

# Table of Content

<b>1.</b>	<b>Introduction: Outline and Synopsis</b>	<b>1</b>
1.1	Outline and Introduction	2
1.2	Data Processing in Sensor Networks with Multi-Agent Systems	8
1.3	The Agent Behaviour Model	11
1.4	Agent Programming Languages and AAPL	14
1.5	Agent Processing Platforms	17
1.6	AAPL MAS and Mobile Processes: The $\Pi$ -Calculus	27
1.7	High-Level Synthesis of Agents and Agent Platforms	27
1.8	High-level Synthesis of SoC Designs	30
1.9	Simulation Techniques and Framework	32
1.10	Event-based Sensor Data Processing and Distribution with MAS	34
1.11	Self-organizing Systems and MAS	35
1.12	From Embedded Sensing to the Internet-of-Things and Sensor Clouds	36
1.13	Use-Case: Structural Monitoring with MAS	37
1.14	Use-Case: Smart Energy Management with MAS and AI	41
1.15	Novelty and Summary	43
1.16	Structure of the Book	45
<b>2.</b>	<b>Agent Behaviour and Programming Model</b>	<b>47</b>
2.1	The Agent Computation and Interaction Model	50
2.2	Activity-Transition Graphs	52
2.3	Dynamic Activity-Transition Graphs (DATG)	53
2.4	Agent Classes	54
2.5	Communication and Interaction of Agents	55
2.6	Multi-Agent Systems and Networked Processing	56
2.7	The Big Thing: Domains, Networks, and Mobile Agent Processing	58
2.8	Distributed Process Calculus	62
2.9	AAPL Programming Model and Language	67

2.10	AAPL Agents, Platforms, Bigraphs, and Mobile Processes	92
2.11	AAPL Agents and Societies	95
2.12	AAPL Agents and the BDI Architecture	96
2.13	Further Reading	99
<b>3.</b>	<b>Agent Communication</b>	<b>101</b>
3.1	Shared Memory	102
3.2	Tuple Space Communication	103
3.3	Communication Signals	107
3.4	Comparison: Signals and Tuples	108
3.5	Process Communication Calculus	111
3.6	FIPA ACL	117
3.7	AAPL Agents and Capability-based Remote Procedure Calls	118
3.8	Further Reading	125
<b>4.</b>	<b>Distributed Sensor Networks</b>	<b>127</b>
4.1	Domains and Networks	128
4.2	The Sensor Node	128
4.3	The Sensor Network	129
4.4	Further Reading	143
<b>5.</b>	<b>Concurrent Communicating Sequential Processes</b>	<b>145</b>
5.1	Parallel Data Processing	146
5.2	The original CSP Model	146
5.3	Inter-Process Communication and Synchronization	155
5.4	The extended CCSP Model	157
5.5	Signal Flow Diagrams, CSP, and Petri-Nets	167
5.6	CSP Programming Languages	169
5.7	The $\mu$ RTL Programming Language	169
5.8	The ConPro Programming Language	171
5.9	Hardware Architecture	184

5.10	Software Architecture	189
5.11	Further Reading	190
<b>6.</b>	<b>PCSP: The Reconfigurable Application-specific Agent Platform</b>	<b>191</b>
6.1	Pipelined Processes	192
6.2	Agent Platform Architecture	193
6.3	Agent Platform and Hardware Synthesis	203
6.4	Platform Simulation	207
6.5	Heterogeneous Networks	210
6.6	Further Reading	211
<b>7.</b>	<b>PAVM: The Programmable Agent Platform</b>	<b>213</b>
7.1	Stack Machines versa Register Machines	214
7.2	Architecture: The PAVM Agent Processing Platform	216
7.3	Agent FORTH: The Intermediate and the Machine Language	221
7.4	Synthesis and Transformation Rules	237
7.5	The Boot Sections and Agent Processing	242
7.6	Agent Platform Simulation	242
7.7	Case Study: A Self-organizing System	245
7.8	The JavaScript WEB Platform JAVM	254
7.9	Further Reading	262
<b>8.</b>	<b>JAM: The JavaScript Agent Machine</b>	<b>263</b>
8.1	JAM: The JavaScript Agent Machine	264
8.2	AgentJS: The Agent JavaScript Programming Language	265
8.3	AIOS: The Agent Execution and IO Environment	268
8.4	JAM Implementations	275
8.5	Performance Evaluation	283
8.6	SEJAM: The JavaScript Agent Simulator	289
8.7	Heterogeneous Environments	291
8.8	Further Reading	292

<b>9.</b>	<b>Self-Organizing Multi-Agent Systems</b>	<b>295</b>
9.1	Introduction to Self-Organizing Systems	296
9.2	Self-organizing Distributed Feature Recognition	298
9.3	Self-organizing Event-based Sensor Data Processing and Distribution	306
9.4	Self-organizing Energy Management and Distribution	315
9.5	Further Reading	323
<b>10.</b>	<b>ML: Machine Learning and Agents</b>	<b>325</b>
10.1	Introduction to Machine Learning	326
10.2	Decision Trees	331
10.3	Artificial Neuronal Networks	339
10.4	Learning with Agents	342
10.5	Distributed Learning	343
10.6	Incremental Learning	350
10.7	Further Reading	362
<b>11.</b>	<b>Simulation</b>	<b>363</b>
11.1	The SeSAm Agent Simulator	364
11.2	Behavioural AAPL MAS Simulation	366
11.3	Simulation of Real-world Sensor Networks	368
11.4	PCSP Platform Simulation	369
11.5	The SEM Simulation Programming Language	373
11.6	SEJAM: Simulation Environment for JAM	383
11.7	Multi-Domain Simulation with SEJAM2P	386
11.8	Further Reading	403
<b>12.</b>	<b>Synthesis</b>	<b>405</b>
12.1	The Big Picture: All together	406
12.2	SynDK: The Synthesis Development Toolkit	409
12.3	Agent and Agent Platform Synthesis	425
12.4	The Agent Simulation Compiler SEMC	436

12.5	ConPro SoC High-level Synthesis	437
12.6	Further Reading	468
<b>13.</b>	<b>Energy Management</b>	<b>469</b>
13.1	Power Analysis and Algorithmic Selection	470
13.2	Smart Energy Management with Artificial Intelligence	480
13.3	Further Reading	488
<b>14.</b>	<b>Use-Cases Environmental Perception, Load Monitoring, and Manufacturing 489</b>	
14.1	Sensorial Material I: A Flat Perceptive Sheet and Machine Learning	493
14.2	Sensorial Material II: A Flat Perceptive Plate and Inverse Numeric	504
14.3	Sensorial Material III: A Perceptive Modular Robot Arm	510
14.4	Sensorial Material IV: A Perceptive Robotic Gripper	512
14.5	Sensor Clouds: Adaptive Cloud-based Design and Manufacturing	514
14.6	Sensor Networks: Distributed Earthquake Monitoring	518
14.7	Crowd Sensing	520
14.8	Further Reading	525
<b>15.</b>	<b>Material-Integrated Sensing Systems</b>	<b>527</b>
15.1	The Sensorial Material	528
15.2	Integration Levels	530
15.3	Integration Technologies and Sensorial Materials	534
15.4	Digital Logic Technologies	537
15.5	Computational Constraints	543
15.6	Further Reading	546
<b>16.</b>	<b>Abbreviations, Notations, Symbols</b>	<b>547</b>
16.1	Abbreviations	547
16.2	Symbols	548
16.3	Notation	550

17.	Publications and References	553
17.1	Publications	554
17.2	Lectures	557
17.3	Supervised Theses	557
17.4	Bibliography	558
	Index	567