

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Introduction to Graph and Model Transformation, and Related Work</b>	<b>7</b>
2.1	Model Transformation . . . . .	7
2.2	Graph Transformation . . . . .	9
2.3	Model Transformation Based on Graph Transformation . . . . .	14
<b>3</b>	<b><math>\mathcal{M}</math>-Adhesive Transformation Systems</b>	<b>19</b>
3.1	Graphs, Typed Graphs, and Typed Attributed Graphs . . . . .	20
3.2	$\mathcal{M}$ -Adhesive Categories . . . . .	22
3.2.1	Introduction to $\mathcal{M}$ -Adhesive Categories . . . . .	22
3.2.2	Construction of $\mathcal{M}$ -Adhesive Categories . . . . .	26
3.2.3	Preservation of Additional Properties via Constructions	28
3.2.3.1	Binary Coproducts . . . . .	28
3.2.3.2	Epi- $\mathcal{M}$ Factorization . . . . .	30
3.2.3.3	$\mathcal{E}'$ - $\mathcal{M}'$ Pair Factorization . . . . .	30
3.2.3.4	Initial Pushouts . . . . .	34
3.3	Algebraic High-Level Petri Nets . . . . .	40
3.4	Transformations in $\mathcal{M}$ -Adhesive Systems . . . . .	46
3.4.1	Conditions and Constraints over Objects . . . . .	47
3.4.2	Rules and Transformations . . . . .	49
3.4.3	Main Analysis Results in $\mathcal{M}$ -Adhesive Transformation Systems . . . . .	51
3.4.3.1	Local Church-Rosser and Parallelism Theorem	51
3.4.3.2	Concurrency Theorem . . . . .	53
3.4.3.3	Embedding and Extension Theorem . . . . .	55
3.4.3.4	Critical Pairs and Local Confluence Theorem	57
<b>4</b>	<b>Amalgamated Transformations</b>	<b>61</b>
4.1	Foundations and Analysis of Amalgamated Transformations .	61
4.1.1	Kernel, Multi, and Complement Rules . . . . .	62

4.1.2	Amalgamated Rules and Transformations . . . . .	69
4.1.3	Parallel Independence of Amalgamated Transforma-	
tions . . . . .		81
4.1.4	Other Results for Amalgamated Transformations . .	87
4.1.5	Interaction Schemes and Maximal Matchings . . . .	88
4.1.6	Main Results for Amalgamated Transformations Based	
	on Maximal Matchings . . . . .	91
4.2	Operational Semantics Using Amalgamation . . . . .	93
4.2.1	Semantics for Elementary Nets . . . . .	93
4.2.2	Syntax of Statecharts . . . . .	98
4.2.3	Semantics for Statecharts . . . . .	104
<b>5</b>	<b>Model Transformation Based on Triple Graph Transfor-</b>	
	<b>mation</b>	<b>115</b>
5.1	Introduction to Triple Graph Transformation . . . . .	115
5.1.1	The Category of Triple Graphs . . . . .	116
5.1.2	Triple Graph Transformation . . . . .	117
5.2	Triple Graph Transformation with Application Conditions .	119
5.2.1	<i>S</i> - and <i>T</i> -Consistent Application Conditions . . . .	120
5.2.2	Composition and Decomposition of Triple Transfor-	
	mations . . . . .	131
5.3	Model Transformation SC2PN from Statecharts to Petri Nets .	136
<b>6</b>	<b>Analysis, Correctness, and Construction of Model Transfor-</b>	
	<b>mations</b>	<b>153</b>
6.1	Syntactical Correctness . . . . .	154
6.2	Termination and Functional Behavior . . . . .	156
6.2.1	Termination . . . . .	156
6.2.2	Termination of Statecharts Semantics . . . . .	157
6.2.3	Functional Behavior . . . . .	159
6.3	Semantical Simulation and Correctness . . . . .	161
6.3.1	Simulation of Petri Nets . . . . .	163
6.3.2	Semantical Correctness of the Model Transformation	
	SC2PN . . . . .	165
6.4	On-the-Fly Construction of Model Transformations . . . .	173
<b>7</b>	<b>Conclusion and Future Work</b>	<b>181</b>
7.1	Theoretical Contributions . . . . .	181
7.2	Relevance for Model-Driven Software Development . . . .	183

Contents	XIII
7.3 Case Studies . . . . .	185
7.4 Tool Support . . . . .	186
7.5 Future Work . . . . .	188
<b>Appendix</b>	<b>191</b>
<b>A Categorical Results</b>	<b>193</b>
A.1 Proofs for Construction of $\mathcal{M}$ -Adhesive Categories . . . . .	193
A.2 Proofs for Generalized AHL Schemas as an $\mathcal{M}$ -Adhesive Category . . . . .	195
A.3 Proofs for AHL Systems as an $\mathcal{M}$ -adhesive Category . . . . .	197
A.3.1 The Category of Markings . . . . .	197
A.3.2 From Nets to Net Systems . . . . .	201
A.4 Proofs for Amalgamated Transformations . . . . .	203
<b>Bibliography</b>	<b>211</b>
<b>Index</b>	<b>223</b>