

Contents

List of Contributors	xv
-----------------------------	-----------

I Introduction	1
-----------------------	----------

1 The Object Paradigm	3
1.1 The Ubiquitous Object	3
1.1.1 Active Objects	4
1.2 Defining the Object Concept	5
1.3 Objects in Software	6
1.4 Object Classes	7
1.4.1 Class Hierarchies and Inheritance of Properties	9
1.4.2 Multiple Inheritance	10
1.5 Clientship	11
1.5.1 Polymorphic Substitutability	12
1.5.2 Abstract Classes and Dynamic Binding	13
1.5.3 Abstract Interfaces	14
1.5.4 Aggregation	15
1.5.5 Reuse	15
1.6 Conclusion	16
2 Formality in Object Technology	17
2.1 Formal Methods Concepts	17
2.2 Formal Methods in Object Technology	21
2.3 Object Technology in Formal Methods	24
2.4 Formal Underpinnings	26
2.5 Concurrency	28
2.6 Conclusions	29

II Formal Methods in Object Technology	31
---	-----------

3 LOTOS in the Object-Oriented Analysis Process	33
3.1 Introduction	33
3.2 Reasons for Choosing LOTOS	34

3.3	The ROOA Method	35
3.4	Structuring Specifications	41
3.4.1	Aggregation	41
3.4.2	Behavioural Inheritance	43
3.5	Conclusions	46
4	The Impact of Inheritance on Software Structure	47
4.1	Introduction	47
4.2	Multiple Inheritance Hierarchies	49
4.3	Type-Module Hierarchies	50
4.4	A Model Of Multiple Inheritance Hierarchies	51
4.4.1	Basic Definitions	51
4.4.2	Discussion: Assumptions in the Model	53
4.5	A Model of Type-Module Hierarchies	53
4.5.1	Basic Definitions	53
4.5.2	Discussion: From Inheritance to Module Hierarchies	55
4.5.3	Discussion: Language Issues	56
4.6	Relating Multiple Inheritance and Module Hierarchies	57
4.7	Summary & Conclusions	58
III	Object Technology in Formal Methods	61
5	D_Parlog⁺⁺: Object-Oriented Logic Programming with Distributed Active Classes	63
5.1	Introduction	63
5.2	Informal Computation Model of D_Parlog ⁺⁺	64
5.3	An Introductory Example	66
5.3.1	State Declaration and State Variables	68
5.3.2	Method Declaration	70
5.4	Communication Between Objects	73
5.4.1	Atomic Transactions	73
5.4.2	Self Communications	74
5.5	Inheritance and Delegation of Classes	77
5.5.1	Super Communication	81
5.5.2	Self Communication in an Inheritance Hierarchy	82
5.6	Concluding Remarks	84
6	Concurrency and Real-time in VDM⁺⁺	86
6.1	Concurrency and Object Structuring	86
6.1.1	Why Concurrency	86
6.2	The world model	87
6.3	Synchronisation and threads in VDM ⁺⁺	88
6.4	Describing the behaviour of active objects	88
6.4.1	A new look at the Dining Philosophers	90
6.5	Concurrency and Contention	91

6.5.1	Declarative synchronization control (permission predicates)	92
6.5.2	Example of a Passive Class	95
6.5.3	A return to the Dining Philosophers	97
6.6	Other Ways of Expressing Synchronisation	99
6.6.1	Traces	99
6.7	Feasibility and the periodic obligation	100
6.8	Specifying Real-time systems	101
6.8.1	Real-time requirements engineering	101
6.9	Language facilities	102
6.9.1	The notion of time	102
6.10	Continuous models	104
6.10.1	Continuous time variables	104
6.11	Continuous classes	105
6.11.1	An example of a continuous model.	106
6.11.2	Subclasses of Component	107
6.12	The principle of discretising	109
6.12.1	Reasoning about sampling	112
6.13	Synchronising the components	112
7	Integrating Formal and Structured Methods in Object-Oriented System Development	113
7.1	B Abstract Machine Notation	114
7.2	Representation of Data Models	117
7.3	Representation of Dynamic Models	120
7.3.1	Process Model for Formalisation	120
7.4	Alternative State Representation	122
7.4.1	Comparison	122
7.4.2	Alarmclocks	123
7.5	Ship Load Planning	126
7.5.1	Results	145
7.6	Formalisation of Dynamic Models: A Lift System	146
7.6.1	From Analysis to Specification	149
7.6.2	Applications of Formalisation	156
8	Introducing Object-Oriented Concepts into a Net-Based Hierarchical Software Development Process	158
8.1	Introduction	158
8.2	Channel/Agency Nets	160
8.2.1	General Presentation	160
8.2.2	Techniques for the Use of CA Nets	161
8.3	General Object Concepts and Characteristics	162
8.4	The O-CA Net Model	164
8.4.1	Integration Methods	165
8.4.2	Description of Object Concepts in O-CA Nets	165
8.4.3	Structure Rules and Transformation Rules of O-CA Nets	170
8.5	O-CA Nets and PROOFS Method	172

8.5.1	Use of O-CA Nets	173
8.5.2	Link from O-CA Nets to PN's and CPN's	174
8.6	Example	175
8.7	Conclusion	179
IV	Formal Foundations of Object Technology	181
9	Design Structures for Object-Based Systems	183
9.1	Introduction	183
9.2	Temporal Specification of Objects	185
9.3	Interconnecting Objects	190
9.4	Interfacing: Action Calling	193
9.5	Abstraction: Object Calling	198
9.6	Concluding Remarks	203
10	Interconnection of Object Specifications	205
10.1	Some Preliminaries	208
10.1.1	Categories	208
10.1.2	Functors and Natural Transformations	210
10.1.3	Limits	211
10.1.4	Monoids	213
10.1.5	Right Actions of Monoids	214
10.1.6	Sheaves	215
10.2	Process Classes	217
10.3	Object Specification	219
10.4	System Specification	222
10.5	Some Speculations	225
11	Refinement of Concurrent Object-Oriented Programs	227
11.1	Overview of FOOPS	228
11.1.1	Functional Level	228
11.1.2	Object Level	230
11.2	Refinement for FOOPS	233
11.2.1	Simulations	235
11.2.2	Refinement of States	239
11.2.3	Refinement of Expressions	240
11.2.4	Refinement of Specifications	241
11.3	Proving Refinement	242
11.3.1	Memory Cells	242
11.3.2	Buffers	248
11.3.3	Laws of FOOPS Method Combiners	256
11.4	Aspects Considered by Refinement	258
11.5	Conclusions	259

12 Static Typing for Object-Oriented Languages	262
12.1 Introduction	262
12.2 Subclasses and Subtypes	263
12.2.1 Type vs. Class	263
12.2.2 Subtype vs. Subclass	264
12.2.3 ST&T: An Example	267
12.3 Types in ST&T	270
12.3.1 Some Subclass Relationships in Smaltalk	271
12.3.2 Object Types	271
12.3.3 The Subtype Relationship	272
12.3.4 Method Signatures	273
12.3.5 Receiver Type, Argument Type, Application of a Signature	274
12.3.6 Method Types	275
12.4 Type Rules in ST&T	275
12.4.1 The Environment	275
12.4.2 Type Checking Classes	276
12.4.3 Types of Assignments	277
12.4.4 Types of Return Expressions	277
12.4.5 Types of Message Expressions	277
12.5 Discussion, Implementation, Soundness	282
12.6 Conclusions and Further Work	285
13 A Note on the Semantics of Inclusion Polymorphism	287
13.1 The Concept of Inclusion Polymorphism	287
13.2 Formalization of Inclusion Polymorphism	288
13.2.1 Object Types, Classes and Theories	288
13.2.2 Behavioural Subtyping - Simple Cases	290
13.2.3 Behavioural Subtyping - Contravariance	292
13.2.4 Behavioural Subtyping - General Case	294
13.3 Inclusion Polymorphism in Practice	298
13.3.1 C++	298
13.3.2 Eiffel	298
13.3.3 Smalltalk-80	300
13.3.4 Objective-C	300
13.4 Related Work	300
13.5 Conclusions	301
14 Categorical Semantics for Object-Oriented Data-Specifications	302
14.1 A Categorical Specification Mechanism	303
14.1.1 Classes and Dependencies	303
14.1.2 An Extended Example	304
14.1.3 Constraints	305
14.1.4 Attributes	306
14.2 Canonical Forms for Specifications	307
14.3 Verification of Specifications	308
14.4 A Note on Terminology	309

14.5 Specifications	309
14.5.1 Specifications without Attributes	309
14.5.2 Specifications with Attributes	310
14.5.3 Elimination of Attributes	311
14.6 Canonical Forms for Specifications	311
14.7 Verification of Specifications	313
14.7.1 Verification of the Underlying Category	314
14.7.2 Verification of Specifications	315
14.8 Conclusion	315
15 A Type-Theoretic Basis for an Object-Oriented Refinement	
Calculus	317
15.1 Introduction	317
15.2 Statements as Predicate Transformers	318
15.3 Objects as Packed Records	323
15.4 Using Abstract and Concrete Classes	329
15.5 Related Work and Conclusions	331
Bibliography	336
Index	357