The handle http://hdl.handle.net/1887/20225 holds various files of this Leiden University dissertation.

**Author:** Heijstek, Werner  
**Title:** Architecture design in global and model-centric software development  
**Date:** 2012-12-05
List of Illustrations

Figures

1.1 The 4 + 1-view model ................................................................. 5
1.2 Example of a UML class diagram .................................................. 6
1.3 A recent version of the RUP “hump” diagram ................................. 9
1.4 The grounded theory data collection and analysis method – applied to a software project .......................................................... 14
1.5 Organization of the four chapters that address RQ1 .......................... 17

2.1 BPMN diagram for GSD process description of case “XYZ” ............ 26

3.1 Class diagram depicting the structure of the examined effort log files 43
3.2 Effort distribution visualization for project A ................................. 45
3.3 Effort distribution visualization for project B ................................. 48
3.4 Effort distribution visualization for project C ................................. 49
3.5 Effort distribution visualization for project D ................................. 51

4.1 Theoretical framework of software architecture design dissemination 61
4.2 Communication of the software architecture design from the onshore to the offshore location ......................................................... 68
4.3 Case 3 iteration strategy ................................................................. 86

5.1 Excerpt of (anonymized) chain-referral sampling graph of interview respondents .............................................................. 94
5.2 Concept relation graph (→ denotes cause and effect) .......................... 95
5.3 Contents of an SAD and associated stakeholder interest ..................... 99

6.1 Experiment environment ............................................................... 112
6.2 Example design ................................................................. 115
6.3 Histograms for the amount of correct answers per treatment .......... 120
6.4 Density plot for amount of correct answers per treatment .............. 121
6.5 Density plot for academic experience, industrial experience and Höst experience class of participants ........................................... 128

7.1 Overview of case system components ..................................... 140
7.2 Frequency of UML diagram type use ...................................... 142
7.3 Model metrics and revision count over time .............................. 146
7.4 Project effort distribution on phase and model level .................... 147
7.5 Effort and duration per phase (normalized at 100 percent). The black line represents the case. The dotted gray line in the background represents the average for a set of 17 projects similar in size and complexity ........ 148
7.6 Software configuration and change management system usage ....... 152
7.7 Cumulative defect discovery over time (case is labeled “Project Alpha”) 154

8.1 Factor integration graph (\(\rightarrow\) denotes cause and effect) .......... 163
8.2 MDD versus non-MDD maintenance (adapted from Van Vliet, 2008) . 171

9.1 Cause-effect diagram integrating the main findings of the study ..... 180

Tables

1.1 MDD provides a common language that augments the individual representations each software engineering stakeholder uses ............... 10

2.1 Organizations Under Study ................................................ 24
2.2 Comparison of GSD process descriptions ............................... 29
2.2 Comparison of GSD process descriptions (continued) ............... 30
2.2 Comparison of GSD process descriptions (continued) ............... 31
2.3 Approach to Process Description Use .................................... 33

3.1 Project Characteristics ......................................................... 44

4.1 Interview Questions as Derived from Theoretical Framework (Figure 4.1) 63
4.2 Case Characteristics ............................................................. 66

5.1 Overview of expert interview respondent characteristics ................ 93

6.1 Experiment Variables .......................................................... 110
6.2 Media Dominance ............................................................... 116
<table>
<thead>
<tr>
<th>Illustration</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3</td>
<td>Example of video coding log for a single question</td>
<td>117</td>
</tr>
<tr>
<td>6.4</td>
<td>Experiment Questions</td>
<td>119</td>
</tr>
<tr>
<td>6.5</td>
<td>Descriptive statistics for the amount of given answers that were correct for text-dominant versus diagram-dominant architecture descriptions</td>
<td>120</td>
</tr>
<tr>
<td>6.6</td>
<td>Language Grouping &amp; Distance</td>
<td>127</td>
</tr>
<tr>
<td>6.7</td>
<td>Multivariate regression for “Amount of Correct Answers”</td>
<td>129</td>
</tr>
<tr>
<td>7.1</td>
<td>Model Size Metrics</td>
<td>143</td>
</tr>
<tr>
<td>7.2</td>
<td>Model Complexity Metrics</td>
<td>144</td>
</tr>
<tr>
<td>7.3</td>
<td>Bi-Variate Correlation Matrix for Common Process Metrics in MDD Context</td>
<td>149</td>
</tr>
<tr>
<td>7.4</td>
<td>Bi-Variate Correlation Matrix for Defect Priority and Changes</td>
<td>151</td>
</tr>
<tr>
<td>8.1</td>
<td>Architectural Artifacts Available in the Case Project</td>
<td>168</td>
</tr>
<tr>
<td>8.2</td>
<td>Relating GSD best practices (Smite et al., 2010) to MDD-related practices</td>
<td>176</td>
</tr>
</tbody>
</table>


M. Kyas. *Verifying OCL Specifications of UML Models: Tool Support and Compositionality*. Faculty of Mathematics and Natural Sciences, UL. 2006-05

M. Hendriks. *Model Checking Timed Automata - Techniques and Applications*. Faculty of Science, Mathematics and Computer Science, RU. 2006-06

J. Ketema. *Böhm-Like Trees for Rewriting*. Faculty of Sciences, VUA. 2006-07

C.-B. Breunesse. *On JML: topics in tool-assisted verification of JML programs*. Faculty of Science, Mathematics and Computer Science, RU. 2006-08

B. Markvoort. *Towards Hybrid Molecular Simulations*. Faculty of Biomedical Engineering, TU/e. 2006-09

S.G.R. Nijssen. *Mining Structured Data*. Faculty of Mathematics and Natural Sciences, UL. 2006-10

G. Russello. *Separation and Adaptation of Concerns in a Shared Data Space*. Faculty of Mathematics and Computer Science, TU/e. 2006-11


B. Badban. *Verification techniques for Extensions of Equality Logic*. Faculty of Sci-
ences, Division of Mathematics and Computer Science, VUA. 2006-13

A.J. Mooij. Constructive formal methods and protocol standardization. Faculty of Mathematics and Computer Science, TU/e. 2006-14


M.E. Warnier. Language Based Security for Java and JML. Faculty of Science, Mathematics and Computer Science, RU. 2006-16

V. Sundaramoorthy. At Home In Service Discovery. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2006-17

B. Gebremichael. Expressivity of Timed Automata Models. Faculty of Science, Mathematics and Computer Science, RU. 2006-18

L.C.M. van Gool. Formalising Interface Specifications. Faculty of Mathematics and Computer Science, TU/e. 2006-19


J.V. Guillen Scholten. Mobile Channels for Exogenous Coordination of Distributed Systems: Semantics, Implementation and Composition. Faculty of Mathematics and Natural Sciences, UL. 2006-21

H.A. de Jong. Flexible Heterogeneous Software Systems. Faculty of Natural Sciences, Mathematics, and Computer Science, UvA. 2007-01

N.K. Kavaldjiev. A run-time reconfigurable Network-on-Chip for streaming DSP applications. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2007-02

M. van Veelen. Considerations on Modeling for Early Detection of Abnormalities in Locally Autonomous Distributed Systems. Faculty of Mathematics and Computing Sciences, RUG. 2007-03


M.W.A. Streppel. Multifunctional Geometric Data Structures. Faculty of Mathematics and Computer Science, TU/e. 2007-07

N. Trčka. Silent Steps in Transition Systems and Markov Chains. Faculty of Mathematics and Computer Science, TU/e. 2007-08

R. Brinkman. Searching in encrypted data. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2007-09

A. van Weelden. Putting types to good use. Faculty of Science, Mathematics and Computer Science, RU. 2007-10

R. Boumen. *Integration and Test plans for Complex Manufacturing Systems*. Faculty of Mechanical Engineering, TU/e. 2007-12


C.F.J. Lange. *Assessing and Improving the Quality of Modeling: A Series of Empirical Studies about the UML*. Faculty of Mathematics and Computer Science, TU/e. 2007-14

T. van der Storm. *Component-based Configuration, Integration and Delivery*. Faculty of Natural Sciences, Mathematics, and Computer Science, UvA. 2007-15


A.H.J. Mathijsen. *Logical Calculi for Reasoning with Binding*. Faculty of Mathematics and Computer Science, TU/e. 2007-17

D. Jarnikov. *QoS framework for Video Streaming in Home Networks*. Faculty of Mathematics and Computer Science, TU/e. 2007-18

M. A. Abam. *New Data Structures and Algorithms for Mobile Data*. Faculty of Mathematics and Computer Science, TU/e. 2007-19


N.C.W.M. Braspennings. *Model-based Integration and Testing of High-tech Multi-disciplinary Systems*. Faculty of Mechanical Engineering, TU/e. 2008-05

M. Bravenboer. *Exercises in Free Syntax: Syntax Definition, Parsing, and Assimilation of Language Conglomerates*. Faculty of Science, UU. 2008-06


I.S.M. de Jong. *Integration and Test Strategies for Complex Manufacturing Machines*. Faculty of Mechanical Engineering, TU/e. 2008-08

I. Hasuo. *Tracing Anonymity with Coalgebras*. Faculty of Science, Mathematics and Computer Science, RU. 2008-09

L.G.W.A. Cleophas. *Tree Algorithms: Two Taxonomies and a Toolkit*. Faculty of Mathematics and Computer Science, TU/e. 2008-10

M. Farshi. *A Theoretical and Experimental Study of Geometric Networks*. Faculty of Mathematics and Computer Science, TU/e. 2008-12


E.M. Bortnik. *Formal Methods in Support of SMC Design*. Faculty of Mechanical Engineering, TU/e. 2008-16


M. van der Horst. *Scalable Block Processing Algorithms*. Faculty of Mathematics and Computer Science, TU/e. 2008-18


E. Mumford. *Drawing Graphs for Cartographic Applications*. Faculty of Mathematics and Computer Science, TU/e. 2008-21

E.H. de Graaf. *Mining Semi-structured Data, Theoretical and Experimental Aspects of Pattern Evaluation*. Faculty of Mathematics and Natural Sciences, UL. 2008-22

R. Brijder. *Models of Natural Computation: Gene Assembly and Membrane Systems*. Faculty of Mathematics and Natural Sciences, UL. 2008-23


H. Kastenberg. *Graph-Based Software Specification and Verification*. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2008-27


M. de Mol. *Reasoning about Functional Programs: Sparkle, a proof assistant for*
Clean. Faculty of Science, Mathematics and Computer Science, RU. 2009-02

M. Lormans. Managing Requirements Evolution. Faculty of Electrical Engineering, Mathematics, and Computer Science, TUD. 2009-03


M.J. van Weerdenburg. Efficient Rewriting Techniques. Faculty of Mathematics and Computer Science, TU/e. 2009-06


A.L. Rodriguez Yakushev. Towards Getting Generic Programming Ready for Prime Time. Faculty of Science, UU. 2009-09

K.R. Olmos Joffré. Strategies for Context Sensitive Program Transformation. Faculty of Science, UU. 2009-10

J.A.G.M. van den Berg. Reasoning about Java programs in PVS using JML. Faculty of Science, Mathematics and Computer Science, RU. 2009-11

M.G. Khatib. MEMS-Based Storage Devices. Integration in Energy-Constrained Mobile Systems. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2009-12


M.R. Czenko. TuLiP - Reshaping Trust Management. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2009-16

T. Chen. Clocks, Dice and Processes. Faculty of Sciences, Division of Mathematics and Computer Science, VUA. 2009-17


R.S.S. O’Connor. Incompleteness & Completeness: Formalizing Logic and Analysis in Type Theory. Faculty of Science, Mathematics and Computer Science, RU. 2009-19

B. Ploeger. Improved Verification Methods for Concurrent Systems. Faculty of Mathematics and Computer Science, TU/e. 2009-20
T. Han. Diagnosis, Synthesis and Analysis of Probabilistic Models. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2009-21

R. Li. Mixed-Integer Evolution Strategies for Parameter Optimization and Their Applications to Medical Image Analysis. Faculty of Mathematics and Natural Sciences, UL. 2009-22

J.H.P. Kwisthout. The Computational Complexity of Probabilistic Networks. Faculty of Science, UU. 2009-23

T.K. Cocx. Algorithmic Tools for Data-Oriented Law Enforcement. Faculty of Mathematics and Natural Sciences, UL. 2009-24

A.I. Baars. Embedded Compilers. Faculty of Science, UU. 2009-25

M.A.C. Dekker. Flexible Access Control for Dynamic Collaborative Environments. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2009-26


C.J. Boogerd. Focusing Automatic Code Inspections. Faculty of Electrical Engineering, Mathematics, and Computer Science, TUD. 2010-01

M.R. Neuhäuser. Model Checking Nondeterministic and Randomly Timed Systems. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2010-02

J. Endrullis. Termination and Productivity. Faculty of Sciences, Division of Mathematics and Computer Science, VUA. 2010-03

T. Staijen. Graph-Based Specification and Verification for Aspect-Oriented Languages. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2010-04

Y. Wang. Epistemic Modelling and Protocol Dynamics. Faculty of Science, UvA. 2010-05

J.K. Berendsen. Abstraction, Prices and Probability in Model Checking Timed Automata. Faculty of Science, Mathematics and Computer Science, RU. 2010-06

A. Nugroho. The Effects of UML Modelling on the Quality of Software. Faculty of Mathematics and Natural Sciences, UL. 2010-07

A. Silva. Kleene Coalgebra. Faculty of Science, Mathematics and Computer Science, RU. 2010-08

J.S. de Bruin. Service-Oriented Discovery of Knowledge - Foundations, Implementations and Applications. Faculty of Mathematics and Natural Sciences, UL. 2010-09

D. Costa. Formal Models for Component Connectors. Faculty of Sciences, Division of Mathematics and Computer Science, VUA. 2010-10

M.M. Jaghoori. Time at Your Service: Schedulability Analysis of Real-Time and Distributed Services. Faculty of Mathematics and Natural Sciences, UL. 2010-11


B.J. Arnoldus. An Illumination of the Template Enigma: Software Code Generation with Templates. Faculty of Mathematics and Computer Science, TU/e. 2011-02

L. Astefanoaei. An Executable Theory of Multi-Agent Systems Refinement. Faculty of Mathematics and Natural Sciences, UL. 2011-04

J. Proença. Synchronous coordination of distributed components. Faculty of Mathematics and Natural Sciences, UL. 2011-05

A. Moralı. IT Architecture-Based Confidentiality Risk Assessment in Networks of Organizations. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2011-06

M. van der Bijl. On changing models in Model-Based Testing. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2011-07

C. Krause. Reconfigurable Component Connectors. Faculty of Mathematics and Natural Sciences, UL. 2011-08


M. Atif. Formal Modeling and Verification of Distributed Failure Detectors. Faculty of Mathematics and Computer Science, TU/e. 2011-10

P.J.A. van Tilburg. From Computability to Executability – A process-theoretic view on automata theory. Faculty of Mathematics and Computer Science, TU/e. 2011-11

Z. Protic. Configuration management for models: Generic methods for model comparison and model co-evolution. Faculty of Mathematics and Computer Science, TU/e. 2011-12


C.P. Tsirogiannis. Analysis of Flow and Visibility on Triangulated Terrains. Faculty of Mathematics and Computer Science, TU/e. 2011-16

Y.-J. Moon. Stochastic Models for Quality of Service of Component Connectors. Faculty of Mathematics and Natural Sciences, UL. 2011-17

R. Middelkoop. Capturing and Exploiting Abstract Views of States in OO Verification. Faculty of Mathematics and Computer Science, TU/e. 2011-18

M.F. van Amstel. Assessing and Improving the Quality of Model Transformations. Faculty of Mathematics and Computer Science, TU/e. 2011-19

A.N. Tamalet. Towards Correct Programs in Practice. Faculty of Science, Mathematics and Computer Science, RU. 2011-20

H.J.S. Basten. Ambiguity Detection for Programming Language Grammars. Faculty of Science, UvA. 2011-21
M. Izadi. Model Checking of Component Connectors. Faculty of Mathematics and Natural Sciences, UL. 2011-22

L.C.L. Kats. Building Blocks for Language Workbenches. Faculty of Electrical Engineering, Mathematics, and Computer Science, TUD. 2011-23

S. Kemper. Modelling and Analysis of Real-Time Coordination Patterns. Faculty of Mathematics and Natural Sciences, UL. 2011-24

J. Wang. Spiking Neural P Systems. Faculty of Mathematics and Natural Sciences, UL. 2011-25


A. Middelkoop. Inference of Program Properties with Attribute Grammars, Revisited. Faculty of Science, UU. 2012-02

Z. Hemel. Methods and Techniques for the Design and Implementation of Domain-Specific Languages. Faculty of Electrical Engineering, Mathematics, and Computer Science, TUD. 2012-03


S. Sedghi. Towards Provably Secure Efficiently Searchable Encryption. Faculty of Electrical Engineering, Mathematics & Computer Science, UT. 2012-05

F. Heidarian Dehkordi. Studies on Verification of Wireless Sensor Networks and Abstraction Learning for System Inference. Faculty of Science, Mathematics and Computer Science, RU. 2012-06


H. Rahmani. Analysis of Protein-Protein Interaction Networks by Means of Annotated Graph Mining Algorithms. Faculty of Mathematics and Natural Sciences, UL. 2012-09

S.D. Vermolen. Software Language Evolution. Faculty of Electrical Engineering, Mathematics, and Computer Science, TUD. 2012-10

L.J.P. Engelen. From Napkin Sketches to Reliable Software. Faculty of Mathematics and Computer Science, TU/e. 2012-11

F.P.M. Stappers. Bridging Formal Models – An Engineering Perspective. Faculty of Mathematics and Computer Science, TU/e. 2012-12

W. Heijstek. Software Architecture Design in Global and Model-Centric Software Development. Faculty of Mathematics and Natural Sciences, UL. 2012-13


### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADL</td>
<td>Architecture Description Language</td>
</tr>
<tr>
<td>BOA</td>
<td>Back Office Architect</td>
</tr>
<tr>
<td>BPMN</td>
<td>Business Process Model and Notation</td>
</tr>
<tr>
<td>CASE</td>
<td>Computer-Aided Software Engineering</td>
</tr>
<tr>
<td>CM</td>
<td>Change Management</td>
</tr>
<tr>
<td>CMMI</td>
<td>Capability Maturity Model Integration</td>
</tr>
<tr>
<td>CRS</td>
<td>Chain Referral Sampling</td>
</tr>
<tr>
<td>DSL</td>
<td>Domain-Specific Language</td>
</tr>
<tr>
<td>ERD</td>
<td>Entity-Relation Diagram</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>FOA</td>
<td>Front Office Architect</td>
</tr>
<tr>
<td>FTE</td>
<td>Full-Time Equivalent</td>
</tr>
<tr>
<td>GNU</td>
<td>GNU’s not Unix!</td>
</tr>
<tr>
<td>GQM</td>
<td>Goal-Question-Metric</td>
</tr>
<tr>
<td>GSD</td>
<td>Global Software Development</td>
</tr>
<tr>
<td>HR</td>
<td>Human Resources</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>MDA</td>
<td>Model-Driven Architecture</td>
</tr>
<tr>
<td>MDD</td>
<td>Model-Driven Development</td>
</tr>
<tr>
<td>MDE</td>
<td>Model-Driven Engineering</td>
</tr>
<tr>
<td>MOF</td>
<td>Meta Object Framework</td>
</tr>
<tr>
<td>OCL</td>
<td>Object Constraint Language</td>
</tr>
<tr>
<td>POC</td>
<td>Proof Of Concept</td>
</tr>
<tr>
<td>RFC</td>
<td>Request For Change</td>
</tr>
<tr>
<td>RUP</td>
<td>Rational Unified Process</td>
</tr>
<tr>
<td>SAD</td>
<td>Software Architecture Document</td>
</tr>
<tr>
<td>SCCMS</td>
<td>Software Configuration and Change Management System</td>
</tr>
<tr>
<td>SLA</td>
<td>Service-Level Agreement</td>
</tr>
<tr>
<td>SLOC</td>
<td>Source Lines of Code</td>
</tr>
<tr>
<td>SQL</td>
<td>Structured Query Language</td>
</tr>
<tr>
<td>SS</td>
<td>Supplementary Specification</td>
</tr>
<tr>
<td>SVN</td>
<td>Subversion</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
</tr>
<tr>
<td>XMI</td>
<td>XML Metadata Interchange</td>
</tr>
<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
</tr>
</tbody>
</table>