The Descartes Modeling Language: Status Quo

Samuel Kounev

University of Würzburg
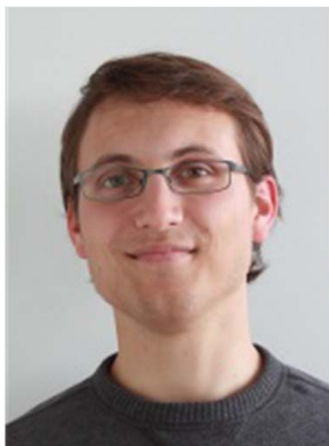
http://se.informatik.uni-wuerzburg.de/

Credits

Fabian Brosig

Nikolaus Huber

Main References

- **Fabian Brosig**. *Architecture-Level Software Performance Models for Online Performance Prediction*. PhD thesis, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany, 2014. [http | http]

- **Nikolaus Huber**. *Autonomic Performance-Aware Resource Management in Dynamic IT Service Infrastructures*. PhD thesis, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany, 2014. [http | http]

Elastic Resource Provisioning

Load Variations
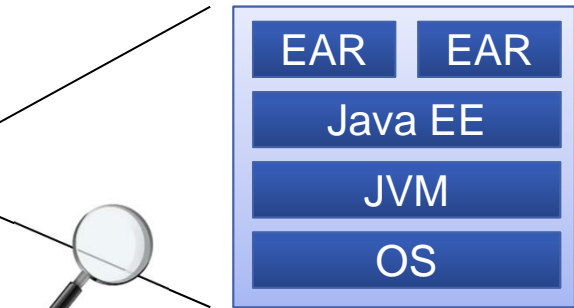
SLAs

Application 1
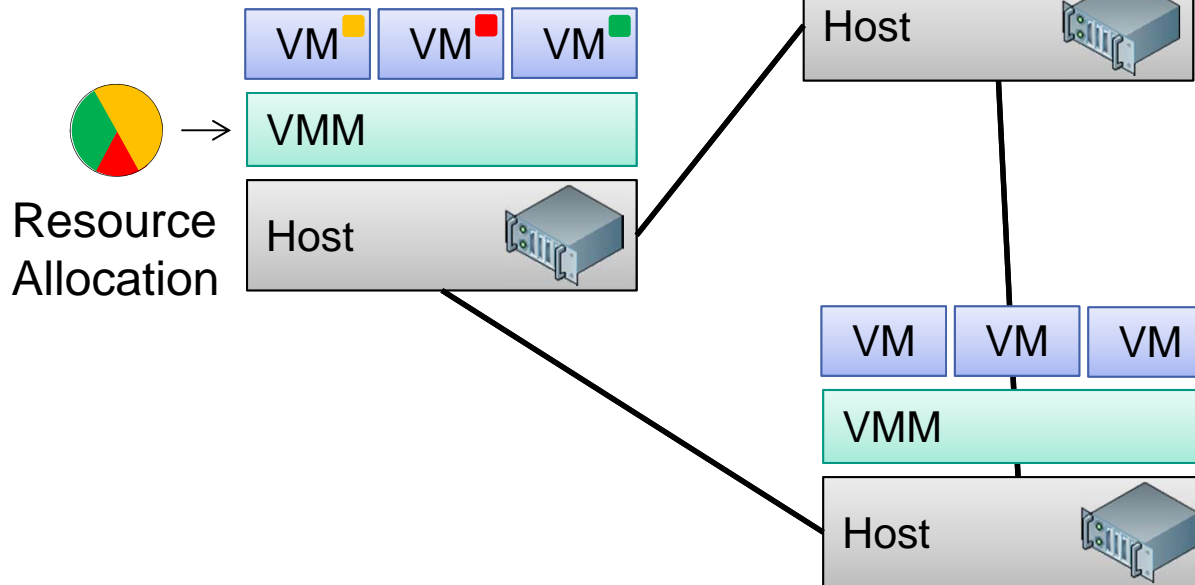
Application 2
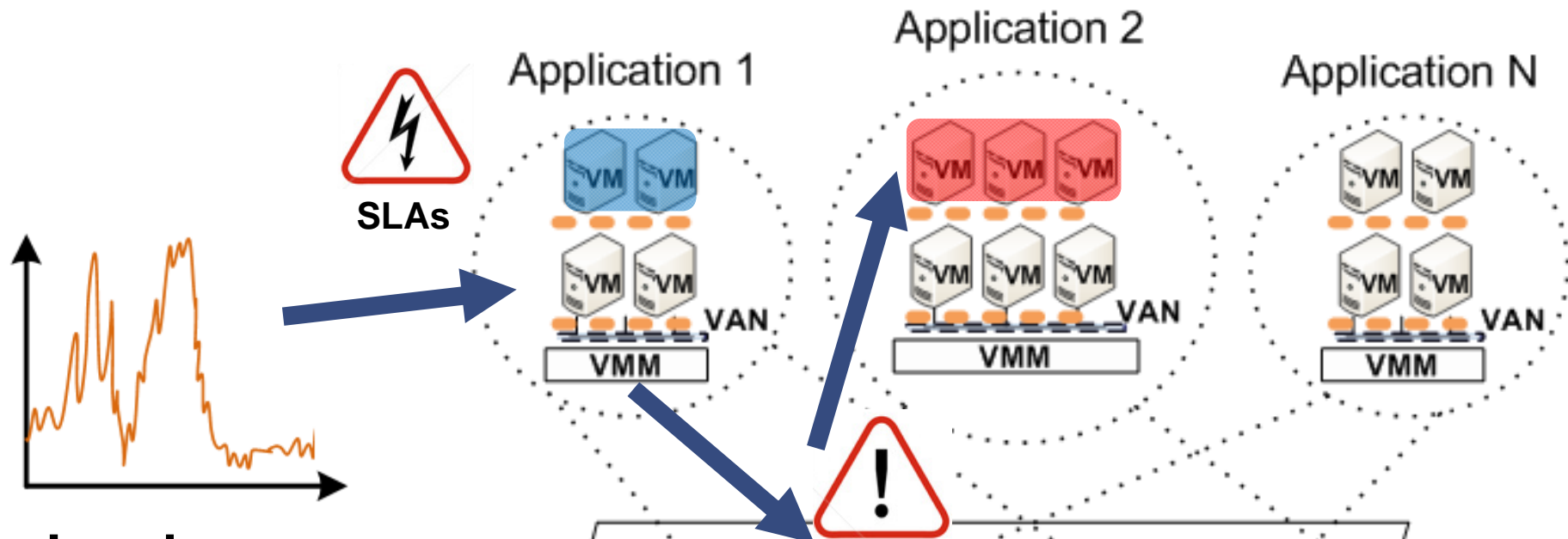
Application N

Challenges

- When exactly should a reconfiguration be triggered?
- Which particular resources should be scaled?
- How quickly and at what granularity?

Semantic Gap Problem

Applications 🟨🟥🟩
- Multiple tiers
- Multiple resource types

Complex Software Stacks
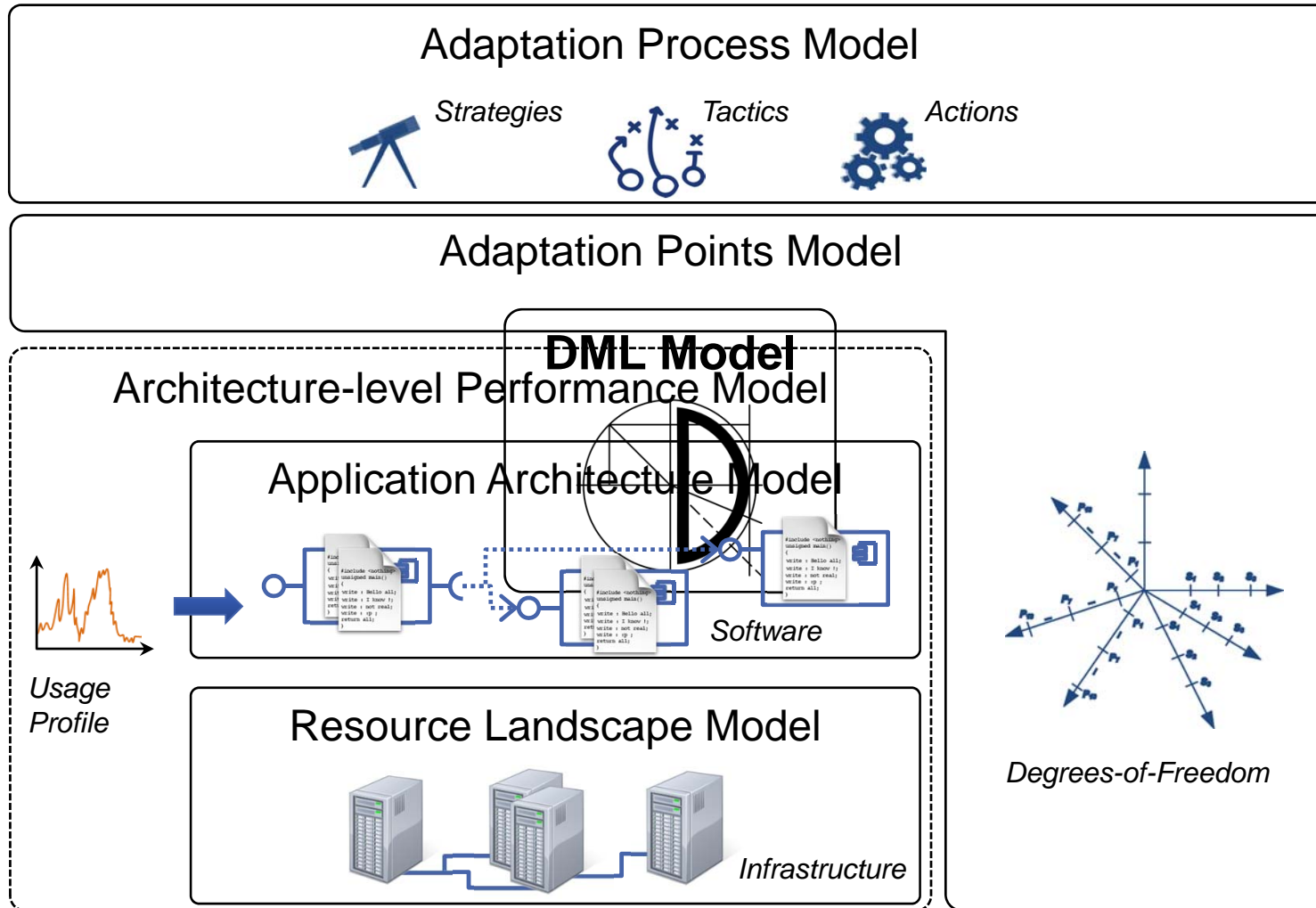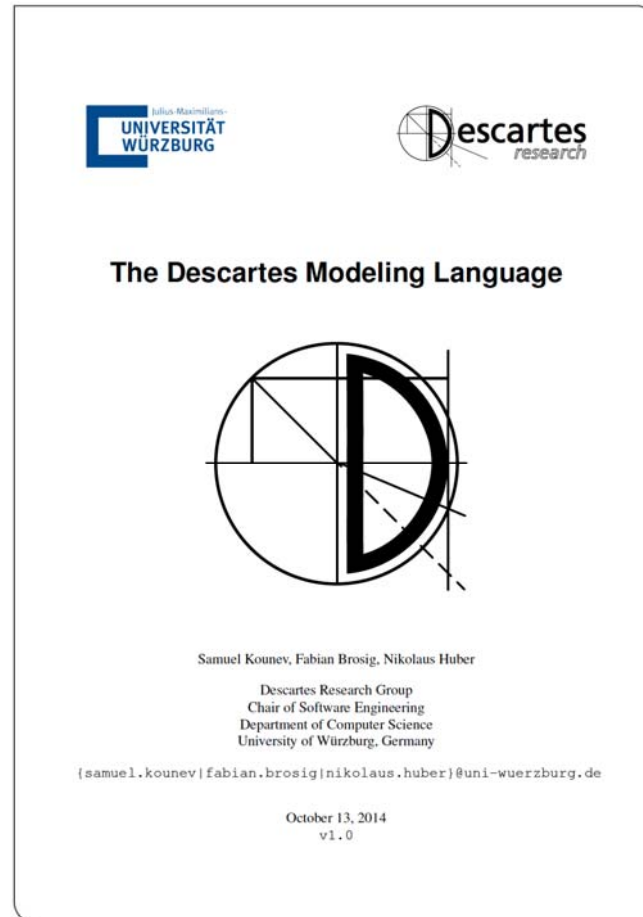- Multiple layers
- Heterogeneous

VM | VM | VM
VMM
Host

VM | VM | VM
VMM
Host

VM | VM | VM
VMM
Host

Resource Allocation

EAR | EAR
Java EE
JVM
OS

End-to-end QoS metrics Application SLAs ⟷ **?** ⟷ Resource Allocations in Each Tier & Each Layer

Descartes Research Group

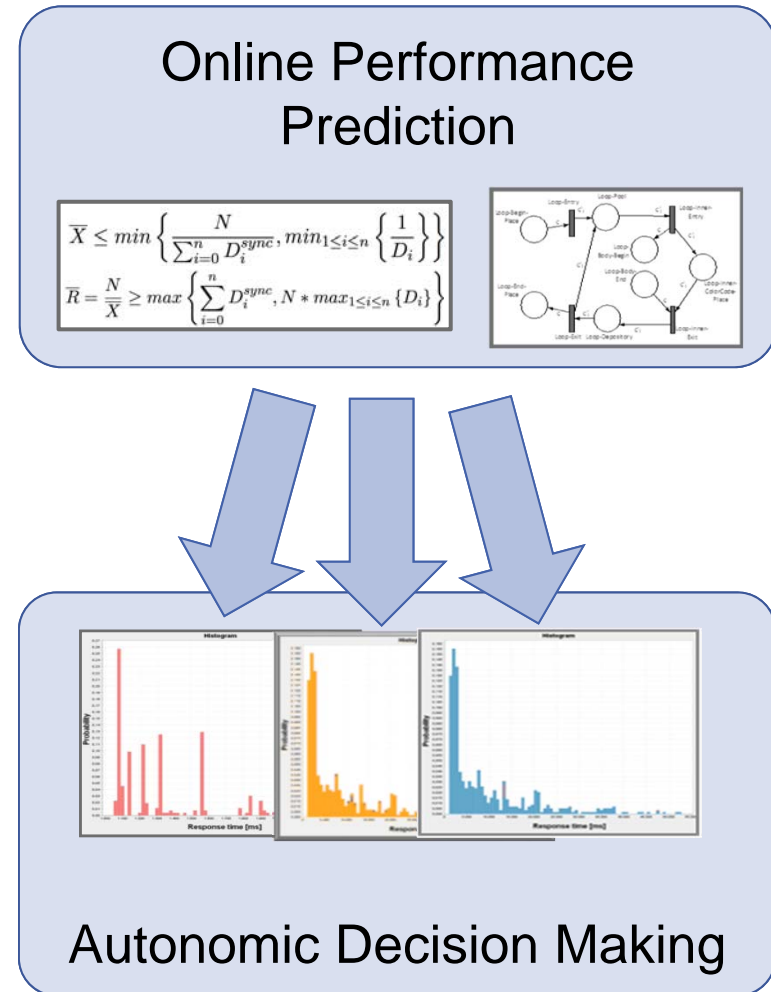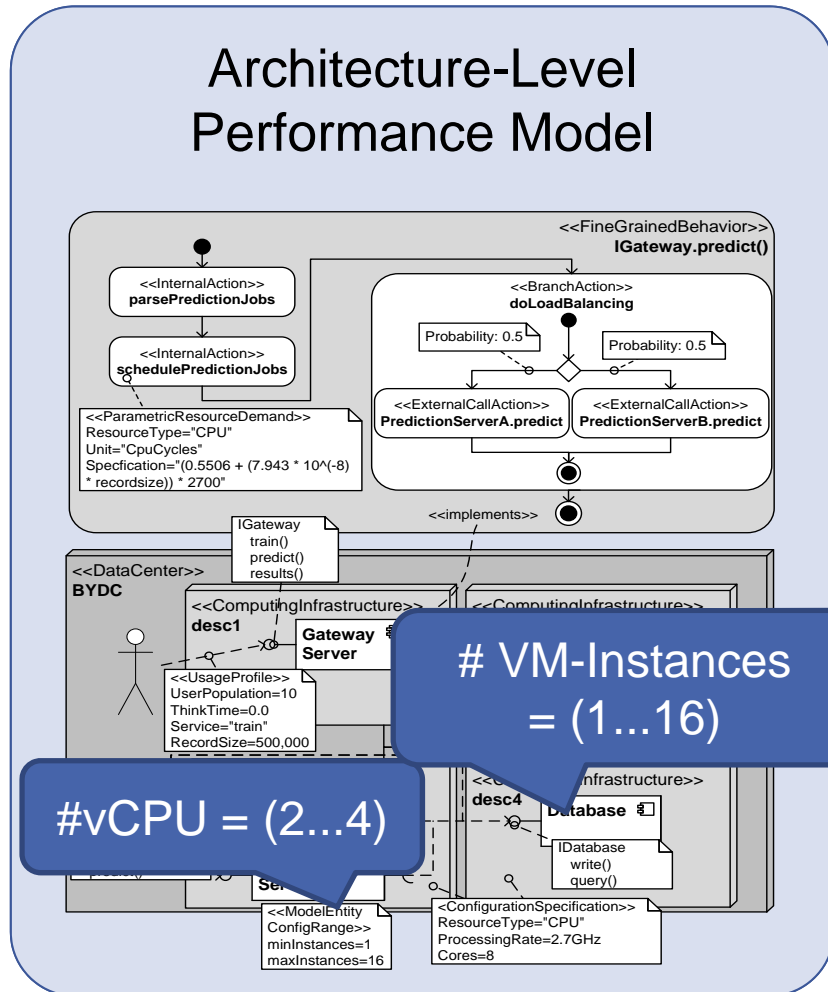- Modeling methods for **predicting at run-time** the effect of dynamic changes on the system Quality-of-Service (QoS)

    - Current focus: availability and performance (response time, throughput and resource/energy efficiency)

- Model-based algorithms and techniques for **autonomic system adaptation** during operation

- Goal:
    - End-to-end QoS guarantees
    - High resource/energy efficiency
    - Low operating costs

Descartes Modeling Language

Adaptation Process Model

Strategies *Tactics* *Actions*

Adaptation Points Model

DML Model

Architecture-level Performance Model

Application Architecture Model

Software

Usage Profile

Resource Landscape Model

Infrastructure

Degrees-of-Freedom

DML Specification

The Descartes Modeling Language

Samuel Kounev, Fabian Brosig, Nikolaus Huber

Descartes Research Group
Chair of Software Engineering
Department of Computer Science
University of Würzburg, Germany

{samuel.kounev|fabian.brosig|nikolaus.huber}@uni-wuerzburg.de

October 13, 2014
v1.0

http://descartes.tools/dml

Online Performance Prediction

Architecture-Level Performance Model

Online Performance Prediction

$$\overline{X} \leq min\left\{\frac{N}{\sum_{i=0}^{n} D_i^{sync}}, min_{1\leq i \leq n}\left\{\frac{1}{D_i}\right\}\right\}$$

$$\overline{R} = \frac{N}{\overline{X}} \geq max\left\{\sum_{i=0}^{n} D_i^{sync}, N * max_{1\leq i \leq n}\{D_i\}\right\}$$

VM-Instances = (1...16)

#vCPU = (2...4)

Autonomic Decision Making

Model-Based System Adaptation

Problem Anticipation → Adaptation on the Model Level → Adaptation Impact Prediction → Adaptation Execution on Real System

Load Forecasting

uses

Online Perf. Prediction

Adaptation Process Model

adapts

Architecture-Level Performance Model

uses

describes

adapts

System

Descartes Tool Chain

http://descartes.tools

http://descartes.tools

DML Bench

- **Editors**
  - Textual and graphical editors for DML models

- **Solvers**
  - Solvers for conducting performance prediction

- **S/T/A Adaptation Framework**
  - Execution of adaptation process on the model level

DML Bench

http://descartes.tools/dml_bench

DQL (Descartes Query Language)

Example of a
performance query specified with DQL

```
SELECT s.avgResponseTime,
app.utilization,
dbs.utilization
CONSTRAINED AS FAST
FOR RESOURCE
'ApplicationServer' AS app,
RESOURCE 'DBServer' AS dbs,
SERVICE 'processOrder' AS s;
```

Performance Query

↓

Model Parameterization

↓

Model Analysis

↓

Query Results

http://descartes.tools/dql
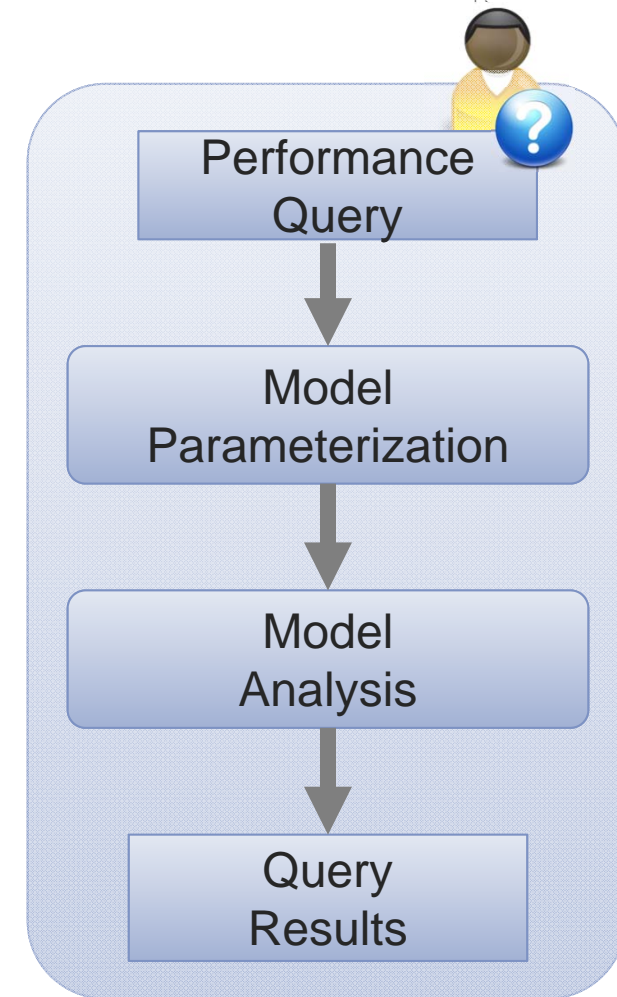
DNI - Descartes Network Infrastructure Modeling

- Language for perf. modeling of data center networks
    - network topology, switches, routers, virtual machines, network protocols, routes, flow-based configuration,...

- Model solvers based on simulation (OMNeT)

http://descartes.tools/dni

LibReDE
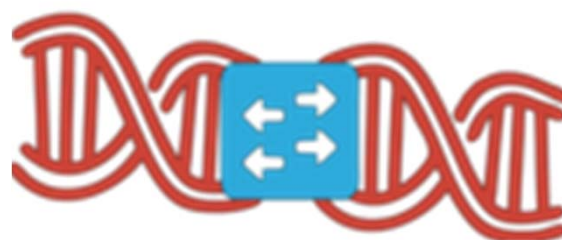
- **Library for Resource Demand Estimation**
  - Ready-to-use implementations of estimation approaches
  - Comparison of the accuracy of different approaches
  - Selection of a suitable approach for a given scenario

http://descartes.tools/librede

LIMBO

- **Load Intensity Modeling Tool**
  - Automated model extraction from recorded traces
  - Creation and composition of custom models
  - Emulation of job arrivals for load generation

http://descartes.tools/limbo

WCF
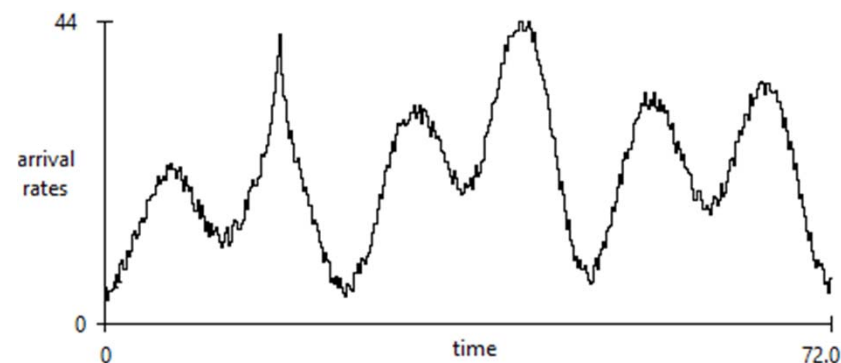
- **Workload Classification & Forecasting Tool**
  - Use of multiple alternative forecasting methods in parallel
  - Selection of method based on its accuracy in the recent past

Workload
Classification & Forecasting

http://descartes.tools/wcf

BUNGEE
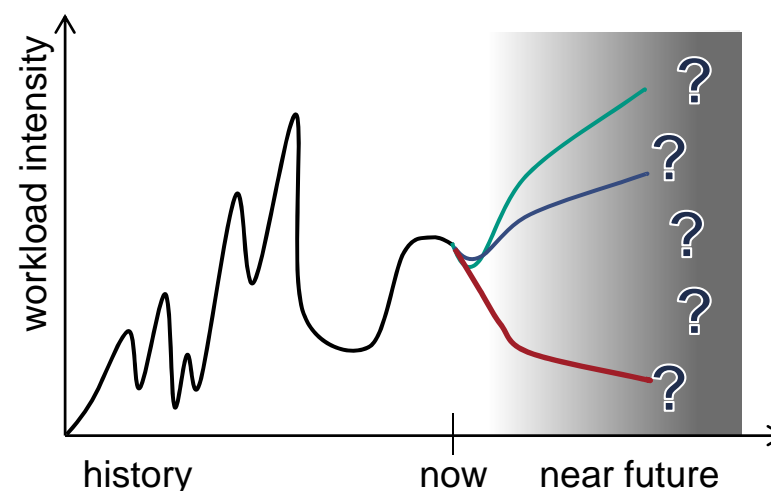
- Framework for benchmarking elasticity
  - Current focus: IaaS cloud platforms

Cloud Elasticity Benchmark
BUNGEE

http://descartes.tools/bungee

Summary

- Descartes Tool Chain
  - **DML Bench** - Editors, solvers and adaptation framework
  - **DQL** – Declarative query language
  - **DNI** – Descartes network infrastructure modeling
  - **LibReDE** - Library for resource demand estimation
  - **LIMBO** – Load intensity modeling tool
  - **WCF** – Workload classification & forecasting tool
  - **BUNGEE** - Framework for benchmarking elasticity

Questions?

http://www.descartes-research.net

http://descartes.tools

Employed Modeling & Analysis Methods

Descriptive Architecture-level Models → DML

- OMG Meta Object Facility (MOF)
  - MOF-based meta-models
- (UML MARTE)
- (UML SPT)

Predictive Performance Models

- Bounding techniques
- Operational analysis
- Statistical regression models
- Stochastic process algebras
- (Extended) queueing networks
- Layered queueing networks
- Queueing Petri nets
- Machine learning-based models
- Detailed simulation models

Workload Forecasting

- AR(I)MA
- Extended exp. smoothing
- tBATS
- Croston's method
- Cubic smoothing splines
- Neural network-based

Resource Demand Estimation

- Regression-based techniques
- Kalman filter
- Nonlinear optimization
- Maximum likelihood estimation
- Independent component analysis

Regression Analysis

- MARS
- CART
- M5 trees
- Cubist forests
- Quantile regression forests
- Support vector machines

S. Kounev