

## Contents

<b>I Motivation</b>	<b>25</b>
<b>1 Aligning organizational goals and technological infrastructure with model-driven software development</b>	<b>25</b>
1.1 The vision: software made in a way everyone can understand . . . . .	25
1.2 Describing organizations with enterprise models . . . . .	26
1.3 Enterprise information systems for supporting organizational tasks . . . . .	29
1.4 Business–IT alignment with methodical support . . . . .	32
1.5 Domain-specific software engineering approaches . . . . .	34
1.6 Deriving requirements towards enterprise information systems from enterprise models . . . . .	35
1.7 Structure of this work . . . . .	36
<b>2 An overview example: Online web-shop</b>	<b>37</b>
<b>II Approach</b>	<b>45</b>
<b>3 Concepts and terminology</b>	<b>45</b>
3.1 Modeling languages, meta-models and model instances . . . . .	45
3.2 Model transformations . . . . .	46
3.3 Validity checks . . . . .	51
3.4 Business process models and workflow models . . . . .	52
3.5 Resources and information objects . . . . .	54
3.6 Perceived type-instance blurring . . . . .	57
<b>4 Requirements towards an enterprise model driven engineering approach for enterprise information systems</b>	<b>60</b>
<b>5 Enterprise models for model-driven software engineering</b>	<b>67</b>
5.1 Organization theory concepts in enterprise modeling languages . . . . .	67
5.1.1 Actors . . . . .	67
5.1.2 Resources . . . . .	68
5.1.3 Interactions . . . . .	69

5.1.4	Business processes . . . . .	69
5.1.5	Strategy . . . . .	71
5.2	Model-driven software engineering as an act of interpretation . . . . .	71
5.2.1	Conceptual vagueness in domain-specific modeling languages and models . . . . .	71
5.2.2	Incorporating semi-formal interpretation transformations into model-driven software engineering with domain-specific models . . . . .	73
5.3	Related research and existing approaches . . . . .	73
5.3.1	Model-driven architecture (MDA) . . . . .	73
5.3.2	Rational Unified Process (RUP) . . . . .	75
5.3.3	Domain-specific software engineering . . . . .	76
5.3.4	Enterprise architecture . . . . .	79
5.3.5	Business process model execution . . . . .	79
5.3.6	Analyses of business process models . . . . .	81
5.3.7	Incorporating actor and resource models into software engineering	82
5.3.8	Strategic models for software engineering . . . . .	83
5.3.9	Process-centered software engineering environments (PCSEEs) . .	84
5.3.10	Self-referential enterprise information systems . . . . .	87
5.4	Deficiencies of existing approaches and contributions by the proposed method . . . . .	88

### **III A Domain-Specific Method for Model-Driven Software Engineering with Enterprise Models**

<b>6</b>	<b>Method constituents</b>	<b>93</b>
6.1	Overview . . . . .	93
6.1.1	Internal enterprise model representation language . . . . .	93
6.1.2	Implementation strategies and mapping model . . . . .	94
6.1.3	Model transformations . . . . .	94
6.1.4	Validity checks . . . . .	94
6.1.5	APIs . . . . .	94
6.1.6	Code generation templates . . . . .	95
6.1.7	Tooling support . . . . .	95
6.1.8	Overview on the methodical procedure . . . . .	95

6.2	Models and modeling languages . . . . .	98
6.2.1	Enterprise models and their internal representation . . . . .	99
6.2.2	Mapping model . . . . .	108
6.2.3	Implementation strategy models and corresponding modeling languages . . . . .	118
6.3	Model transformations . . . . .	119
6.3.1	Adapter transformation for enterprise models . . . . .	120
6.3.2	Mapping model initialization transformation . . . . .	121
6.3.3	Artifact generation and alternative approaches . . . . .	123
6.4	Validity checks . . . . .	124
6.4.1	Validity check for enterprise models . . . . .	125
6.4.2	Validity check for the mapping model . . . . .	126
6.5	Domain APIs for EIS . . . . .	127
<b>7</b>	<b>Applying the method</b>	<b>131</b>
7.1	Applying the method to enterprise information system development . . . . .	131
7.1.1	Step 1: Create and edit enterprise models . . . . .	131
7.1.2	Step 2: Transform enterprise models to a internal representation . . . . .	132
7.1.3	Step 3: Check validity of the enterprise model representation . . . . .	133
7.1.4	Step 4: Initialize or update the mapping model and the implementation strategy models . . . . .	133
7.1.5	Step 5: Manually edit the mapping model and the implementation strategy models . . . . .	134
7.1.6	Step 6: Check validity of the mapping model and the implementation strategy models . . . . .	135
7.1.7	Step 7: Generate deployable artifacts . . . . .	135
7.2	Configuring the method to be used with a specific enterprise modeling language . . . . .	136
7.2.1	Step 1: Identify language concepts equivalent in EML and EEM . . . . .	137
7.2.2	Step 2: Implement transformation rules for equivalent language concepts . . . . .	137
7.2.3	Step 3: Formulate hints to express other EEM concepts in EML . . . . .	137
7.2.4	Step 4: Implement transformation rules for other language concepts via hints . . . . .	139
7.3	Configuring the method for specific target architectures . . . . .	140
7.3.1	Step 1: Conceptualize a target architecture API . . . . .	141

7.3.2	Step 2: Implement the target architecture API . . . . .	142
7.3.3	Step 3: Meta-model architecture-specific process-step implementation strategy types . . . . .	142
7.3.4	Step 4: Meta-model architecture-specific event implementation strategy types . . . . .	143
7.3.5	Step 5: Meta-model architecture-specific actor implementation strategy types . . . . .	144
7.3.6	Step 6: Meta-model architecture-specific resource implementation strategy types . . . . .	145
7.3.7	Step 7: Meta-model architecture-specific information resource implementation strategy types . . . . .	146
7.3.8	Step 8: Meta-model architecture-specific sequence implementation strategy types . . . . .	148
7.3.9	Step 9: Conceptualize hints at choosing default implementation strategies . . . . .	148
7.3.10	Step 10: Implement hints at choosing default implementation strategies . . . . .	149
7.3.11	Step 11: Implement code generation templates for generic implementation strategies . . . . .	150
7.3.12	Step 12: Implement code generation templates for architecture-specific implementation strategies . . . . .	152
<b>8</b>	<b>Design of a prototypical enterprise information system</b>	<b>162</b>
8.1	General architectural design considerations . . . . .	163
8.1.1	Coordination in a distributed environment . . . . .	163
8.1.2	Realizing data storages . . . . .	165
8.1.3	Automatically executed process-steps . . . . .	166
8.2	User interface sketch . . . . .	166
8.2.1	Process instance management functionality . . . . .	167
8.2.2	Process-step editor functionality . . . . .	168
8.2.3	Information access and document editing functionality . . . . .	168
8.2.4	Manual task handling functionality . . . . .	169
8.2.5	Decision functionality . . . . .	169
8.2.6	Communication functionality . . . . .	170
8.2.7	Project specific functionality . . . . .	171
8.3	Abstract domain API . . . . .	171

8.3.1	Front-end API interfaces . . . . .	172
8.3.2	Back-end API interfaces . . . . .	175
<b>9</b>	<b>Example implementation strategies</b>	<b>180</b>
9.1	Implementation strategies for process-members . . . . .	180
9.1.1	Interactive process-steps . . . . .	180
9.1.2	Additional high-level process-member implementation strategies .	184
9.1.3	Automatic process-steps . . . . .	186
9.1.4	Event implementation strategies . . . . .	189
9.1.5	Sequence implementation strategies . . . . .	190
9.2	Implementation strategies for actors . . . . .	196
9.3	Resource implementation strategies . . . . .	197
9.3.1	Information resource implementation strategies . . . . .	198
9.3.2	Software resource implementation strategies . . . . .	202
9.3.3	Physical resource implementation strategies . . . . .	204
9.3.4	Resource access implementation strategies . . . . .	205

## **IV Applying the Method: Prototypical Design and Implementation** **213**

<b>10</b>	<b>Example scenario of a BPEL-orchestrated SOA target application architecture</b>	<b>213</b>
10.1	Application scenario in the food supply chain domain . . . . .	213
10.2	Domain-specific language for supply chain modeling . . . . .	214
10.3	A distributed service oriented architecture (SOA) . . . . .	216
10.4	Implementation strategy meta-model for a SOA platform . . . . .	216
10.5	Executable BPEL workflow . . . . .	220
10.6	Overall implemented example . . . . .	225
<b>11</b>	<b>MEMO enterprise models for developing JSP web applications</b>	<b>228</b>
11.1	Adapting the MEMO enterprise modeling method . . . . .	228
11.1.1	The MEMO language family as input enterprise modeling languages	228
11.1.2	MEMOCENTERNG as editor application . . . . .	228
11.1.3	Adapter transformation to configure the method for the MEMO language family . . . . .	229

11.2	Configuring a JSP web-application target architecture . . . . .	230
11.2.1	Example implementation strategy meta-model for a JSP web-application platform . . . . .	230
<b>12</b>	<b>Code generation and tooling support</b>	<b>233</b>
12.1	Deriving executable artifacts . . . . .	233
12.2	Code generation templates . . . . .	234
12.3	Requirements towards tooling support . . . . .	235
12.4	Enterprise modeling with the MEMOCENTERNG platform . . . . .	236
12.5	Tooling on top of the ECLIPSE MODELING FRAMEWORK (EMF) . . . . .	237
12.5.1	Mapping model editor . . . . .	237
12.5.2	Implementation strategy meta-modeling with ECORE . . . . .	238
12.5.3	Model-to-model transformations with the XTEND language . . . . .	238
12.5.4	Model-checking with the CHECK language . . . . .	240
12.5.5	Code generation with XPAND templates . . . . .	240
12.5.6	GUI components to invoke the transformation steps in the method	242
12.5.7	EEM model editor for test purposes . . . . .	243
<b>V</b>	<b>Reflection</b>	<b>245</b>
<b>13</b>	<b>Evaluation</b>	<b>245</b>
<b>14</b>	<b>Remaining Work</b>	<b>255</b>
<b>A</b>	<b>Example software artifacts</b>	<b>257</b>
A.1	Source code packages of the provided examples . . . . .	257
A.1.1	Package de.gulden.modeling.seem.eem . . . . .	257
A.1.2	Package de.gulden.modeling.seem.generator . . . . .	258
A.1.3	Package de.gulden.modeling.seem.generator.memo . . . . .	258
A.1.4	Package de.gulden.modeling.seem.generator.ui . . . . .	258
A.1.5	Package de.gulden.modeling.seem.mapping . . . . .	258
A.1.6	Package de.gulden.modeling.seem.workflow . . . . .	258
A.1.7	Package de.gulden.modeling.seem.architecture.web . . . . .	259
A.1.8	Package de.gulden.server.xmldb . . . . .	259
A.1.9	Package org.rescueit.modeling.targetarchitecture . . . . .	259

A.1.10 Package <code>org.rescueit.modeling.workflow</code> . . . . .	259
A.1.11 Package <code>de.gulden.modeling.seem.api.web</code> . . . . .	260
A.1.12 Package <code>de.gulden.modeling.seem.example.webshop</code> . .	260
A.1.13 Package <code>webshop</code> . . . . .	260
A.2 Example artifacts overview . . . . .	260
A.3 Introductory example artifacts . . . . .	264
A.3.1 Adaptation to the MEMO enterprise modeling languages . . . . .	265
A.3.2 Mapping model handling . . . . .	270
A.3.3 Code generation . . . . .	278
A.3.4 Generated example artifact . . . . .	290
A.3.5 Modeling conventions to incorporate additional semantics into the enterprise models . . . . .	292
A.4 Artifacts of the comprehensive example . . . . .	294
A.4.1 Adaptation to a domain-specific supply chain modeling language	294
A.4.2 Mapping model handling . . . . .	296
A.4.3 Code generation . . . . .	300
A.4.4 Input model and generated example artifacts . . . . .	305