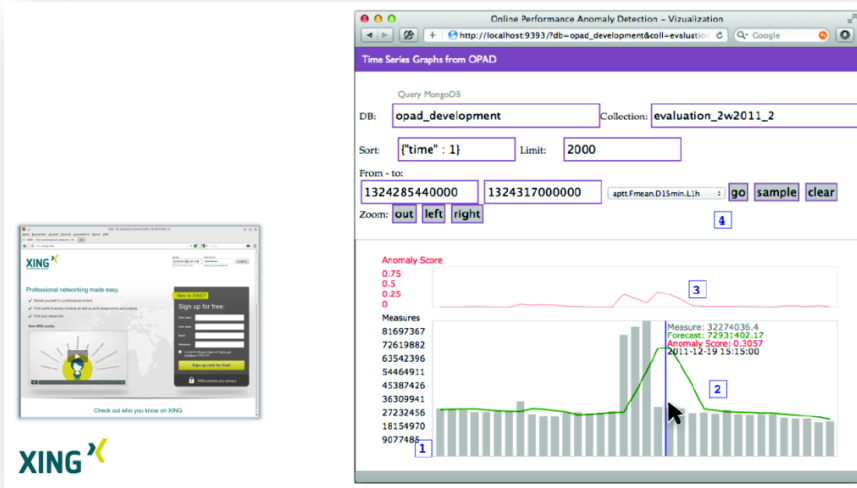
ⓂPAD (cont'd) – Anomaly Score Calculation



ⓂPAD (cont'd) – Anomaly Detection

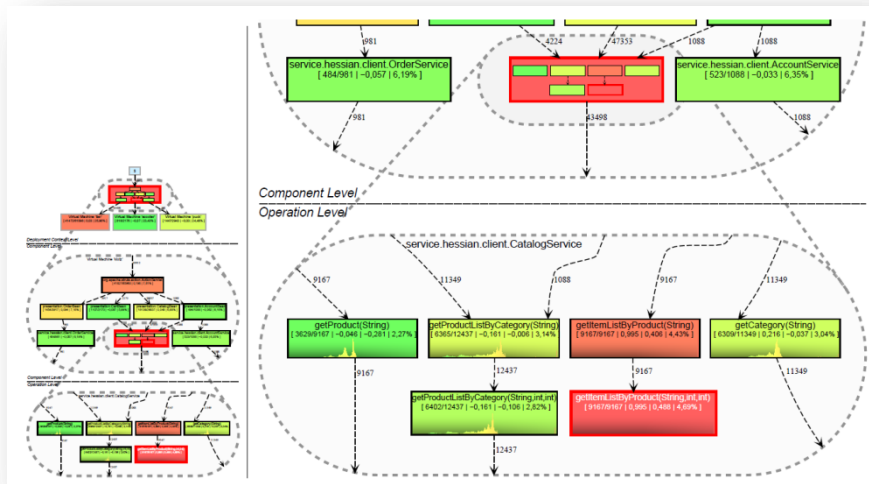


Kieker-based PPD&D Approaches



(Bielefeld, 2012), (Frotscher, 2013)

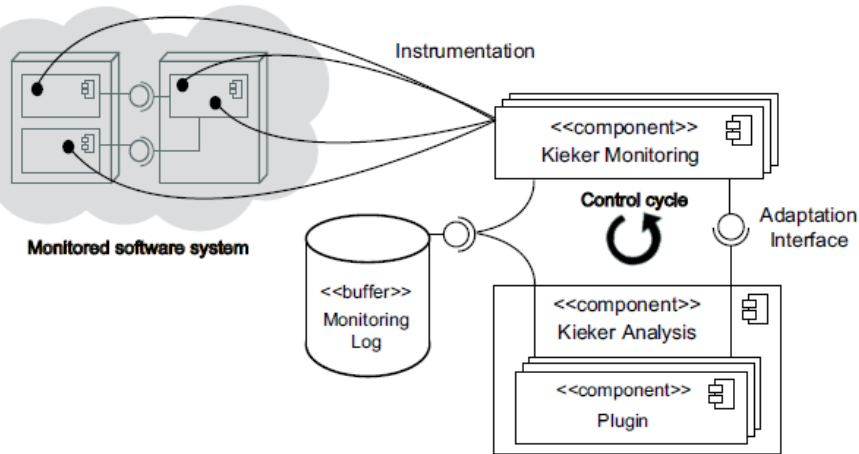
- Based on time series analysis (various algorithms)
- ⓄPAD part of Kieker release
- Limited to problem detection
- No architecture consideration
- Case study at XING



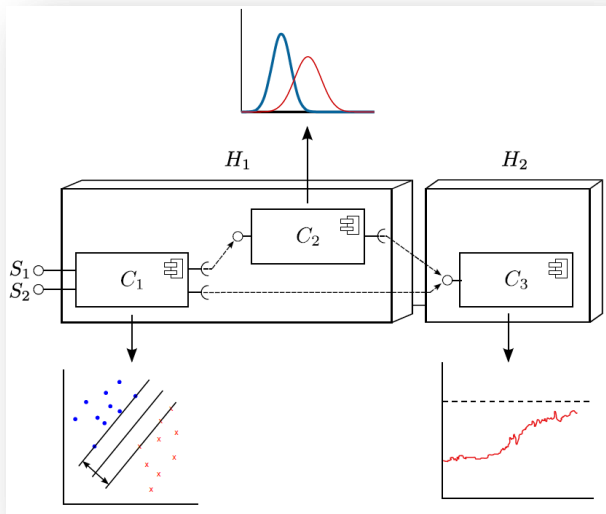
(Marwede et al., 2009)

- Incorporates architectural knowledge (e.g., deployment, calling dependencies)
- Focusing on offline analysis
- Cf. Rohr (2015)

Kieker-based PPD&D Approaches



(Ehlers et al., 2011, 2012)



(Pitakrat et al., 2013, 2014)

- Adaptive monitoring
 - OCL-based decisions
 - Cf. Okanovic et al. (2013)
 - No dynamic (bytecode) instrumentation
-
- Proactive, hierarchical
 - Inclusion of different statistical techniques (e.g., time series analysis, machine learning)
 - Combination of multiple data sources (e.g., HDD SMART, log files) and architectural knowledge

Agenda

1

- Introduction – Performance Problems

2

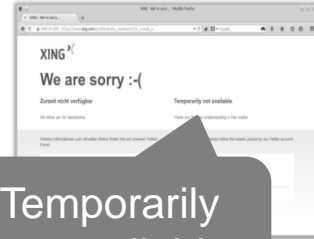
- Kieker – Open Source APM Framework

3

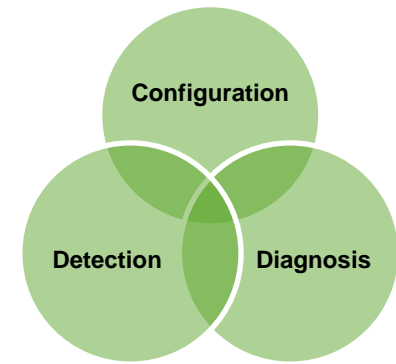
- Performance Problem Detection and Diagnosis with Kieker

4

- diagnoseIT Project – Vision and Approach



Reasons for Low APM Adoption Rate



Manual effort



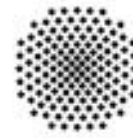
Error prone



Lack of expertise



diagnoseit Consortium



University of Stuttgart
Germany

COMMERZBANK 



GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung



Universität
Stuttgart



diagnoseit Goals

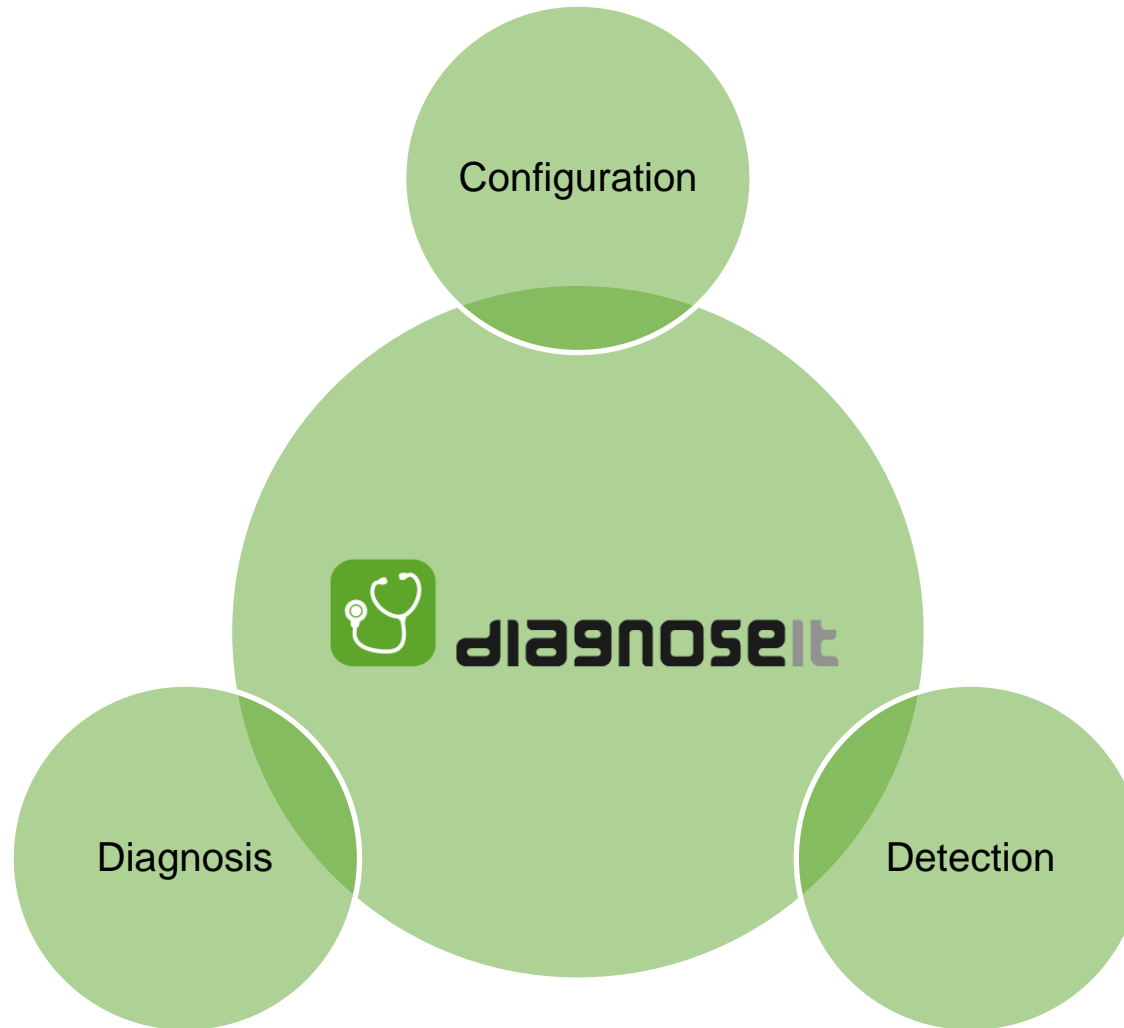
Reduce
maintenance
effort by 50%

Detect 100% of
all problems
automatically

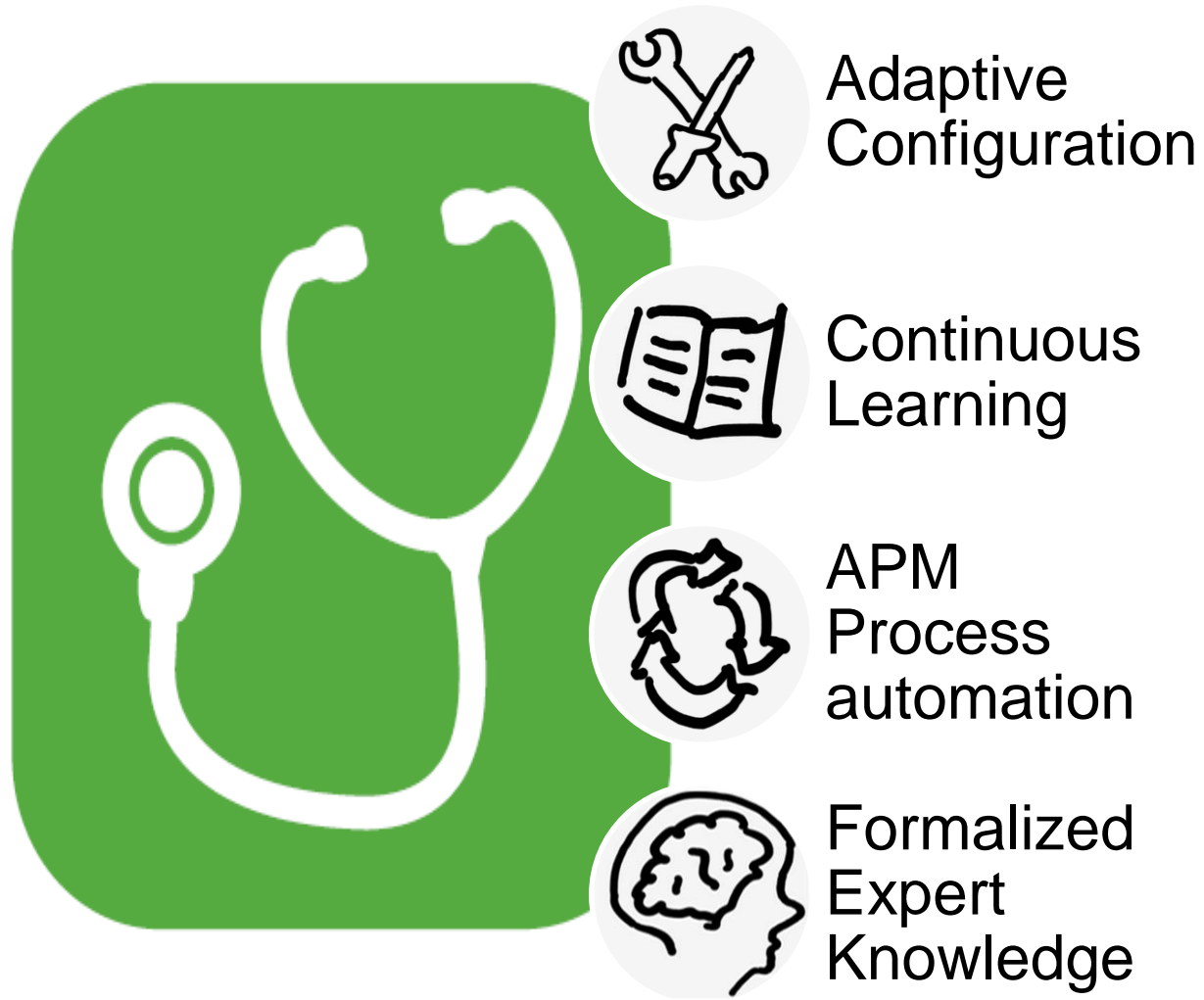
Identify 80% of
the root causes
automatically

No APM
vendor lock-in

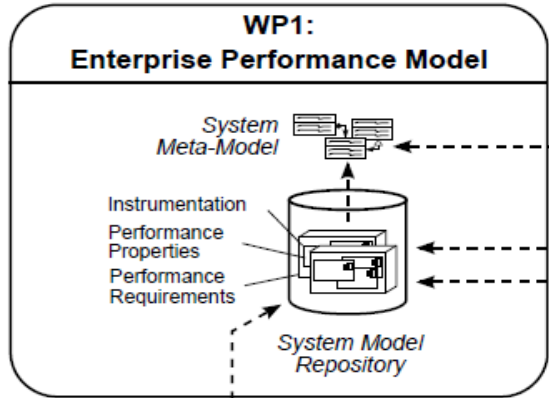
diagnoseIT Automates Common APM Activities



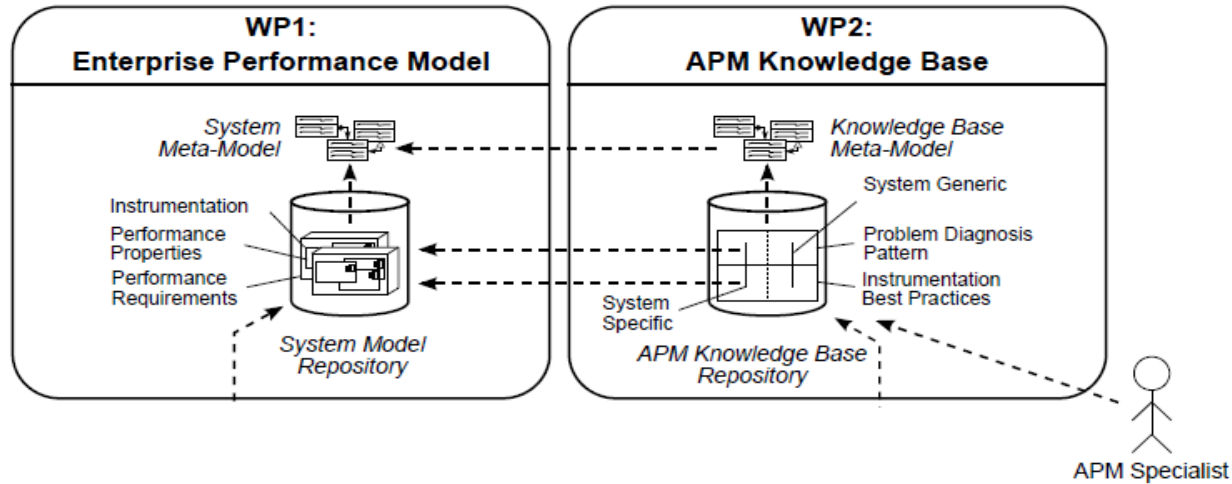
diagnoseIT Key Components



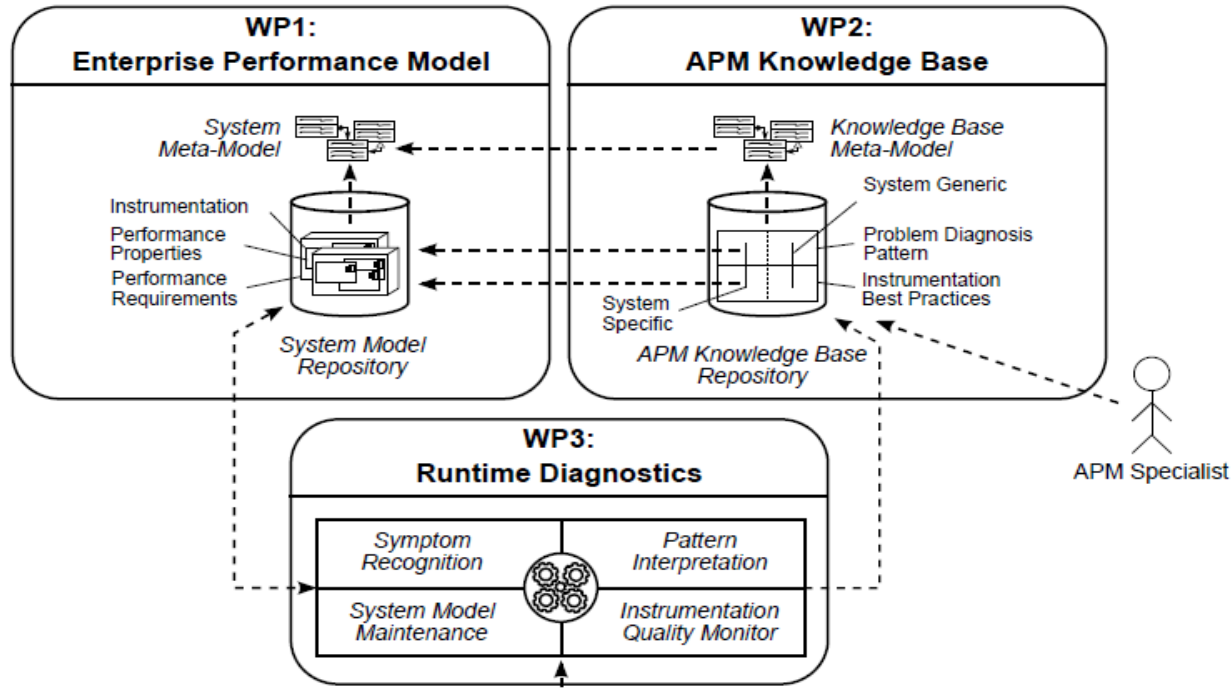
System Architecture



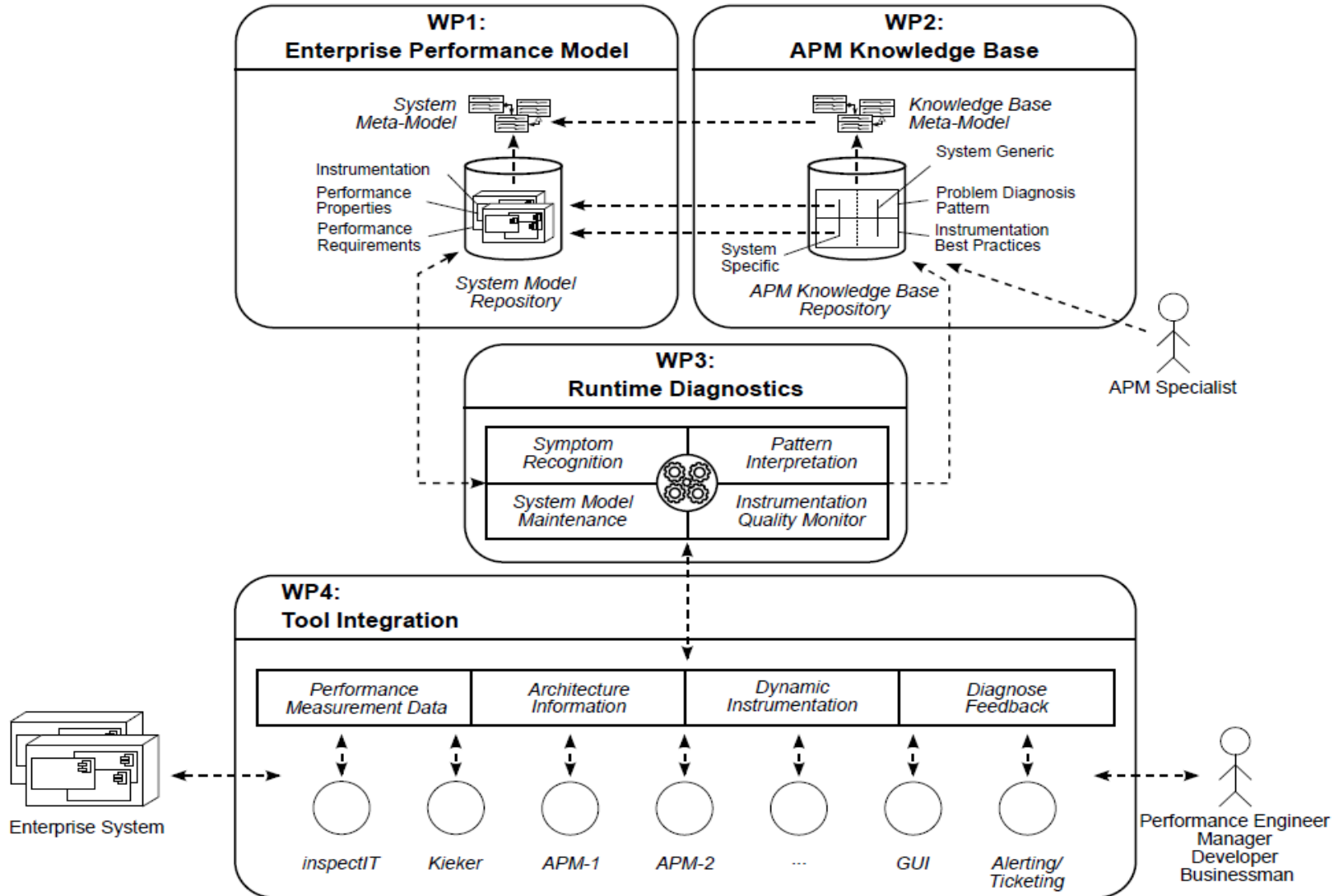
System Architecture



System Architecture

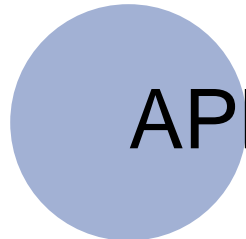
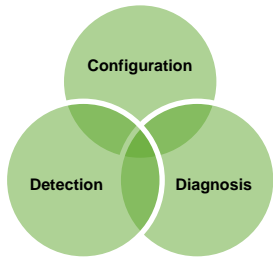
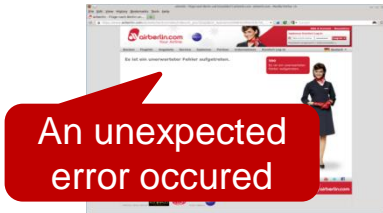


System Architecture

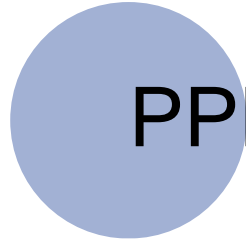


CONCLUSIONS AND PROJECT IDEAS

Summary



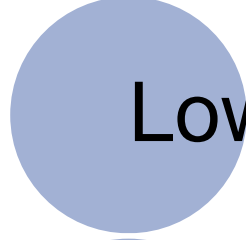
APM is increasingly important



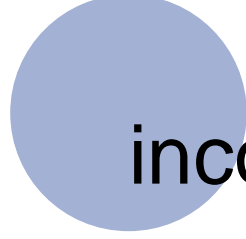
PPD&D is one APM activity




Mature APM tools exist



Low adoption of APM



 **diagnoseIT** approach:
incorporation of expert knowledge



Manual effort



Error prone




Lack of expertise



The End – My APM Wish List

- **Transparency, Openness, Technology Transfer**
 - e.g., sharing of best practices (libraries, white papers) for framework-specific instrumentation, problem detection and diagnosis
- **Interoperability**
 - e.g., common formats for instrumentation description, configuration, measurement data (traces)
- **Reproducibility, Comparability**
 - e.g., sample/benchmark applications and datasets, case studies

➤  **SPEC RG DevOps Performance Working Group**
<http://research.spec.org/devopswg/>

➤  **Kieker** <http://kieker-monitoring.net>

➤  **DiagnoseIt** <http://diagnoseit.github.io/>


QUDOS Workshop @ ESEC/FSE 2015

- 1st Int'l Workshop on **Quality-Aware DevOps**
<http://qudos2015.fortiss.org/>
- Co-located with ESEC/FSE in Bergamo, Italy (09/15)
- Co-organized by
 - fortiss GmbH
 - Imperial College London
 - Politecnico di Milano
 - University of Stuttgart



Co-located with the 10th Joint Meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering (ESEC/FSE 2015)

Project Ideas

1. Investigate extension/adoption of PANDA performance anti-pattern formalization and detection approach to  **diagnoseit**
 - design time → runtime
 - system-level analysis + transaction-level analysis
 - controlled environment → production environment
 - model-based → measurement-based
2. Work on DESPACE Microsoft Azure Case Study
 - Instrumentation and model extraction with Kieker
 - Model analysis and refactoring with PANDA
 - Possible systems: Netflix OSS (maybe start w/ JPetStore)

References

- **(Döhring, 2012)** P. Döhring. Visualisierung von Synchronisationspunkten in Kombination mit der Statik und Dynamik eines Softwaresystems. Master's thesis, Kiel University, Oct. 2012.
- **(Ehlers, 2012)** J. Ehlers. Self-Adaptive Performance Monitoring for Component-Based Software Systems. PhD thesis, Department of Computer Science, Kiel University, Germany, 2012.
- **(Ehlers et al., 2011)** J. Ehlers, A. van Hoorn, J. Waller, and W. Hasselbring. Self-adaptive software system monitoring for performance anomaly localization. In Proceedings of the 8th ACM International Conference on Autonomic computing (ICAC'11). ACM, 2011.
- **(Fittkau et al., 2014)** F. Fittkau, A. van Hoorn, and W. Hasselbring. Towards a dependability control center for large software landscapes. In Proceedings of the 10th European Dependable Computing Conference (EDCC '14), IEEE, 2014.
- **(Frotscher, 2013)** T. Frotscher. Architecture-based multivariate anomaly detection for software systems, Master's Thesis, Kiel University, 2013.
- **(Gartner, 2014)** J. Kowall and W. Cappelli. Gartner's Magic Quadrant for Application Performance Monitoring 2014
- **(Marwede et al., 2009)** N. S. Marwede, M. Rohr, A. van Hoorn, and W. Hasselbring. Automatic failure diagnosis support in distributed large-scale software systems based on timing behavior anomaly correlation. In Proc. CSMR '09. IEEE, 2009.

References (cont'd)

- **(Okanovic et al., 2013)** D. Okanovic, A. van Hoorn, Z. Konjovic, and M. Vidakovic. SLA-driven adaptive monitoring of distributed applications for performance problem localization. *Computer Science and Information Systems (ComSIS)*, 10(10), 2013.
- **(Pitakrat, 2013)** T. Pitakrat. Hora: Online failure prediction framework for component-based software systems based on kieker and palladio. In *Proc. SOSP 2013*. CEUR-WS.org, Nov. 2013.
- **(Pitakrat et al., 2014)** T. Pitakrat, A. van Hoorn, and L. Grunske. Increasing dependability of component-based software systems by online failure prediction. In *Proc. EDCC'14*. IEEE, 2014.
- **(Richter, 2012)** B. Richter. Dynamische Analyse von COBOL-Systemarchitekturen zum modellbasierten Testen ("Dynamic analysis of cobol system architectures for model-based testing", in German). Diploma Thesis, Kiel University. 2012.
- **(Rohr, 2015)** M. Rohr. Workload-sensitive Timing Behavior Analysis for Fault Localization in Software Systems. PhD thesis, Department of Computer Science, Kiel University, Germany, 2015.
- **(Rohr et al., 2010)** M. Rohr, A. van Hoorn, W. Hasselbring, M. Lübcke, and S. Alekseev. Workload-intensity-sensitive timing behavior analysis for distributed multi-user software systems. In *Proc. WOSP/SIPEW '10*. ACM, 2010.

References (cont'd)

- **(van Hoorn, 2014)** A. van Hoorn. Model-Driven Online Capacity Management for Component-Based Software Systems. PhD thesis, Department of Computer Science, Kiel University, Germany, 2014
- **(van Hoorn et al., 2009)** 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. TR-0921, Department of Computer Science, University of Kiel, Germany, 2009.
- **(van Hoorn et al., 2012)** A. van Hoorn, J. Waller, and W. Hasselbring. Kieker: A framework for application performance monitoring and dynamic software analysis. In Proc. ACM/SPEC ICPE '12. ACM, 2012.
- **(Wulf, 2012)** C. Wulf. Runtime visualization of static and dynamic architectural views of a software system to identify performance problems. B.Sc. Thesis, University of Kiel, Germany, 2010.

BONUS/BACK-UP

Netflix OSS Recipes Application (Motivating Example)

Netflix OSS RSS Reader

Enter the feed URL

NBCNews.com: Top NBCNews headlines

Returning troops face "white knuckled" first weeks

Country singer Mindy McCready dead in apparent suicide

Another meteor? "Fireballs" light up Florida sky

Sources: Dornier tried to charm his way to Mexico

Gun suspect dead after hospital lockdown

TechCrunch » Startups

DealAngel Launching API To Let Other Sites

Country singer Mindy McCready was found dead Sunday "from what appears to be a single self-inflicted gunshot wound," police said.

Fly Your Flag? Let's See Some European Country Pavilions At Disrupt In New York

Iterations: How Founders Can Fight Through The Great Fragmentation Of Talent

U.S. News Headlines - Yahoo! News

Thousands at climate rally in Washington call on Obama to reject Keystone pipeline

White House drafts backup immigration plan, Republicans balk

JFK items auctioned 50 years after his assassination

In a first, Obama plays golf with Tiger Woods

Storm brings snow, gusty winds to New England

CNN.com - Top Stories

Model: Getting what I don't deserve

U.S. "slave narratives" should shock us

Afghanistan's future: Five questions

Meteor and asteroid: 1 in 100M odds

Catholic church is more than the pope

Football News Headlines - Yahoo! News

Goodell paid more than \$29 million by NFL in 2011

Gay rights groups say U.S. sport reaching "tipping point"

Soccer-Gay rights groups say U.S. sport reaching "tipping point"

Packers release record-setting defensive back Woodson

NFL-Packers release record-setting defensive back Woodson

Post Politics: Breaking Politics News, Political Analysis & More - The Washington Post

Congressional staffers often travel on tabs of foreign governments

Senate Republicans willing to clear way for Hagel confirmation, but keep up criticism of him

The question of Clarence Thomas

President Obama enjoys guys' weekend, golfs with Tiger Woods

?Saturday Night Live? on Marco Rubio?s sip slip

Netflix Inc. 2013

Source: <http://techblog.netflix.com/2013/03/introducing-first-netflix-oss-recipe-rss.html>

Sample Applications and Recipes

RECIPES-RSS

Recipes-rss

RSS Reader Recipes that uses several of the Netflix OSS components [More Info](#)

Stars: 191

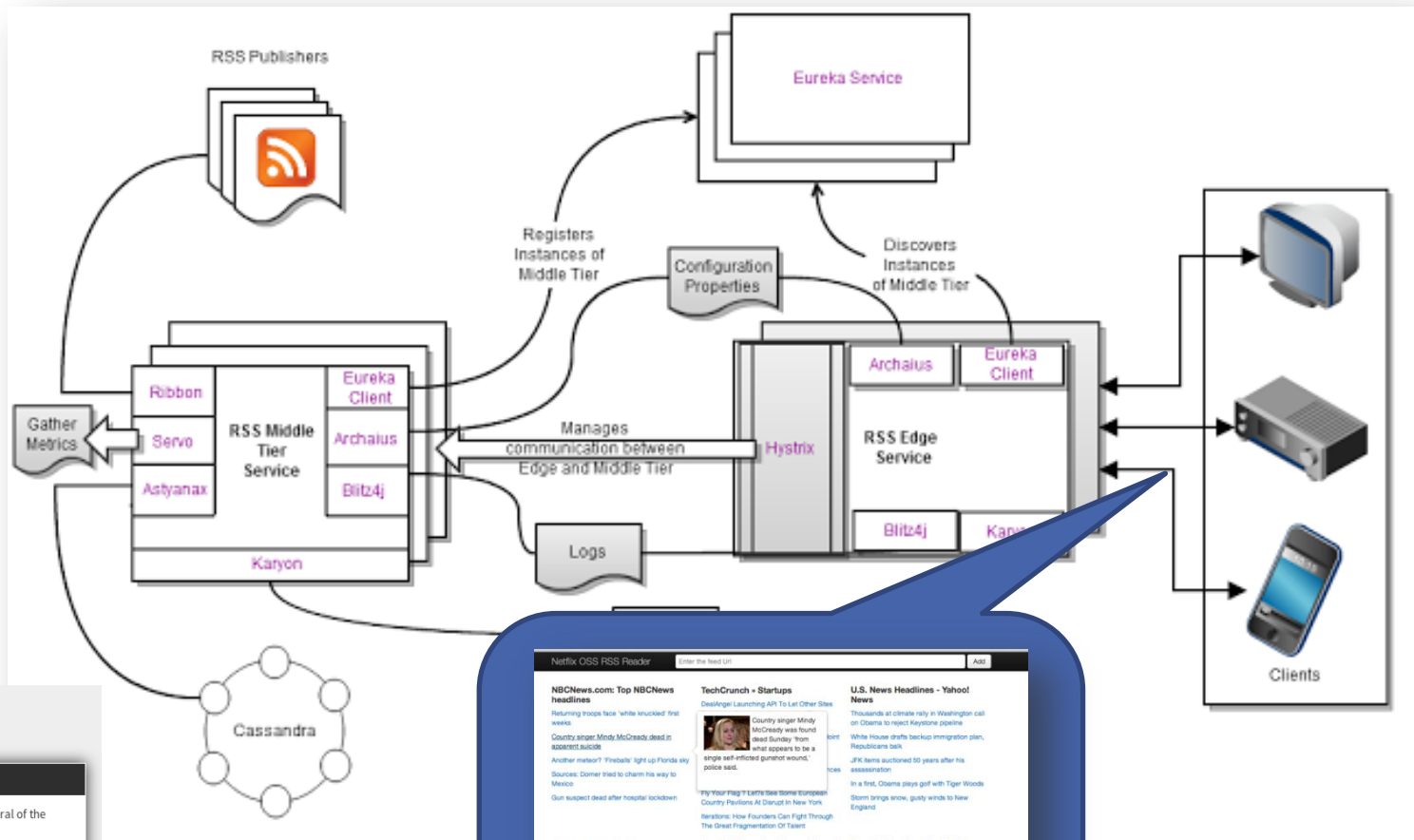
Forks: 55

Language: Java

Open Issues: 4

Updated: 03/11/15 @07:15:43

Netflix OSS Recipes Application (cont'd)



Sample Applications and Recipes

RECIPES-RSS

Recipes-rss

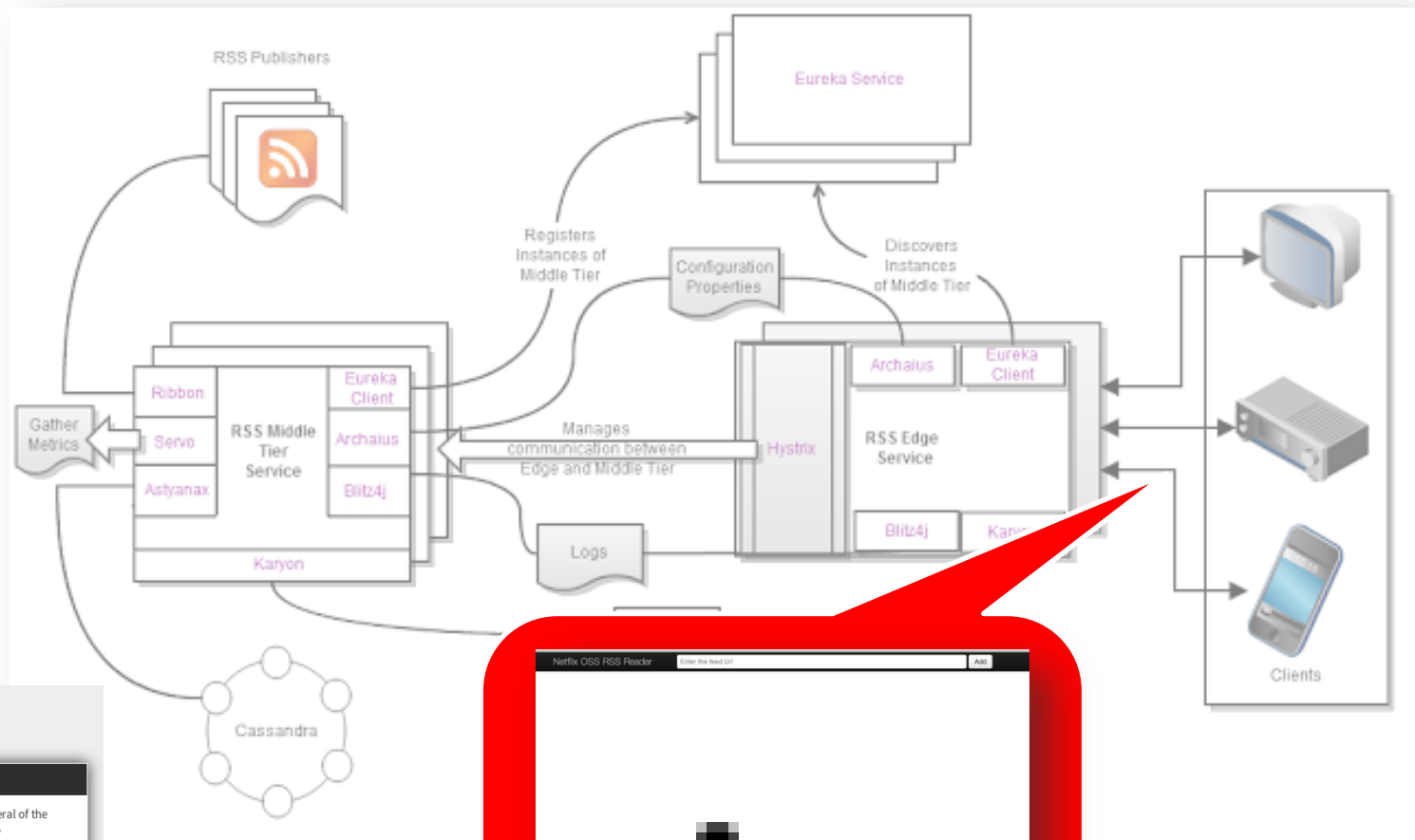
RSS Reader Recipes that uses several of the Netflix OSS components [More Info](#)

Stars: 191
 Forks: 55
 Language: Java
 Open Issues: 4
 Updated: 03/11/15 @07:15:43



Source: <https://github.com/Netflix/recipes-rss/wiki/Architecture>

Problem Symptom 1: Increased Response Times



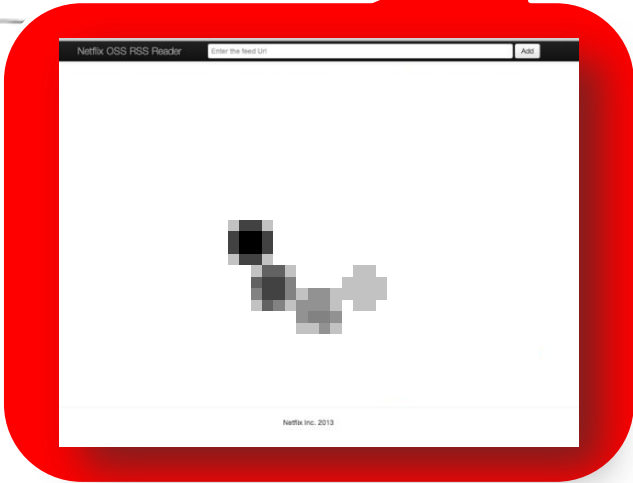
Sample Applications and Recipes

RECIPES-RSS

Recipes-rss

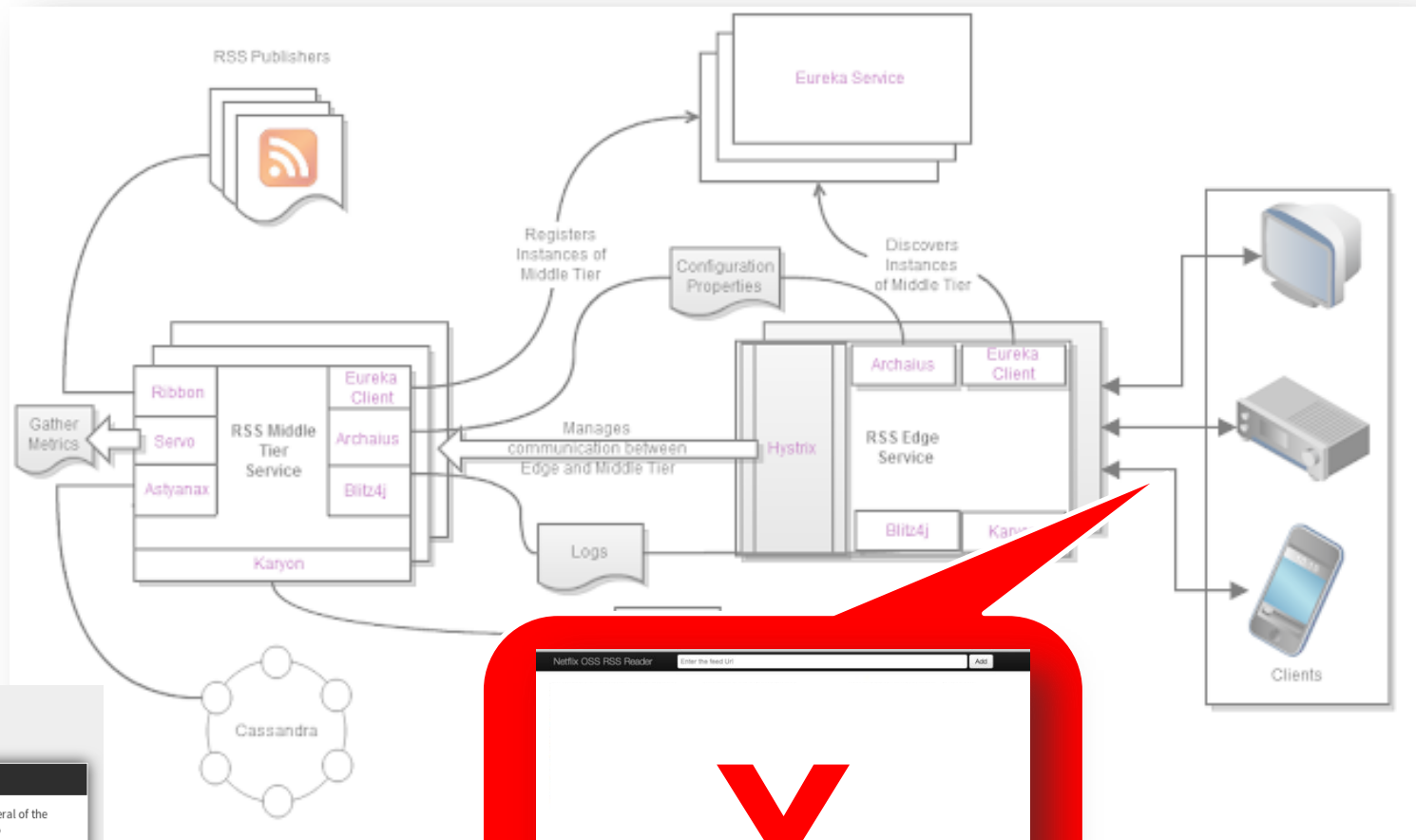
RSS Reader Recipes that uses several of the Netflix OSS components [More Info](#)

- Stars: 191
- Forks: 55
- Language: Java
- Open Issues: 4
- Updated: 03/11/15 @07:15:43



Source: <https://github.com/Netflix/recipes-rss/wiki/Architecture>

Problem Symptom 2: Service Unavailability



Source: <https://github.com/Netflix/recipes-rss/wiki/Architecture>

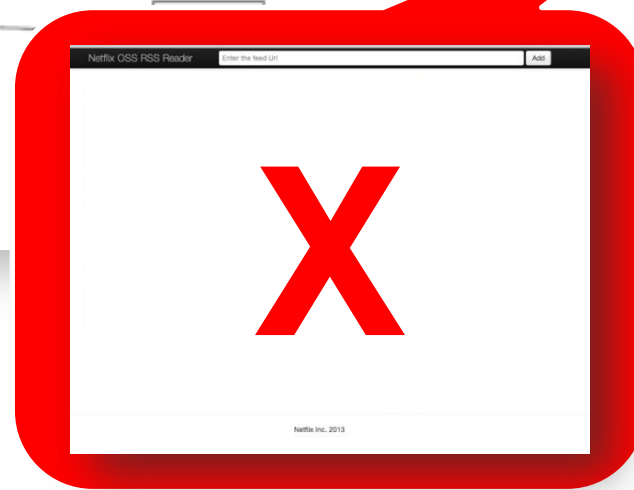
Sample Applications and Recipes

RECIPES-RSS

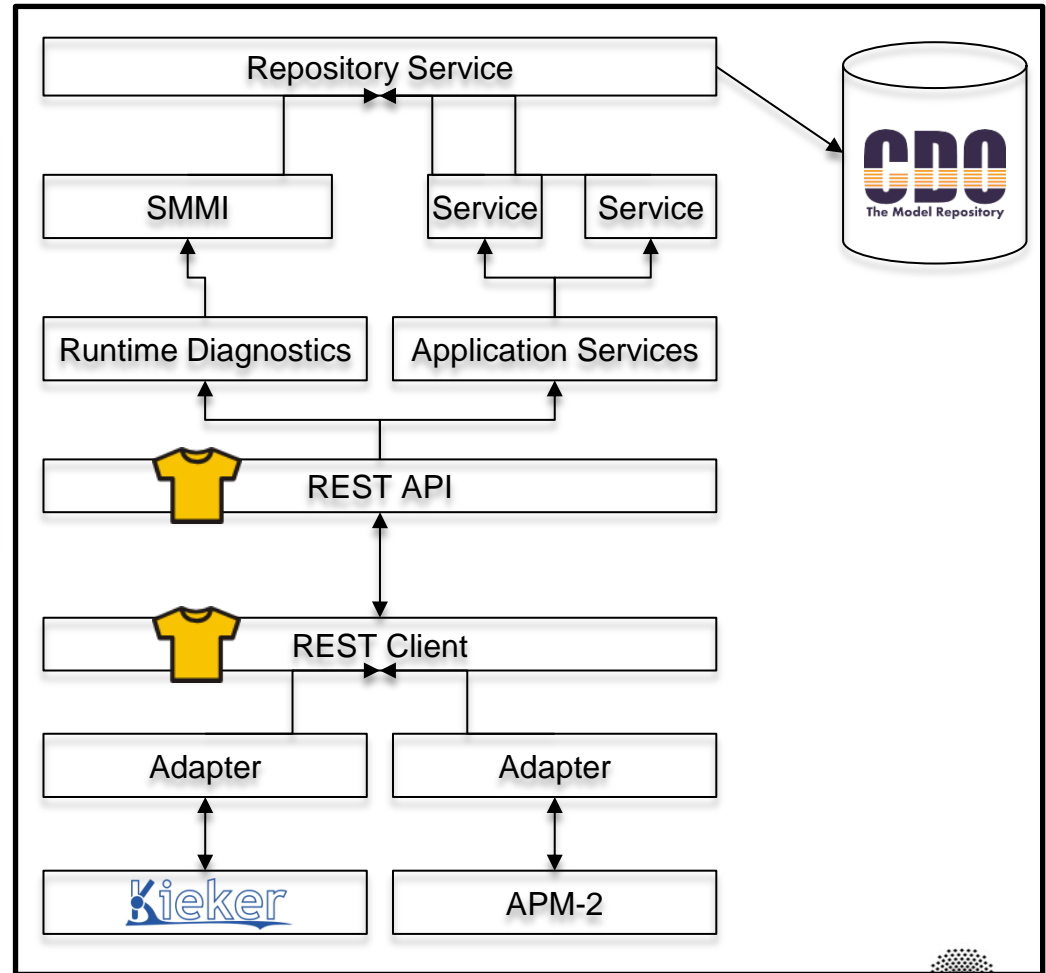
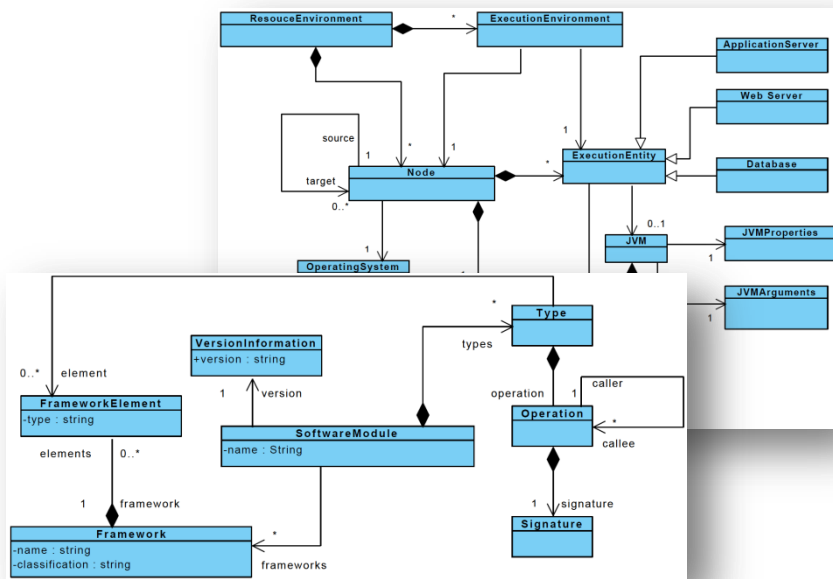
Recipes-rss

RSS Reader Recipes that uses several of the Netflix OSS components [More Info](#)

- Stars: 191
- Forks: 55
- Language: Java
- Open Issues: 4
- Updated: 03/11/15 @07:15:43



Master's Thesis Claudio Waldvogel (cont'd)



Problem Detection and Diagnosis Approaches

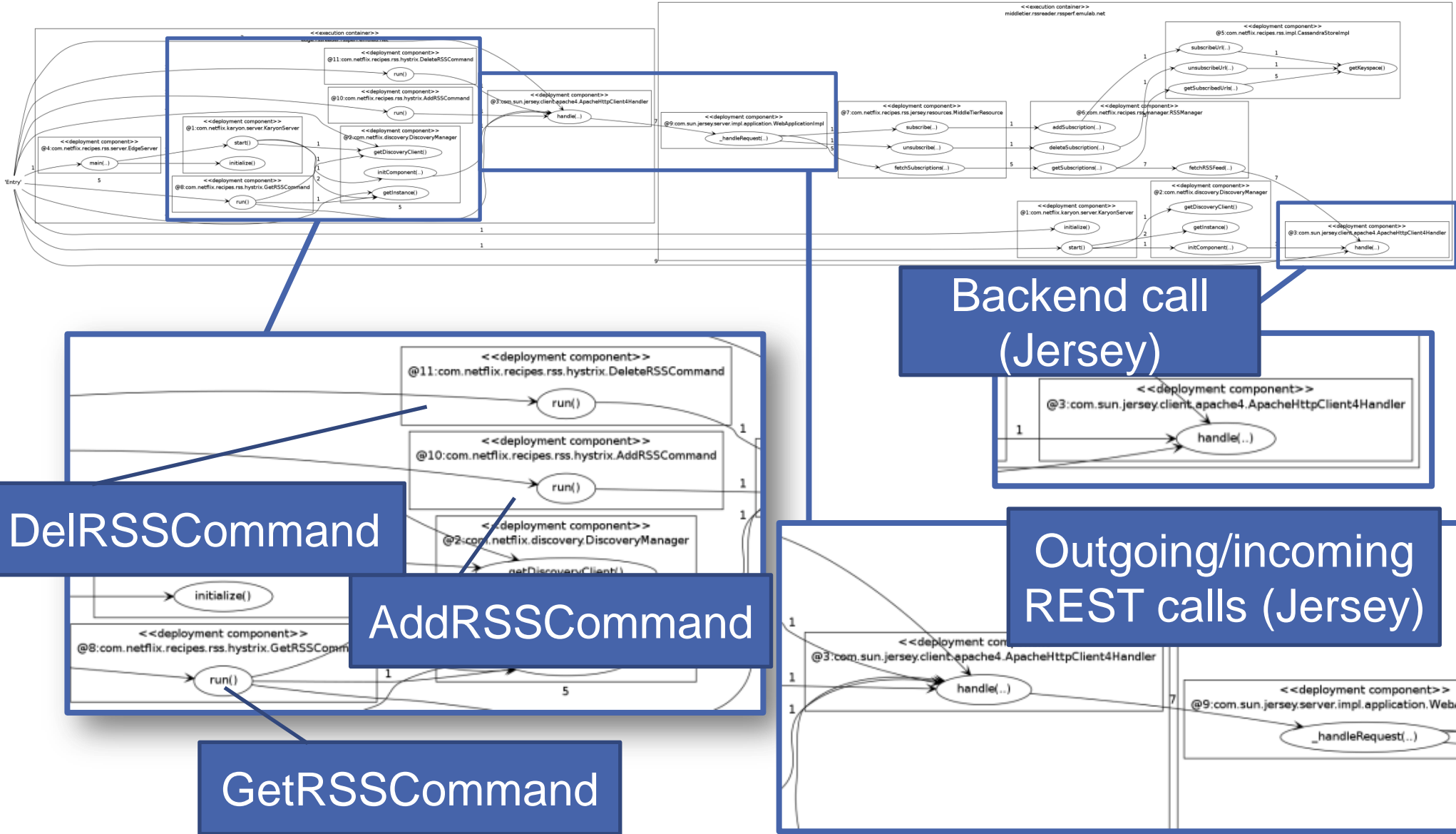
- Features
 - Reactive vs. proactive
 - Manual vs. automatic
 - State-based vs. transaction-based etc.

- Statistical techniques
 - Time series analysis
 - Anomaly detection (incl. change detection)
 - Machine learning etc.

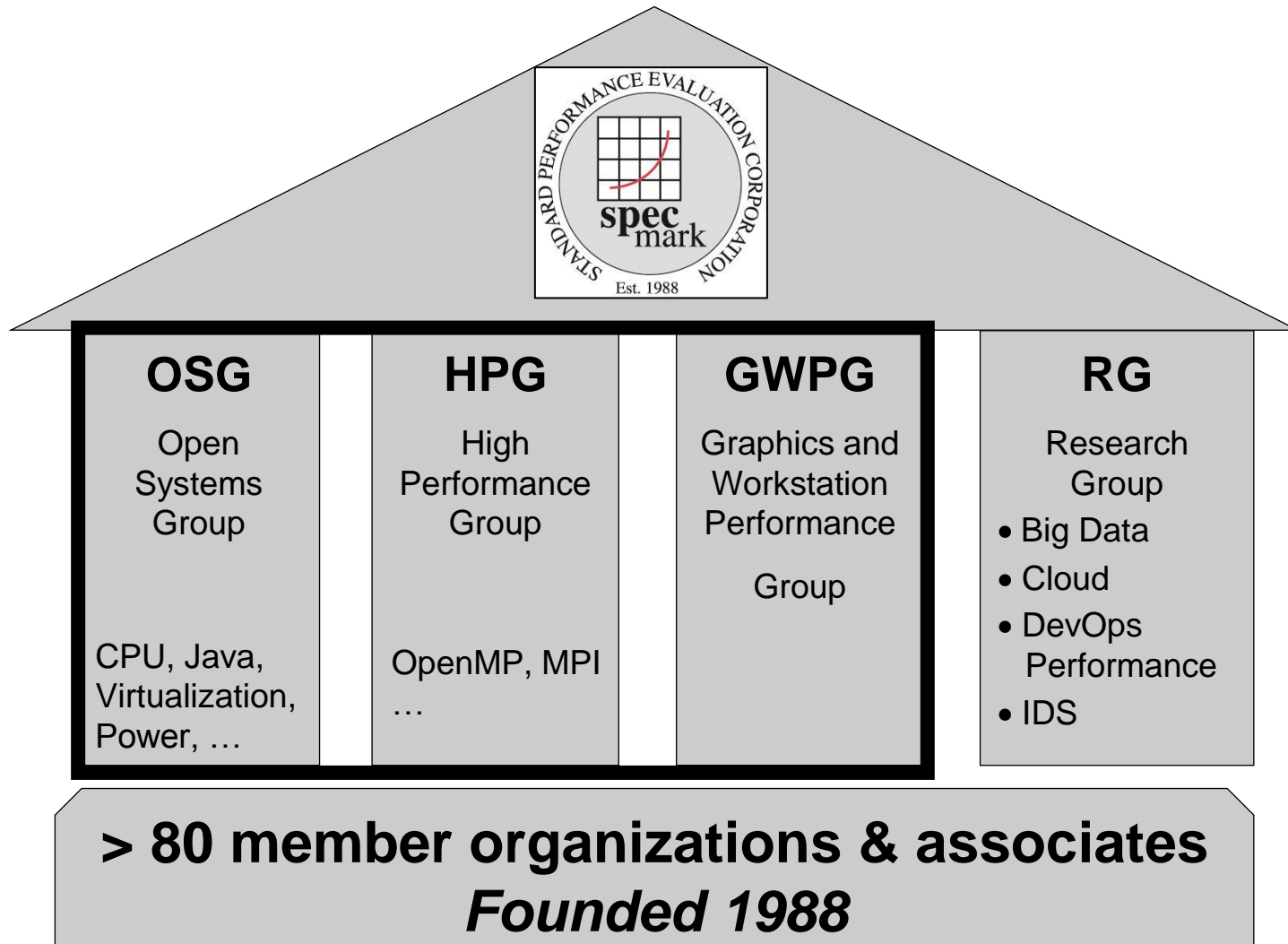
Example Kieker Plots for Netflix OSS Recipes Application

Edge

Middletier



SPEC RG DevOps Performance WG Launched



SPEC RG DevOps Performance WG Launched

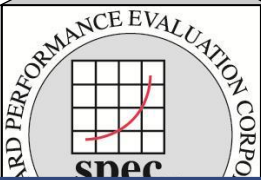
- Founded in 2010
- 40+ Member Organizations:



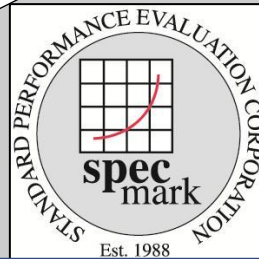
RG
Research Group

- Big Data
- Cloud
- DevOps Performance
- IDS

& associates



SPEC RG DevOps Performance WG Launched



RG DevOps WG

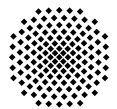
- Founded in 2014
- Current Member Organizations:



RG
Research Group

- Big Data
- Cloud
- DevOps Performance
- IDS

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Germany

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NOVATEC

Imperial College
London



- diagnosesIT is one of the DevOps projects

André van Hoorn



Universität
Stuttgart