

# Beagle

## Software Requirements Specification

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# Contents

<b>List of Figures</b>	<b>iii</b>
<b>Abbreviations</b>	<b>iv</b>
<b>Reference notation</b>	<b>v</b>
<b>1 Purpose and Goals</b>	<b>1</b>
1.1 Criteria . . . . .	1
1.2 Boundary . . . . .	3
<b>2 Application</b>	<b>5</b>
2.1 Application Field . . . . .	5
2.2 Target Group . . . . .	5
<b>3 Environment</b>	<b>11</b>
3.1 Component Model . . . . .	11
<b>4 Data</b>	<b>13</b>
4.1 Input . . . . .	13
4.2 Output . . . . .	14
<b>5 Functional Requirements</b>	<b>15</b>
5.1 Measurement . . . . .	15
5.2 Control . . . . .	16
5.3 Result Annotation . . . . .	17
<b>6 Non Functional Requirements</b>	<b>19</b>
6.1 Dependencies . . . . .	19
6.2 User Interface and Experience . . . . .	20
6.2.1 GUI model . . . . .	20
<b>7 Test Cases</b>	<b>23</b>

<b>8</b>	<b>Discussion</b>	<b>27</b>
8.1	Assumptions . . . . .	27
8.2	Challenges . . . . .	27
<b>9</b>	<b>Models</b>	<b>29</b>
9.1	Scenario . . . . .	29
	<b>Terms and Definitions</b>	<b>31</b>
	<b>Bibliography</b>	<b>35</b>

# List of Figures

1.1	UML Use Case Diagram . . . . .	2
2.1	UML Activity diagram for /A10/ . . . . .	6
2.2	UML Activity diagram for /A20/ . . . . .	7
2.3	UML Activity diagram for /A30/ . . . . .	8
2.4	UML Activity diagram for /A40/ . . . . .	9
3.1	Component Model . . . . .	11

# Abbreviations

**CTA** Common Trace API

**GUI** Graphical User Interface

**JRE** Java Runtime Environment

**PCM** Palladio Component Model

**QoS** quality of service

**SEFF** service effect specification

# Reference notation

This document uses a fixed notation for all of its contents, making them referenceable:

/A#/	application attribute
/B#/	purpose boundary
/C#/	challenge or assumption
/D#/	data
/E#/	software environment attribute
/F#/	functional requirement
/G#/	target group
/M#/	model
/P#/	purpose criterion
/Q#/	non functional requirement
/T#/	test case

A preceding “O” marks optional points. These relate to features that are desired and planned, but can not surely be implemented in the project’s scope. They also serve as an outlook for further development.





# 1 Purpose and Goals

When developing software, specifying its architecture in a sophisticated way is a crucial, yet challenging task. Decisions made at this point highly influence the software's quality of service (QoS), but are usually difficult to change, as redesigns may be costly [Reussner et al., 2011]. To prevent poor design in the first place, Palladio, a model-driven approach for software simulation, enables developers to analyse component-based softwares' QoS during the definition phase before actually writing any code. Using Palladio, all parties involved in the development of component-based software model their domain in the Palladio Component Model (PCM). This information is then used to simulate the software's behaviour with a focus on its QoS attributes.

In many scenarios, however, some to all source code may already exist. Analysis with Palladio might still be desired: For example to simulate a component's interaction with a software system or to freshly start analysing existing software. For such cases, SoMoX, a software for static source code analysis, allows users to re-engineer their software's architecture into a PCM. The results contain the software's component boundaries, their bindings to the provided source code, and their service effect specification (SEFF) [Krogmann, 2011]. Unfortunately, SoMoX' static approach does not allow it to determine the software's resource demands, which are essential for performance analysis.

[Krogmann, 2011] also describes Beagle, an approach for dynamic source code analysis to complement SoMoX. It aims to conduct performance measurements on software's source code in order to determine its component's internal actions resource demands. Adding this information to the software's PCM enables developers to import their software into Palladio with minimal effort. The purpose of this project is to implement Beagle. Based on the foundations in [Krogmann, 2011], it aims to develop a piece of software adding dynamic properties to a PCM using contemporary measurement software.

## 1.1 Criteria

### Mandatory

- /P10/ Beagle enables the user to analyse given source code regarding the resources its internal actions' demand when executed.

- /P20/ Beagle annotates its resource demand findings in a given instance of the software's PCM, enabling the user to import existing software into Palladio for analysis.

### Optional

- /OP10/ Beagle analyses consigned source code for further dynamic behavioural attributes like the number of loop executions in SEFF loops and the probability for branches in SEFF conditions.
- /OP20/ Beagle outputs the results as a function of the input parameters of the internal actions as resource demand annotations in the PCM.
- /OP30/ Beagle provides the user to control the analysis with a Graphical User Interface (GUI).



Figure 1.1: UML Use Case Diagram. Optional features are drawn grey.

## 1.2 Boundary

- /B10/ Beagle does not perform actual measurements on source code. This is done by other software like Kieker. Their results are transferred to Beagle using the Common Trace API (CTA).
- /B20/ Beagle does not reconstruct a model of software's architecture from its source code. This is done by other software like SoMoX.
- /B30/ Beagle does not reconstruct the internal structure of components like their SEFF. This is done by other tools like SoMoX.
- /B40/ Beagle does not assert that analysis of source code written in a language other than Java 6 is possible.
- /B50/ Beagle does neither do performance analysis nor prediction. That is may be achieved with Palladio.



## 2 Application

### 2.1 Application Field

- /A10/ Beagle can be used to re-engineer source code. To start using Palladio for an existing software, Beagle can be combined with a tool for static code analysis like SoMoX. This way, the software can quickly be analysed with Palladio. Modelling an existing software is such a time-consuming task that automatic modelling is a valuable feature that may be crucial for developers to start using Palladio
- /A20/ Beagle can be used for software development. Early implementations of components modelled in the PCM can be analysed with Beagle in order to predict their performance in interaction with the software system. This leads to earlier detection of arising problems (like implementation errors or unrealistic modelling in the PCM), which can hence be fixed in time.
- /A30/ Beagle may be used for prototyping. Different implementations of a component modelled in the PCM may be analysed with Beagle to determine their resource demands. Palladio can then be used to simulate the software system's performance with each implementation. As performance is multi-dimensional, this can lead to more precise information about the different implementation's effects on the system's runtime.
- /A40/ Beagle can be used to verify software's design and implementation. After developing the software with Palladio and implementing it, a static code analysis tool like SoMoX and Beagle can be re-engineer a PCM which can then be compared to the initial one. With this approach, differences and problems in the implementation can be detected and resolved easier.

### 2.2 Target Group

- /G10/ Software architects will use Beagle predominantly for /A10/ and /A40/.
- /G20/ System deployers will use Beagle predominantly for /A40/.
- /G30/ Component developers will use Beagle predominantly for /A20/ and /A30/.



Figure 2.1: A typical workflow when using Beagle to re-engineer existing source code (/A10/).



Figure 2.2: A typical workflow when using Beagle during software development (/A20/).



Figure 2.3: A typical workflow when using Beagle for prototyping (/A30/).





Figure 2.4: A typical workflow when using Beagle to verify the implementation (/A40/).



## 3 Environment

- /E10/ Beagle should run on a Java 8 runtime environment (or higher) and Eclipse distribution that is up to date with Eclipse Mars (4.5).
- /E20/ Beagle requires a PCM instance modelling the software to be analysed. The model must contain all components and their SEFFs, the source code and the PCM source code decorator
- /E30/ Beagle requires the CTA to communicate with performance measurement software.
- /E40/ The user should not run other programs while Beagle is running as this disturbs the measurement. To receive optimal measurements Beagle should run on a dedicated server.

### 3.1 Component Model



Figure 3.1: Beagle and its interaction with other software



## 4 Data

In the following chapter, “the software” refers to the software a user wants to analyse with Beagle. The term refers not only to source code, but also its conceptional attributes, like its purpose, structure and architecture.

Beagle deals with two major data artefacts: The software’s source code and an instance of the PCM describing the software (hereafter to be called “input source code”, “input PCM” or simply “input artefacts ”). Beagle will use the provided data to execute its tasks and write its results back into the PCM instance (hereafter to be called “ result PCM ”) afterwards.

### 4.1 Input

#### Mandatory

- /D10/ The software’s source code. It must be written in Java and either
  - be provided together with .class files compiled out of it, such that the files are executable on a Java Runtime Environment (JRE) installed on the computer Beagle runs on, or
  - be compilable by a JDK installed on the computer Beagle runs on.
- /D20/ Information about the software’s components. They must be modelled in the input PCM.
- /D30/ Information about the software’s components’ SEFFs. They must be modelled in the input PCM.
- /D40/ Mappings of the software’s components’ SEFFs to the parts in the source code implementing them. They must be modelled in the input PCMs source code decorator.

#### Optional

- /OD10/ User provided information about the software’s parts he wishes to analyse.
- /OD20/ User provided information about measurement timeouts. May be provided prior to or during Beagle’s execution.

## 4.2 Output

### Mandatory

/D100/ The software's components' CPU resource demands.

### Optional

/OD100/ The software's components' internal actions' further resource demands, like hard disk or network usage.

/OD110/ Probabilities of branches to be taken SEFF conditions.

/OD120/ Probable number of repeats in SEFF loops.

/OD130/ Measurement status data, containing all information required to resume a measurement (see /OF130/, /OF140/, enables /OF160/).

/OD140/ Verification data to check whether input artefacts changed (enables /OF150/).

## 5 Functional Requirements

Given Beagle is called with valid input artefacts (see p. 13), it must fulfil the following requirements:

### 5.1 Measurement

#### Mandatory

- /F10/ Using the information provided in the PCM, Beagle determines the sections in the source code to be measured in order to find internal actions' resource demands.
- /F20/ Beagle conducts measurements of the sections found by /F10/ by utilising measurement softwares.
- /F30/ Beagle uses existing measurement software for /F20/.
- /F40/ Beagle supports the CTA to communicate with measurement software.
- /F50/ Beagle provides a functionality to stop measurements by an adaptive timeout when enabled. This means that it aborts a measurement when it exceeds a certain period of time. This timeout is adapted based on previous runs with the same or similar arguments. It is increased if these previous runs took a long time (as it is expected that these measurements will take a long time, too) and decreased if they took a short time to answer a request.
- /F60/ The user can disable the adaptive timeout described in /F50/ and replace it with a set timeout or disable the timeout entirely.

#### Optional

- /OF10/ Beagle approximately determines relations between components' interface parameters and their resource demands.
- /OF20/ Beagle determines the probability for each case to be taken in encountered SEFF conditions.

- /OF30/ Beagle determines /OF20/ depending on the component's interface parameters.
- /OF40/ Beagle determines the probable number of repeats in encountered SEFF loops.
- /OF50/ Beagle determines /OF40/ depending on the component's interface parameters.

### 5.2 Control

#### Optional

- /OF100/ The user may choose whether Beagle will analyse the whole source code or only parts of it.
- /OF110/ The user may choose to re-measure the source code or parts of it, in order to either gain more precision or to reflect source code changes.
- /OF120/ The user may launch and control a measurement running on another computer over a network.
- /OF130/ The user may pause and resume a measurement. Pausing causes all measurement activity to stop. Resuming continues the measurement from where they were paused.
- /OF140/ The user may resume a paused measurement (/OF130/), even if Beagle was closed after pausing it.
- /OF150/ Beagle asserts that no input artefact (p. 14) was changed between pausing (/OF130/) and resuming (/OF140/) a measurement to assure its result's integrity.
- /OF160/ Beagle's results do not change, no matter how often the user chooses to pause and resume the measurements. Therefore Beagle assures approximately constant measurement conditions, e.g. by heating up the CPU with load before starting measurements when resuming.
- /OF170/ If requested by the user, Beagle shuts down the computer it's running on after it finished a measurement.



## 5.3 Result Annotation

### Mandatory

- /F200/ Beagle stores all its results in the software's PCM ("result PCM", see p. 13).
- /F210/ The result PCM is a valid PCM instance.
- /F220/ As far as technically possible, Beagle's results can be read from the result PCM by a Palladio installation without Beagle.
- /F230/ The result PCM contains all contained components' internal actions' resource demands.
- /F240/ Beagle does not remove any information from the provided PCM.
- /F250/ Measurement results are saved onto a persistent medium to avoid data loss.

### Optional

- /OF200/ If Beagle found parametrised results (e.g. in /OF10/, /OF30/, /OF50/), they are expressed using the PCM Stochastic Expression Language.



## 6 Non Functional Requirements

In order to be as independent as possible and to provide good quality of service and user experience, Beagle must fulfil the following requirements:

### 6.1 Dependencies

#### Mandatory

- /Q10/ In order to use Beagle, the user is not required to have any software installed but Java, Eclipse, Palladio and a measurement software supported by Beagle.
- /Q20/ Beagle does not depend on any specific measurement software.
- /Q30/ Beagle does not require its input artefacts to be generated by a specific software.

#### Optional

- /OQ10/ Beagle can be used on every combination of operating system and hardware platform Eclipse and Palladio runs on.
- /OQ20/ No user interaction is required while Beagle conducts measurements.
- /OQ30/ Beagle shall handle any error caused by the measured software (uncaught exceptions, uncaught errors, calls to `System#exit`, or other unexpected termination of the software's process(es)). This means that neither will Beagle crash because of such errors nor will other measurements be affected by them.
- /OQ40/ Beagle runs benchmarks on hardware systems in order to provide information to make its results portable.
- /OQ50/ Beagle does not modify the provided source code files.

## 6.2 User Interface and Experience

### Mandatory

- /Q100/ Beagle is implemented as an Eclipse plugin. As both Palladio and its extensions are Eclipse plugins, this ensures good usability for users.
- /Q110/ Beagle uses native Eclipse features for its GUI.
- /Q120/ Beagle can be controlled by context sensitive menus in Eclipse.

### Optional

- /OQ100/ Beagle is integrated into SoMoX to automatically be executed after SoMoX has finished.
- /OQ110/ Beagle can obtain its input artefacts from SoMoX, such that the user does not need to provide further information after SoMoX was started. If Beagle requires more information than SoMoX provides, the user can already submit it while configuring SoMoX.
- /OQ120/ Beagle reports its progress to the user.

### 6.2.1 GUI model

The user has multiple options to launch the analysis:

1. To analyse the whole project, there is an entry “Analyse with Beagle” in the context menu of the `.repository` or `.repository_diagram` file in eclipse.
2. To analyse a single component, there is an entry “Analyse with Beagle” in the context menu of each component in the repository diagram.
3. To analyse a single internal action, there is an entry “Analyse with Beagle” in the context menu of each internal action in the SEFF diagram.

If an analysis with Beagle is not possible in option 1, 2 or 3, the context menu entry will be shown greyed and a description why the analysis is not possible appears, when the users tries to start the analysis.

4. If /OQ100/ is realised, the user has the option, when launching SoMoX to automatically launch the analysis with Beagle after SoMoX has finished.

When the users launches the analysis, he gets an window where he can change some settings for Beagle:

1. If /OQ40/ is realised, the user may adapt the default timeout.
2. If /OF120/ is realised, the connection to the measurement machine can be set up.
3. If /OQ40/ is realised, the user can select to additionally benchmark its hardware system.

If /OQ40/ is realised, Beagle also provides a button for benchmarking the hardware without running any analysis.

When the analysis is running, a window reporting progress is displayed.

In this window there is also button for pausing, if /OF130/ is realised. If the measurement is paused, this button changes to a resume button. If /OF140/ is implemented and the user chooses to close Eclipse, a dialogue allowing him to resume the measurement will appear every time he starts Eclipse afterwards. This dialogue also offers the options to disable the dialogue in the future and to abort the measurement and drop the data collected so far. Additionally, in each context menu having an entry “Analyse with Beagle”, there will be another entry called “Resume last Beagle measurement”, allowing the user to resume the measurement.

In the progress window, there is also a button to abort the measurement.



## 7 Test Cases

As Beagle has to work with the above defined interfaces it has to be tested in complete. However, this could result into testing the other software, which is not what should be done, or even worse it could result in not detecting errors and failures as they are compensated by other software. On account of this two types of tests are needed: one testing the whole system with its dependencies and another with parameters put in at the interfaces and therefore only testing Beagle itself.

### Mandatory

- /T10/ Assert that software is starting, running and terminating by a simple run-through. For a valid input this has to work without exceptions and the software has to terminate.
- /T20/ Assert that Beagle discovers all sections needed for measurement and that they are correct. For a correct result in the PCM it is essential to measure at the correct points. A part of this can be realised by checking if all code sections (of the measured part) were measured. Tests /F10/.
- /T30/ Assert that Beagle works for a system with only the software specified in /Q10/. A new system has to be set up with only these software applications and Beagle has to be tested on it.
- /T40/ Assert that transferring data between interfaces and Beagle works correctly in both directions. All interfaces with other software have to be tested.
- /T50/ Assert that in PCM all measured resource demands are added and nothing else is changed. This includes to assure that the PCM is valid. Tests /P10/, /P20/, /F200/, /F210/, /F230/ and /F240/.
- /T60/ Assert that Beagle measures the sections with measurement software through the CTA. Tests /F20/, /F30/ and /F40/.
- /T70/ Assert that Beagle stops measurements after timeout. Therefore run a measurement for software (which e.g. does not terminate) and define a timeout. Additional assert that this timeout can be turned off. Tests /F50/ and /F60/.

- /T80/ Assert that results are stored in the PCM by a manual test: run a measurement and check the PCM afterwards. Tests /F200/.
- /T90/ Assert that the result PCM can be read by a Palladio installation without Beagle by opening it on such a system. Tests /F220/.
- /T100/ Assert that all the result PCM contains all gained information (see /F230/) by checking if it is similar to a before defined PCM. Test /F230/ and /F240/.

### Optional

- /OT10/ Assert that Beagle works for different operating systems and hardware by running measurements on different systems. Tests /OQ10/.
- /OT20/ Assert that Beagle detects invalid input (e.g. if the PCM source code decorator does not fit to the code) and does not crash but responds to it in an acceptable way.
- /OT30/ Assert that Beagle works with different software through the CTA. Therefore it is necessary to test Beagle with Kieker and other measurement software. Tests /F40/, /Q20/ and /OQ30/.
- /OT40/ Assert that Beagle does not change source code files and other input except from the PCM. Tests /F50/.
- /OT50/ Tests /OF10/, /OF20/ and /OF40/.
- /OT60/ Assert that Beagle reacts to different component's interface parameters. Tests /OF30/ and /OF50/.
- /OT70/ Assert that it is possible for users to decide whether the whole source code or only parts of it are analysed. Therefore do several runs and determine the different parts which have to be tested. Tests /OF100/.
- /OT80/ Assert that users are able to re-measure source code by measuring same source code several times. Tests /OF110/.
- /OT90/ Assert that pausing and resuming measurements works as defined in /OF130/, /OF140/, /OF150/ and /OF160/ by testing same source code without pausing and several different numbers of pauses. The result has to be the same as long as nothing else changes.
- /OT100/ Assert that Beagle shuts down the computer if requested by a manual test. First, run a measurement and activate shutting down and then check if it worked and the results are saved. Tests /OF170/.



- 
- /OT110/ Assert that no user interaction is needed for measurements by running several measurements without user interaction. Tests /OQ20/.
- /OT120/ Assert that it is possible to run Beagle automatically after SoMoX has finished by having a SoMoX run with activated automatic Beagle run. Another test run has to assert that between both runs no user interaction is needed. Tests /OQ100/ and /OQ110/.



## 8 Discussion

### 8.1 Assumptions

- /C10/ The measured software was built using component-based software architecture. This assumption is derived from working with Palladio, which was built for analysing component-based software. Fortunately, it most of the time imposes little loss of generality, as any object oriented software can be described using terms of component-based software architecture (regarding each class as a component in the worst case). Such software will naturally not have the advantages that come with the component-based software approach, but might still be analysed for their performance.
- /C20/ The measured software has a constant, deterministic runtime for a fixed configuration of input parameters, when ignoring influences of the hardware, operating system and error of measurement. This will be the case for most software. The fact the user tries to measure the software when using Beagle implies he expects it to behave in such a manner.
- /C30/ The input artefacts (see p. 13) are integer. This means that all parts of the provided PCM describe the software correctly, completely and exactly like implemented in the source code. Beagle relies on this to be true and may produce inaccurate or wrong results if it is not.
- This assumption will not cause problems if the PCM was re-engineered from the software's source code. But if the model and implementation diverged at any point (likely during the software's implementation), it may, however, lead to unexpected results.
- /C40/ In the use of JaMopp the source code's Java version likely is restricted by JaMopp. To get Beagle independent from JaMopp can be useful for further projects, to use higher Java versions functions.

### 8.2 Challenges

- /C100/ There are a lot of factors influencing a CPU's performance: operating temperature, number of other processes, previous load, and data in cache,

to name just a few. Beagle aims to find ways to compensate these factors. This may involve disabling TURBO BOOST on INTEL CPUs, reading the cores' temperature and making sure the CPU is in a real world application thermal state, and further measures.

- /C110/ Beagle must ensure the transferability and scalability of its measurement results across different hardware platforms. This stretches from software running on an average desktop pc via servers through to clusters of servers. Different hardware platforms vary in many different dimensions (CPU frequency, number of CPU cores, size and distribution of CPU caches, speed of RAM, network speed, hard disk throughput, etc.), yet the results have to be representative.
- /C120/ As Beagle should be able to measure on specific components, other components of the software, that are called during the measured component's execution, may wish to be mocked (especially those, which take long time to return or do not return at all, e.g. a GUI). Mocking a component might be very effortful or even impossible. If this cannot be solved, Beagle may require the user to provide a test bed in which the measured components can be executed.
- /C130/ On modern operating systems, multitasking is the default. Users are used to work on multiple tasks at the same time and have multiple programs running. This could, however, influence Beagle's measurement results. If a considerable impact on measurement results is recognised, strategies to avoid them can be developed. These may include prompting the user to close certain applications.
- /C140/ Beagle aims to parametrise its measurement results by the component's interface parameters. Such parametrisation will likely be described by a regression function  $\mathbb{R}^n \rightarrow \mathbb{R}$ . This elicits multiple challenges:
- regression of multi-dimensional functions is a challenging task.
  - the regression functions might likely not be continuous.
  - It is unclear what the real number representation of an arbitrary Java object might be.

Note that even if not all of the above points can be fully resolved, approximate parametrisation might still produce better results than no parametrisation at all.

## 9 Models

### 9.1 Scenario

Imagine, that a Java based online shop is running on a middle-class web server of a company named “EmmaSun”. During the first few years the software could deal with almost 99.9% of the requests and orders that are handled quite well without any delay. After an enormous expansion since the last year, the user numbers are currently growing for about 5 percent each week. Although the current servers are designed to fulfil a distinctly higher amount of user requests, the administration reported some few dropouts as well as increasing waiting times in single applications. Unfortunately, the software is based on an early design that has grown over years with missing documentation in many cases. The effort to re-write the complete software is an impossible act. The only solution is, to re-analyse the software’s source code and hopefully find any bottlenecks that can be repaired with lesser effort. But re-analysing source code is also a quite unmanageable task. So at this point, Beagle is used.

Beagle helps the team of software architects that was commissioned by EmmaSun to analyse the whole software. As Beagle depends on a PCM, the architects use the reversed-engineering plug-in SoMoX to create a valid PCM including all software components and their SEFFs. Providing Beagle a monitoring software named Kieker, that matches the Common Trace API, Beagle starts with conducting measurements on single software components, extending the PCM. After around 6 hours of measuring, the results of measuring are added into the PCM and Beagle calls Palladio to do a performance prediction. The prediction indicates an architectural violation of some software components, that lead to a a huge amount of sub-function calls through hierarchical layers.

The software architects decide to add an extra cache, that can store the results of the sub-function calls and make them available immediately. Fortunately, before they turn this idea into reality, they can adopt this design decision into the PCM. The little changes in the PCM lead to a much better performance prediction and the software architects agree to re-implement the new design.



# Terms and Definitions

## **Beagle**

“**BE**haviour Analysis using **GE**netic Learning and **E**volution”. Approach for dynamic analysis of source code in order to find its behavioural attributes developed in [Krogmann, 2011]. This project aims to implement Beagle.

## **Common Trace API**

an API developed by NovaTec GmbH for measuring the time, specific code sections need to be executed.

## **component**

“a [software] unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to third-party composition.” [Szyperski, 2002]

There is no equivalent of components in modern programming languages, in particular, a component usually consists of multiple Java classes. Components can be nested.

## **component developer**

“[specifies] the functional and extra-functional properties of their components. They put the specification as well as the implementation in repositories, where software architects can retrieve them.” [Koziolek et al., 2007]

In the PCM, component developers create service effect specifications to define components’ behavioural properties and store modelling and implementation artefacts in repositories. [Reussner et al., 2011]

## **component-based software**

a software constituted of components.

## **component-based software architecture**

a software architecture utilising the concept of component-based software, therefore taking advantage of the reusability of its parts and preserving the same for newly created components.

**internal action**

sequence of commands a component executes without leaving its scope (e.g. without calling other components). Part of a component's SEFF.

**Java Runtime Environment**

a software set containing a Java Virtual Machine, a browser plugin, the Java standard libraries, and a configuration tool. The Java Virtual Machine it contains is needed to run Java applications or applets.

**Kieker**

“a Java-based application performance monitoring and dynamic software analysis framework.” [van Hoorn et al., 2012]

A measurement software Beagle aims to support.

**measurement software**

software capable of measuring the time, given source code needs to execute some task. The software's results are usually returned in a time unit like nanoseconds. Beagles interacts with such software through the CTA and uses it to find resource demands.

**Palladio**

an approach for the definition of component-based software architectures with a special focus on performance properties.

**Palladio Component Model**

a domain-specific modelling language (DSL) used by Palladio.

It is designed to enable early performance predictions for software architectures and is aligned with a component-based software development process. [Kounev, 2009]

**PCM source code decorator**

realises links from the source code to the elements in the PCM and the other way round. [Krogmann, 2011]

**PCM Stochastic Expression Language**

expression language used by the PCM to define random variables. These variables can for example be used to specify glsplresource demand. Random variables can be defined using basic mathematic operations, common stochastic distributions and interface parameters [Reussner et al., 2011].



**quality of service**

a software's extra-functional attributes, like performance, reliability, maintainability or security.

**resource demand**

how much of a certain resource—like CPU, Network or hard disk drive—a component needs to offer a certain functionality. In the PCM, resource demands are part of the SEFF. They are ideally specified platform independently, e.g. by specifying required CPU cycles, megabytes to be read, etc. If such information is not available, resource demands can be expressed platform dependent, e.g. in nanoseconds. In this case, a certain degree of portability can still be achieved if information about the used platforms' speed relative to each other is available.

**SEFF condition**

conditions (like Java's `if`, `if-else` and `switch-case` statements) which affect the calls a component makes to other components. Such conditions are—contrary to conditions that stay within an internal action—modelled in the component's SEFF.

**SEFF loop**

loops (like Java's `for`, `while` and `do-while` statement) which affect the calls a component makes to other components. Such loops are—contrary to loops that stay within an internal action—modelled in the component's SEFF.

**service effect specification**

description of a component's behaviour in the PCM. SEFFs contain information about the component's calls to other components as well as its resource demands. This information is used to derive the component's performance for simulation and prediction.

**software architect**

developer role in the component-based software development process. Leads the development process by designing the software's architecture from existing or planned components and interfaces. Usually delegates the specification of required components to component developers. Uses architectural styles and patterns, analyses architectural specifications, and makes design decisions. In the PCM, software architects create the assembly model, specifying how existing components are composed.[Reussner et al., 2011]

**software architecture**

the high-level structure and design of a software system as well as the discipline of creating and documenting these.

**SoMoX**

“**Software Model eXtractor**”, a Palladio plugin for static code analysis to re-engineer a software’s architecture from its source code developed in [Krogmann, 2011]. Constructs a PCM instance including the reconstructed components and their SEFF.

**system deployer**

developer role in the component-based software development process. Specifies the resource environment and allocates components to resources. Resources can both be hardware resources (CPU, hard disk, network connection) and software resources (thread pool, database connection). In the PCM, system deployers create the resource environment specification, modelling the resource environment and component allocations. [Reussner et al., 2011]

# Bibliography

- [Conway, 1968] Conway, M. E. (1968). *How Do Committees Invent?*
- [Kounev, 2009] Kounev, S. (2009). *Automated extraction of palladio component models from running enterprise Java applications*. PhD thesis, University of Wuerzburg.
- [Koziolk et al., 2007] Koziolk, H., Happe, J., Becker, S., and Reussner, R. (2007). *Palladio Paper*. PhD thesis.
- [Krogmann, 2011] Krogmann, K. (2011). *Reconstruction of Software Component Architectures and Behaviour Models using Static and Dynamic Analysis*. PhD thesis, Karlsruhe Institute of Technology.
- [Reussner et al., 2011] Reussner, R., Becker, S., Burger, E., Happe, J., Hauck, M., Koziolk, A., Koziolk, H., Krogmann, K., and Kuperberg, M. (2011). The palladio component model. Technical report, Department of Informatics Institute for Program Structures and Data Organization (IPD).
- [Szyperski, 2002] Szyperski, C. (2002). *Component Software: Beyond Object-Oriented Programming*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2nd edition.
- [van Hoorn et al., 2012] van Hoorn, A., Waller, J., and Hasselbring, W. (2012). Kieker: A framework for application performance monitoring and dynamic software analysis. In *Proceedings of the 3rd joint ACM/SPEC International Conference on Performance Engineering (ICPE 2012)*, pages 247–248. ACM.