

Contents

Part I Programming with Conceptual Models

1	Conceptual-Model Programming: A Manifesto	3
	David W. Embley, Stephen W. Liddle, and Óscar Pastor	
1.1	Preamble	3
1.2	CMP Articles	4
1.3	Exposition	4
1.3.1	Executable Conceptual Models	4
1.3.2	Conceptual Modeling and CMP	10
	Appendage	13
	References	15
2	Model-Driven Software Development	17
	Stephen W. Liddle	
2.1	Introduction	17
2.2	Overview of Model-Driven Approaches	18
2.3	Modeling	21
2.4	Software Modeling	23
2.5	OSM: Making Conceptual Models Formal and Executable	25
2.6	Model-Driven Architecture (MDA)	29
2.6.1	MDA Overview	30
2.6.2	An MDA Manifesto	32
2.6.3	Executable UML	34
2.6.4	MDA Readings	36
2.7	OO-Method	37
2.8	Model-Driven Web Engineering (MDWE)	40
2.9	Agile MDD	43
2.10	Conclusions	45
	References	47

Part II Structure Modelling

3	Entity-Relationship Model (Reprinted Historic Data)	57
	Peter P.-S. Chen	
3.1	Introduction	57
3.2	The Entity-Relationship Model	58
3.2.1	Multilevel Views of Data	58
3.2.2	Information Concerning Entities and Relationships (Level 1)	58
3.2.3	Information Structure (Level 2)	62
3.3	Entity-Relationship Diagram and Inclusion of Semantics in Data Description and Manipulation	67
3.3.1	System Analysis Using the Entity-Relationship Diagram	67
3.3.2	An Example of a Database Design and Description	68
3.3.3	Implications on Data Integrity	70
3.3.4	Semantics and Set Operations of Information Retrieval Requests	71
3.3.5	Semantics and Rules for Insertion, Deletion, and Updating	73
3.4	Analysis of Other Data Models and Their Derivation from the Entity-Relationship Model	73
3.4.1	The Relational Model	73
3.4.2	The Network Model	77
3.4.3	The Entity Set Model	80
	References	83
4	UML and OCL in Conceptual Modeling	85
	Martin Gogolla	
4.1	Introduction	85
4.2	Basic Conceptual Modeling Features in UML	86
4.2.1	Class and Object Diagrams	86
4.2.2	Object Constraint Language	89
4.3	Advanced Conceptual Schema Elements in UML	95
4.3.1	Class Diagram Features for Conceptual Schemas	96
4.3.2	Representation of Standard ER Modeling Concepts	102
4.4	Employing OCL for Conceptual Schemas	104
4.4.1	Standard ER Concepts Expressed with OCL	104
4.4.2	Constraints and Stereotypes	105
4.4.3	Queries	108
4.5	Describing Relational Schemas with UML	109
4.5.1	Relational Schemas	109
4.5.2	Constraints for Primary and Foreign Keys	110
4.6	Metamodeling Data Models with UML	111
4.6.1	Class Diagram	111
4.6.2	Object Diagrams	115

4.6.3	Constraints	116
4.7	Further Related Work	118
4.8	Conclusions	119
	Appendix A: Original ER Diagram from Chen's Paper	120
	References	121
5	Mapping Conceptual Models to Database Schemas	123
	David W. Embley and Wai Yin Mok	
5.1	Introduction	123
5.2	Entity-Relationship Model Mappings	124
5.2.1	Basic Mappings	124
5.2.2	Complex Key Attributes	129
5.2.3	Recursive Relationship Sets and Roles	131
5.2.4	Weak Entity Sets	133
5.3	Extended Entity-Relationship Model Mappings	135
5.3.1	ISA Mappings	135
5.3.2	Mappings for Complex Attributes	139
5.3.3	Mappings for Mandatory/Optional Participation	142
5.4	UML Mappings	145
5.5	Normal-Form Guarantees	149
5.5.1	Map – Then Normalize	151
5.5.2	Normalize – Then Map	152
5.6	Mappings for Object-Based and XML Databases	157
5.7	Additional Readings	162
	References	163
6	The Enhanced Entity-Relationship Model	165
	Bernhard Thalheim	
6.1	Database Design	165
6.1.1	Database Design and Development	165
6.1.2	Implicit Assumptions and Inherent Constraints of Database Specification Languages	167
6.1.3	Storage and Representation Alternatives	168
6.1.4	The Higher-Order Entity-Relationship Model	170
6.2	Syntax of EER Models	171
6.2.1	Structuring Specification	171
6.2.2	Functionality Specification	182
6.2.3	Views in the Enhanced Entity-Relationship Models	188
6.2.4	Advanced Views and OLAP Cubes	190
6.3	Semantics of EER Models	193
6.3.1	Semantics of Structuring	193
6.3.2	Semantics of Functionality	201
6.4	Problems with Modelling and Constraint Specification	203
	References	205

Part III Process Modelling

7	Object–Process Methodology for Structure–Behavior Codesign	209
	Dov Dori	
7.1	The Cognitive Assumptions and OPM’s Design	209
7.1.1	Mayer’s Three Cognitive Assumptions	210
7.1.2	Meeting the Verbal–Visual Challenge	211
7.1.3	Dual-Channel Processing and the Bimodality of OPM	211
7.1.4	Limited Capacity and the Refinement Mechanisms of OPM	214
7.1.5	Active Processing and the Animated Simulation of OPM	215
7.2	Function, Structure, and Behavior: The Three Major System Aspects	216
7.2.1	Function vs. Behavior	218
7.2.2	Ontology	219
7.3	The OPM Ontology	220
7.3.1	Entities: Objects, Processes, and Object States	221
7.4	Existence, Things, and Transformations	222
7.4.1	Physical and Informatical Objects	222
7.4.2	Object Defined	223
7.4.3	Process as a Transformation Metaphor	223
7.4.4	Process Defined	224
7.4.5	Cause and Effect	225
7.5	Syntax vs. Semantics	226
7.5.1	Objects to Semantics Is Like Nouns to Syntax	226
7.5.2	Syntactic vs. Semantic Sentence Analysis	227
7.6	The Process Test	227
7.6.1	The Preprocess Object Set and Object Involvement	228
7.6.2	The Postprocess Object Set and Object Transformation	228
7.6.3	Association with Time	229
7.6.4	Association with Verb	230
7.6.5	Boundary Cases of Objects and Processes	230
7.6.6	Thing Defined	232
7.6.7	States	233
7.6.8	Things and States Are Entities, Entities and Links are Elements	234
7.7	A Reflective Metamodel of OPM Elements	235
7.7.1	An Initial OPM Reflective Metamodel	235
7.7.2	The OPM Graphics–Text Equivalence Principle	236
7.7.3	The Five Basic Thing Attributes	236
7.8	OPM Links	238
7.8.1	Structural Links	238
7.8.2	Procedural Links	240
7.9	OPM Structure Modeling	240
7.9.1	Aggregation–Participation	242

7.9.2	Generalization–Specialization	243
7.9.3	Exhibition–Characterization	244
7.9.4	Classification–Instantiation	244
7.10	OPM Behavior Modeling	245
7.10.1	Enabling Links	245
7.10.2	Transforming Links	247
7.10.3	Control Links	249
7.11	Complexity Management	251
7.11.1	The Need for Complexity Management	252
7.11.2	Middle-Out as the De Facto Architecting Practice	253
7.11.3	The Completeness-Comprehension Dilemma	255
7.12	Applications and Standardization of OPM	255
	References	256
8	Business Process Modeling and Workflow Design	259
	Horst Pichler and Johann Eder	
8.1	Introduction	259
8.1.1	Business Process Modeling and Workflow Design	260
8.1.2	Business Process Modeling Versus Workflow Design	260
8.1.3	Workflow Characteristics	261
8.2	An Overview of Process Modeling	262
8.2.1	Process Perspectives	262
8.2.2	Process Modeling Techniques	264
8.2.3	Standardization Efforts	265
8.3	Modeling Process Perspectives	266
8.3.1	Control Flow Perspective	266
8.3.2	Organizational Perspective	268
8.3.3	Data Perspective	271
8.4	Detection and Avoidance of Control Flow Errors	274
8.4.1	Control Flow Errors	274
8.4.2	Blocked Structures	275
8.4.3	Sound Processes	276
8.5	Process Views	278
8.5.1	Process Graph	279
8.5.2	Correctness of Process Views	279
8.5.3	Generation of Process Views by Activity Elimination	279
8.6	Timed Processes	280
8.6.1	Modeling the Temporal Perspective	281
8.6.2	Timed Graph	282
8.7	Conclusions	284
	References	285

9	BPMN Core Modeling Concepts:	
	Inheritance-Based Execution Semantics	287
	Egon Börger, Ove Sörensen	
9.1	Introduction	287
9.2	Structure of the Class Hierarchy of BPMN 2.0	289
	9.2.1 Message Flow	289
	9.2.2 Diagram Structure (Sequence Flow)	289
	9.2.3 Flow Nodes	291
9.3	Gateways	292
	9.3.1 Parallel Gateway (Fork and Join)	294
	9.3.2 Exclusive Gateway (Data-Based Exclusive Decision)	294
	9.3.3 Inclusive Gateway	295
	9.3.4 Event-Based Gateway (Event-Based Exclusive Decision)	296
	9.3.5 Complex Gateway	299
9.4	Activities	301
	9.4.1 Tasks	303
	9.4.2 Subprocesses	305
	9.4.3 Call Activity	309
	9.4.4 Iterated (Loop) Activities	309
9.5	Events	312
	9.5.1 Start Events	313
	9.5.2 End Events	314
	9.5.3 Intermediate Events	316
	9.5.4 Boundary Events	319
9.6	An Example	320
9.7	Conclusion	322
	Appendix	323
	9.7.1 Gateway Behavior	323
	9.7.2 Activity Behavior	326
	9.7.3 Event Behavior	329
	References	332

Part IV User Interface Modelling

10	Conceptual Modelling of Interaction	335
	Nathalie Aquino, Jean Vanderdonckt, José Ignacio Panach, and Óscar Pastor	
10.1	Introduction	336
10.2	Related Work	338
10.3	The Presentation Model of OO-Method	341
	10.3.1 Elementary Patterns	342
	10.3.2 Interaction Units	343
	10.3.3 Hierarchical Action Tree	346

10.4	Explicitly Distinguishing Abstract and Concrete Interaction Modeling in OO-Method	347
10.4.1	Abstract Interaction Modeling	347
10.4.2	Concrete Interaction Modeling: Transformation Templates	347
10.5	Conclusion	352
	References	356
11	Conceptual Modelling of Application Stories	359
	Antje Düsterhöft, Klaus-Dieter Schewe	
11.1	Introduction	359
11.2	The Conceptual Model of Storyboarding	360
11.2.1	The Storyboard	361
11.2.2	Plots	365
11.3	Pragmatics of Storyboarding	367
11.3.1	Life Cases	367
11.3.2	User Modelling	369
11.3.3	Contexts	371
11.4	Analysis of Storyboards	372
11.4.1	Customisation with Respect to Preferences	372
11.4.2	Deontic Consistency	374
11.5	Bibliographic Remarks	375
	References	376
 Part V Special Challenge Area		
12	Evolution and Migration of Information Systems	381
	Meike Klettke, Bernhard Thalheim	
12.1	Introduction	382
12.1.1	Information System Modernisation	382
12.1.2	Models for Information Systems	382
12.2	Overview of System Modernisations	384
12.2.1	Fundamental Terms	384
12.2.2	Migration, Evolution, and Legacy	385
12.2.3	Evolving Information Systems	386
12.3	Foundations of Evolution and Migration Transformations	388
12.3.1	Specification of Information System Models	388
12.3.2	Model Construction and Combination	391
12.3.3	Evolving Information Systems	393
12.3.4	Properties of Evolving Information Systems	395
12.4	Strategies for Migration	398
12.4.1	Big Bang	399
12.4.2	Chicken Little	402
12.4.3	Butterfly	405
12.5	Evolution	409
12.5.1	Evolution on a Small Scale	409

12.5.2	Wrapper-Based Evolution	412
12.5.3	Refinement of the Information System Model	415
12.6	Related Work	417
	References	417
13	Conceptual Geometric Modelling	421
	Hui Ma and Klaus-Dieter Schewe	
13.1	Introduction	421
13.2	Spatial Data Models	424
13.3	Geometrically Enhanced ER Model (GERM)	426
13.3.1	Data Types and Nested Attributes	426
13.3.2	Entity and Relationship Types	427
13.3.3	Schemata and Instances	429
13.4	Geometric Types and Algebraic Varieties	429
13.4.1	Natural Modelling Algebra	431
13.4.2	Computing with Polyhedra and Surface Representations	432
13.4.3	The Choice of the Natural Modelling Function	434
13.5	Key Application Area GIS	434
13.6	Conclusion	438
	References	439
14	Data Integration	441
	Sonia Bergamaschi et al.	
14.1	Outcomes and Challenges in Data Integration	441
14.1.1	Mediator-Based Systems	445
14.2	The MOMIS Integration Framework	456
14.2.1	The MOMIS Integration System	456
14.2.2	Global Schema Generation	457
14.2.3	Global Schema Refinement	460
14.2.4	Querying the MOMIS System	466
14.2.5	New Trends in the MOMIS System	471
14.3	Conclusions	472
	References	472
15	Conceptual Modeling Foundations for a Web of Knowledge	477
	David W. Embley, Stephen W. Liddle and Deryle W. Lonsdale	
15.1	Introduction	477
15.2	WoK Conceptualization	479
15.3	WoK Formalization	484
15.4	WoK Construction	488
15.4.1	Construction via XML Reverse Engineering	489
15.4.2	Construction via Nested Table Interpretation	490
15.4.3	Construction via Semantic Integration	493
15.4.4	Construction via Form Filling	501
15.5	WoK Usage	502

15.5.1	Free-Form Query Processing	503
15.5.2	Grounded Reasoning Chains	505
15.5.3	Knowledge Bundles for Research Studies	508
15.6	Conclusion	511
	References	513
16	A Conceptual Modeling Approach to Improve Human Genome Understanding	517
	Oscar Pastor et al.	
16.1	Introduction	517
16.2	Why a Conceptual Model for the Human Genome?	519
16.3	Models: Explaining the Domain	521
16.4	Existing Modeling/Ontology-Based Approaches	527
16.5	Results of Conceptual Modeling	530
16.6	Problem Statement and Conclusions	537
	References	538
17	The Theory of Conceptual Models, the Theory of Conceptual Modelling and Foundations of Conceptual Modelling	543
	Bernhard Thalheim	
17.1	Towards a Theory of Conceptual Models and Conceptual Modelling	543
17.1.1	Artifacts, Concepts and Intentions	545
17.1.2	Dimensions of Models and Modelling	547
17.1.3	Postulates of Modelling	552
17.1.4	Artifacts and Models	554
17.2	The Theory of Conceptual Models	555
17.2.1	Conceptual Models and Languages	555
17.2.2	Concepts and Models	562
17.2.3	Information Exchange of Stakeholders Based on Models	564
17.2.4	Mappings Among Models and Originals	566
17.2.5	Development Phases That Use Models	570
17.2.6	Properties of the Models-Origin and the Models-Reflections Analogies	573
17.3	Conclusion	575
	References	576
Index		579