

List of Figures	xii
List of Tables	xv
1 Introduction	1
1.1 The Evolvable Hardware Principle	1
1.2 Challenges of Evolvable Hardware	4
1.3 Thesis Contributions	8
1.4 Thesis Organization	11
2 Evolutionary Algorithms	13
2.1 Historical overview	18
2.1.1 Evolutionary Programming	18
2.1.2 Evolutionary Strategies	19
2.1.3 Genetic Algorithms	20
2.1.4 Genetic Programming	21
2.2 Multi-objective Evolutionary Algorithms	22
2.2.1 Multi-objective Optimization Terminology	22
2.2.2 Non-Dominated Sorting Genetic Algorithm II	26
2.2.3 Strength Pareto Evolutionary Algorithm 2	27
2.3 Variants of Specialized Evolutionary Algorithms	29
2.3.1 Parallel Evolutionary Algorithms	29
2.3.2 Hybrid Evolutionary Algorithms	30
2.4 Performance Analysis	31
2.4.1 The Computational Effort	31
2.4.2 Comparing Non-Dominated Sets	32
2.5 Chapter Conclusion	34
3 Evolvable Hardware	35
3.1 The Basic Idea	36
3.2 Digital Logic Evolvable Hardware	40

3.2.1	Reconfigurable Logic Devices	40
3.2.2	Programmable logic array Evolvable Hardware	52
3.2.3	Unconstrained Evolution	53
3.2.4	The POETic Tissue Project	58
3.2.5	Evolvable Components	59
3.2.6	The Functional Unit Row Architecture	65
3.3	Analog Evolvable Hardware	68
3.3.1	Heidelberg Field Programmable Transistor Array	69
3.3.2	NASA Field Programmable Transistor Array	73
3.3.3	Lattice ispPAC	76
3.4	Cartesian Genetic Programming	77
3.4.1	The Representation Model	79
3.4.2	Enzyme Cartesian Genetic Programming	86
3.4.3	Recombination for Cartesian Genetic Programming	87
3.4.4	Automatic Acquisition and Reuse of Subfunctions in Cartesian Genetic Programming	88
3.4.5	Self-modifying Cartesian Genetic Programming	90
3.5	Chapter Conclusion	91
4	Digital Logic Evolution Framework and Experimentation Toolbox	93
4.1	Framework Core Architecture	93
4.2	Representation Models and Algorithms	98
4.2.1	General Methods	99
4.2.2	Methods Specific to a Genotype	101
4.3	Experimentation Support and Tools	104
4.3.1	Visualization and Analysis	104
4.3.2	Command Line Tools and Distributed Simulation	107
4.4	Chapter Conclusion	108
5	Evolvable Hardware Abstraction Models and Operators	109
5.1	Structural Crossover for Cartesian Genetic Programming	111
5.1.1	The CGP Crossover Algorithm	112
5.1.2	Evaluation	114
5.2	Automatic Acquisition of Structural and Age Based Modules	117
5.2.1	Age Based Module Creation	117
5.2.2	Cone Based Module Creation	118
5.2.3	Evaluation	118
5.3	Chapter Conclusion	120
6	Efficient Multi-Objective Optimization for CGP	121
6.1	Selection Schemes for Multi-Objective CGP	122
6.1.1	Objective Prioritization	123
6.1.2	Evaluation	126
6.2	Evolutionary Algorithm Periodization	137

6.2.1	The Periodization Model	138
6.2.2	Hybrid Evolutionary Strategies	139
6.2.3	Evaluation	140
6.3	Chapter Conclusion	151
7	Evolvable Hardware Applications	153
7.1	ECGP Based Architecture for Electromyographic Signal Classification	154
7.1.1	Classification of Electromyographic Signals	155
7.1.2	Recording Electromyographic Signals	159
7.1.3	Electromyographic Signals Processing and Feature Extraction	162
7.1.4	The Embedded Cartesian Genetic Programming Classification Architecture	163
7.1.5	Conventional Classifiers	166
7.1.6	Evaluation	168
7.2	Classifier Adaptation to Resource Fluctuations	176
7.2.1	The Reconfigurable Functional Unit Row Architecture	177
7.2.2	Evaluation	177
7.2.3	Functional Unit Row Architecture Reconfiguration Schemes	182
7.2.4	Evaluation	184
7.3	Adaptation of Cache Mappings	190
7.3.1	The Concept of EvoCaches	190
7.3.2	Algorithms, Representation Models, and Metrics	192
7.3.3	Evaluation	194
7.4	Chapter Conclusion	201
8	Summary and Outlook	203
8.1	Contributions	203
8.2	Conclusions and Lessons Learned	206
8.3	Future Directions	207
	Author's Publications	211
	Bibliography	215