Denis Caromel · Ludovic Henrio

A Theory of Distributed Objects

Asynchrony - Mobility - Groups - Components

Preface by Luca Cardelli

With 114 Figures and 48 Tables



Denis Caromel

University of Nice Sophia Antipolis 13S CNRS – INRIA Institut universitaire de France 2004 Rt. des Lucioles, BP 93 06902 Sophia Antipolis Cedex, France e-mail: Denis.Caromel@inria.fr

Ludovic Henrio

University of Westminster Harrow School of Computer Science Watford Rd, Northwick Park Harrow HA1 3TP, UK e-mail: Ludovic.Henrio@m4x.org

Library of Congress Control Number: 2005923024

ISBN-10 3-540-20866-6 Springer Berlin Heidelberg New York ISBN-13 978-3-540-20866-2 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable for prosecution under the German Copyright Law.

Springer is a part of Springer Science+Business Media springeronline.com

© Springer-Verlag Berlin Heidelberg 2005 Printed in Germany

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Typeset by the authors using a Springer T_EX macro package Production: LE-T_EX Jelonek, Schmidt & Vöckler GbR, Leipzig Cover design: KünkelLopka, Heidelberg

Printed on acid-free paper 45/3142/YL - 5 4 3 2 1 0

Contents

Pı	Preface by Luca Cardelli				
Table of Contents				IX	
Lists of Figures, Tables, Definitions and Properties					
Pı	Prologue				
\mathbf{R}	eadir	ng Patl	h and Teaching	XXIX	
Pa	art I	Revie	w		
1	Ana	llysis		. 3	
	1.1		Definitions		
	1.2		bution, Parallelism, Concurrency		
		1.2.1	Parallel Activities	. 5	
		1.2.2	Sharing	. 6	
		1.2.3	Communication	. 6	
		1.2.4	Synchronization	. 10	
		1.2.5	Reactive vs. Proactive vs. Synchronous		
	1.3	Objec	ts	. 14	
		1.3.1	Object vs. Remote Reference and Communication .	. 14	
		1.3.2	Object vs. Parallel Activity	. 14	
		1.3.3	Object vs. Synchronization	. 15	
	1.4	Summ	ary and Orientation	. 17	
2					
	2.1		Formalisms		
		2.1.1	Functional Programming and Parallel Evaluation		
		2.1.2	Actors	. 23	

	2.2	2.1.3 π -calculus 2.1.4 Process Networks 2.1.5 ς -calculus Concurrent Calculi and Languages 2.2.1 MultiLisp 2.2.2 PICT 2.2.3 Ambient Calculus 2.2.4 Join-calculus 2.2.5 Other Expressions of Concurrency Concurrent Object Calculi and Languages 2.3.1 ABCL 2.3.2 Obliq and Øjeblik	26 30 31 35 35 37 40 42 43 45 45		
		2.3.3 The $\pi o \beta \lambda$ Language	51 54		
	2.4	Synthesis and Classification	54 56		
		~,			
_					
Pa	rt I.	I ASP Calculus			
3	An	Imperative Sequential Calculus	63		
	3.1	Syntax	63		
	3.2	Semantic Structures	65		
		3.2.1 Substitution	65		
		3.2.2 Store	66		
		3.2.3 Configuration	66		
	3.3	Reduction	66		
	3.4	Properties	68		
4	Asynchronous Sequential Processes				
_	4.1	Principles	69		
	4.2	New Syntax	71		
	4.3	Informal Semantics	71		
	_	4.3.1 Activities	72		
		4.3.2 Requests	73		
		4.3.3 Futures	73		
		4.3.4 Serving Requests	73		
_					
5		1	75 76		
	5.1	Binary Tree	76		
	$5.2 \\ 5.3$	Distributed Sieve of Eratosthenes	77 79		
	5.3 - 5.4		79 80		
	$\frac{5.4}{5.5}$	Example: Fibonacci Numbers	81		
	5.5	A Dank Account Server	0 Τ		

Part III Semantics and Properties						
6	Para 6.1	allel Semantics	87 87			
	6.2	Parallel Reduction	89			
		6.2.1 More Operations on Store	89			
		6.2.2 Reduction Rules	91			
	6.3	Well-formedness	98			
7	Basic ASP Properties					
	7.1	Notation and Hypothesis	101			
	7.2	Object Sharing	104			
	7.3	Isolation of Futures and Parameters	105			
8	Con	ifluence Property	107			
	8.1	Configuration Compatibility	107			
	8.2	Equivalence Modulo Future Updates	111			
	-	8.2.1 Principles	113			
		8.2.2 Alias Condition	114			
		8.2.3 Sufficient Conditions	115			
	8.3	Properties of Equivalence Modulo Future Updates	117			
	8.4	Confluence	118			
9	Determinacy					
	9.1	Deterministic Object Networks	121			
	9.2	Toward a Static Approximation of DON Terms	124			
	9.3	Tree Topology Determinism	126			
	9.4	Deterministic Examples	126			
		9.4.1 The Binary Tree	126			
		9.4.2 The Fibonacci Number Example	127			
	9.5	Discussion: Comparing Request Service Strategies	130			
— Pa	rt IV	V A Few More Features				
			197			
10			137 137			
		Delegation	141			
		Explicit Wait				
	10.3	Method Update	141			
11			143			
		Testing Future Reception	143			
		Non-blocking Services	144			
		Testing Request Reception	145			
	11.4	Join Patterns	146			
		11.4.1 Translating Join Calculus Programs	146			

	11.4.2 Extended Join Services in ASP	147			
12	Migration	151			
	12.1 Migrating Active Objects	151			
	12.2 Optimizing Future Updates	153			
	12.3 Migration and Confluence	154			
	O				
13	Groups	157			
	13.1 Groups in an Object Calculus	157			
	13.2 Groups of Active Objects	160			
	13.3 Groups, Determinism, and Atomicity	162			
14	Components	169			
	14.1 From Objects to Components	169			
	14.2 Hierarchical Components	170			
	14.3 Semantics	172			
	14.4 Deterministic Components	175			
	14.5 Components and Groups: Parallel Components	176			
	14.6 Components and Futures	178			
	r				
15	Channels and Reconfigurations				
	15.1 Genuine ASP Channels	181			
	15.2 Process Network Channels in ASP	183			
	15.3 Internal Reconfiguration	184			
	15.4 Event-Based Reconfiguration	186			
Pa	t V Implementation Strategies				
16	A Java API for ASP: ProActive	189			
10	16.1 Design and API	189			
	16.1.1 Basic API and ASP Equivalence	190			
	16.1.2 Mapping Active Objects to JVMs: Nodes	191			
	16.1.3 Basic Patterns for Using Active Objects	192			
	16.1.4 Migration	192			
	16.1.5 Group Communications	195			
	16.2 Examples	198			
	16.2.1 Parallel Binary Tree	198			
	16.2.2 Eratosthenes	201			
	16.2.3 Fibonacci	$\frac{201}{206}$			
	10.2.5 Fiboliacci	200			
17	Future Update	213			
	17.1 Future Forwarding	213			
	17.2 Update Strategies	215			
	17.2.1 ASP and Generalization: Encompassing All Strategies	215			
	17.2.2 No Partial Replies and Requests	217			

		Contents	XIII
	17.2.3 Forward-Based		219
	17.2.4 Message-Based		220
	17.2.5 Lazy Future Update		222
	17.3 Synthesis and Comparison of the Strategies		223
	17.0 Symmosis and Comparison of the Strategies		220
18	Loosing Rendezvous		225
	18.1 Objectives and Principles		225
	18.2 Asynchronous Without Guarantee		227
	18.3 Asynchronous Point-to-Point FIFO Ordering		229
	18.4 Asynchronous One-to-All FIFO Ordering		232
	18.5 Conclusion		235
			200
19	Controlling Pipelining		237
	19.1 Unrestricted Parallelism		238
	19.2 Pure Demand Driven		238
	19.3 Controlled Pipelining		239
			-50
20	Garbage Collection		241
	20.1 Local Garbage Collection		241
	20.2 Futures		242
	20.3 Active Objects		242
	J		
Pa	rt VI Final Words		
21	ASP Versus Other Concurrent Calculi		245
	21.1 Basic Formalisms		245
	21.1.1 Actors		245
	21.1.2 π -calculus and Related Calculi		246
	21.1.3 Process Networks		248
	21.1.4 <i>ς</i> -calculus		249
	21.2 Concurrent Calculi and Languages		249
	21.2.1 MultiLisp		249
	21.2.2 Ambient Calculus		250
	21.2.3 join-calculus		250
	21.3 Concurrent Object Calculi and Languages		250
	21.3.1 Obliq and Øjeblik		250
	21.3.2 The $\pi o \beta \lambda$ Language		251
	211012 111c 110p/1 20008c 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		-01
22	Conclusion		253
	22.1 Summary		253
	22.2 A Dynamic Property for Determinism		254
	22.3 ASP in Practice		255
	22.4 Stateful Active Objects vs. Immutable Futures		256
	22.5 Perspectives		$\frac{250}{257}$
			201
23	Epilogue		26 1

\mathbf{A}	Equ	ivalence Modulo Future Updates	269
	A.1	Renaming	269
	A.2	Reordering Requests $(R_1 \equiv_R R_2) \ldots \ldots$	269
	A.3	Future Updates	270
		A.3.1 Following References and Sub-terms	270
		A.3.2 Equivalence Definition	273
	A.4	Properties of \equiv_F	276
	A.5	Sufficient Conditions for Equivalence	281
	A.6	Equivalence Modulo Future Updates and Reduction	283
	A.7	Another Formulation	288
	A.8	Decidability of \equiv_F	290
	A.9	Examples	291
		- r	
\mathbf{B}	Con	Ifluence Proofs	295
	B.1	Context	295
	B.2	Lemmas	296
	B.3	Local Confluence	298
		B.3.1 Local vs. Parallel Reduction	299
		B.3.2 Creating an Activity	300
		B.3.3 Localized Operations (SERVE, ENDSERVICE)	301
		B.3.4 Concurrent Request Sending: REQUEST/REQUEST .	304
	B.4	Calculus with service based on activity name: $Serve(\alpha)$	305
	B.5	Extension	306
Re	efere	nces	309
TNT.	.4.4:.	on	321
TNO	Juanie	UII	321
$\mathbf{S}\mathbf{y}$	ntax	of ASP Calculus	327
Oı	perat	ional Semantics	329
_			0.64
Οī	ervi	ew of Properties	331
O	ervi	ew of ASP Extensions	333
In	dex		343