

Contents

1	Introduction to Evolutionary Computation and Genetic Programming	1
	Julian F. Miller	
1.1	Evolutionary Computation	1
1.1.1	Origins	1
1.1.2	Illustrating Evolutionary Computation: The Travelling Salesman Problem	2
1.2	Genetic Programming	4
1.2.1	GP Representation in LISP	5
1.2.2	Linear or Machine Code Genetic Programming	6
1.2.3	Grammar-Based Approaches	8
1.2.4	PushGP	10
1.2.5	Cartesian Graph-Based GP	11
1.2.6	Bloat	14
	References	14
2	Cartesian Genetic Programming	17
	Julian F. Miller	
2.1	Origins of CGP	17
2.2	General Form of CGP	17
2.3	Allelic Constraints	19
2.4	Examples	20
2.4.1	A Digital Circuit	20
2.4.2	Mathematical Equations	20
2.4.3	Art	22
2.5	Decoding a CGP Genotype	24
2.5.1	Algorithms for Decoding a CGP Genotype	25
2.6	Evolution of CGP Genotypes	28
2.6.1	Mutation	28
2.6.2	Recombination	29
2.6.3	Evolutionary Algorithm	30

2.7	Genetic Redundancy in CGP Genotypes	31
2.8	Parameter Settings for CGP	31
2.9	Cyclic CGP	33
	References	33
3	Problem Decomposition in Cartesian Genetic Programming	35
	James Alfred Walker, Julian F. Miller, Paul Kaufmann and Marco Platzner	
3.1	Introduction	35
3.2	Embedded Cartesian Genetic Programming (ECGP)	36
3.2.1	Genotype Representation	37
3.2.2	Modules	38
3.2.3	Genotype Operators	41
3.2.4	Module Operators	47
3.2.5	Evolutionary Strategy	49
3.2.6	Benchmark Experiments	50
3.3	Digital-Adders	60
3.4	Symbolic Regression	63
3.5	Lawnmower Problem	66
3.6	Alternative ECGP Operators	70
3.6.1	Cone-Based and Age-Based Module Creation	70
3.6.2	Cone-Based Crossover	76
3.7	Modular Cartesian Genetic Programming (MCGP)	78
3.7.1	Multi-level Module Hierarchy Representation	78
3.7.2	Benchmark Experiments	82
3.8	Multi-chromosome Cartesian Genetic Programming (MC-CGP) ..	88
3.8.1	Multi-chromosome Representation	88
3.8.2	Multi-chromosome Evolutionary Strategy	90
3.8.3	Benchmark Experiments	91
	References	97
4	Self-Modifying Cartesian Genetic Programming	101
	Simon L. Harding, Julian F. Miller and Wolfgang Banzhaf	
4.1	Introduction	101
4.1.1	Discovering Mathematical Results Using Genetic Programming	102
4.2	Overview of Self-Modification	102
4.3	SMCGP and Its Relation to CGP	103
4.3.1	Self-Modification Operators	104
4.3.2	Computational Functions	104
4.3.3	Arguments	106
4.3.4	Relative Addressing	107
4.3.5	Input and Output Nodes	107
4.3.6	A Simple Example	108
4.3.7	Discussion	108
4.3.8	And Back to CGP	110

4.4	Solving Computational Problems with SMCGP: Parity	110
4.4.1	Definition of Fitness	111
4.4.2	Results	112
4.4.3	A General Solution to Computing Even-Parity	113
4.4.4	Why GP Cannot Solve General Parity Without Iteration	116
4.5	SM vs GP vs GA	118
4.6	Implementing Incremental Fitness Functions	120
4.7	Conclusions	122
4.8	Acknowledgements	123
	References	123
5	Evolution of Electronic Circuits	125
	Lukas Sekanina, James Alfred Walker, Paul Kaufmann and Marco Platzner	
5.1	Introduction	125
5.2	Direct Evolution of Small Combinational Circuits	126
5.2.1	Evolutionary vs Conventional Synthesis of Combinational Circuits	126
5.2.2	CGP for Logic Synthesis	127
5.2.3	Benchmark Problems	128
5.2.4	Summary	130
5.3	Multi-objective Evolution of Combinational Circuits	131
5.3.1	Multi-objective Fitness Function	131
5.3.2	Benchmarks	132
5.3.3	Summary	136
5.4	Evolution of Polymorphic Circuits	136
5.4.1	Polymorphic Electronics	137
5.4.2	Gate-Level Evolution of Polymorphic Circuits	138
5.4.3	CGP as Optimizer	139
5.4.4	REPOMO32: CGP on a Chip	140
5.5	Evolution of Multiple-Constant Multipliers	143
5.5.1	Multiplierless Multiplication	143
5.5.2	Results of CGP	144
5.6	CMOS-Level Circuit Evolution	145
5.6.1	Intrinsic Parameter Fluctuations	146
5.6.2	Modifying CGP for CMOS Design	148
5.6.3	Experiments	154
5.6.4	Conclusions and Future Work	158
5.7	Evolution of Classification Hardware Using a Modular Approach	159
5.7.1	Classifier Architecture	159
5.7.2	EMG Signal Domain	160
5.7.3	Classifier Hardware Representation Model	162
5.7.4	Fitness Assignment and Evolutionary Algorithm	163
5.7.5	Experiments and Results	164
5.8	EvoCaches: Application-Specific Adaptation of Cache Mappings	165

5.8.1	The EvoCache Concept	166
5.8.2	System Simulation and Metrics	168
5.8.3	Experiments and Results	170
5.8.4	Conclusion	175
5.9	Acknowledgements	176
	References	176
6	Image Processing and CGP	181
	Lukas Sekanina, Simon L. Harding, Wolfgang Banzhaf and Taras Kowaliw	
6.1	Introduction	181
6.2	Evolutionary Design of Image Filters for FPGAs	181
6.2.1	Sliding-Window Function	182
6.2.2	Types of Noise	183
6.2.3	Conventional Filters	184
6.2.4	Edge Detectors	186
6.2.5	Basic Approach to Filter Evolution	186
6.2.6	Bank of Evolved Filters	187
6.2.7	Extended Kernel	188
6.2.8	Experimental Results	188
6.2.9	Summary	196
6.3	Evolving Advanced Image Filters	196
6.3.1	Fitness Function	198
6.3.2	Changes to the Standard CGP Genotype	198
6.3.3	Evolutionary Algorithm, Parameters and Function Set	198
6.3.4	Results	199
6.4	The Automated Design of Features for Image Classification	205
6.4.1	Motivation	205
6.4.2	The Model	206
6.4.3	Transform Evolution	209
6.4.4	Future Directions	212
6.5	Acknowledgements	212
	References	213
7	CGP Acceleration Using Field-Programmable Gate Arrays	217
	Lukas Sekanina and Zdenek Vasicek	
7.1	Reconfigurable Chips	217
7.2	Field-Programmable Gate Arrays	218
7.3	Hardware Accelerators for CGP	219
7.3.1	Architecture Overview	220
7.3.2	VRC for Symbolic Regression Problems	223
7.3.3	VRC for Combinational-Circuit Evolution	225
7.4	Performance Evaluation	226
7.4.1	Evolution of Combinational Circuits	226
7.4.2	Symbolic Regression Problems	228
7.5	Summary	229

7.6	Acknowledgements	229
	References	229
8	Hardware Acceleration for CGP: Graphics Processing Units	231
	Simon L. Harding and Wolfgang Banzhaf	
8.1	Graphics Processing Units	231
8.2	The Architecture of Graphics Processing Units	231
8.3	Programming a GPU	233
8.4	Parallel Implementation of GP	234
8.5	Initial GPU Results	235
	8.5.1 Floating-Point-Based Expressions	236
	8.5.2 Binary	237
	8.5.3 Regression and Classification	237
8.6	Image Processing on the GPU	240
	8.6.1 Evolving Image Filters Using Accelerator	243
	8.6.2 Results	243
8.7	CUDA Implementation	245
	8.7.1 Algorithm	246
	8.7.2 Compilation and Code Generation	247
	8.7.3 Fitness Function	251
	8.7.4 Results	251
8.8	Conclusions	252
8.9	Acknowledgements	252
	References	253
9	The CGP Developmental Network	255
	Gul Muhammad Khan and Julian F. Miller	
9.1	Introduction	255
9.2	Biology of Neurons	257
9.3	The CGP Developmental Network	258
	9.3.1 Health, Resistance, Weight and State-Factor	260
	9.3.2 Cartesian Genetic Program (Chromosome)	260
	9.3.3 Inputs and Outputs	263
9.4	CGP Model of Neuron	263
	9.4.1 Electrical Processing	263
	9.4.2 Weight Processing	268
	9.4.3 Life Cycle of Neuron	268
9.5	Applications	270
	9.5.1 Wumpus World Problem	271
	9.5.2 Competitive Learning Scenario	277
9.6	Learning 'How to Play' Checkers	285
	9.6.1 Coevolution of Two Agents Playing Checkers	285
	9.6.2 An Agent Plays Against a Minimax-Based Checkers Program	287
9.7	Conclusions	288
	References	289

10 CGP, Creativity and Art	293
Steve DiPaola and Nathan Sorenson	
10.1 Introduction	293
10.2 Creativity and Art	294
10.3 Evolutionary Systems and Creativity	295
10.4 Evolutionary Art	295
10.5 Genetic Programming and Creativity	296
10.5.1 Advantages of CGP in Creative Systems	297
10.6 Implementation	298
10.6.1 Fitness Function	300
10.6.2 Contextual Focus	301
10.7 Results	302
10.8 Conclusions and Future Directions	305
10.9 Acknowledgements	306
References	306
11 Medical Applications of Cartesian Genetic Programming	309
Stephen L. Smith, James Alfred Walker, Julian F. Miller	
11.1 Introduction	309
11.2 CGP Applied to the Diagnosis of Breast Cancer	309
11.2.1 Classification of Mammograms Using a Vector of Conventional Statistical Features	312
11.2.2 Classification of Mammograms Using Raw Pixel Values	312
11.2.3 Classification of Mammograms Using Multi- chromosome CGP	314
11.2.4 Summary	319
11.3 CGP Applied to the Diagnosis of Parkinson's Disease	319
11.4 CGP Applied to the Diagnosis of Alzheimer's Disease	325
11.5 Conclusions	333
References	334
Appendix A Resources for Cartesian Genetic Programming	337
A.1 General Advice	337
A.2 Web Sites	337
A.3 Tutorial Material	337
A.4 Software	338
A.4.1 CGP in C	338
A.4.2 CGP in Java	338
A.4.3 CGP in MATLAB	339
A.4.4 Evolutionary Art with Laurence Ashmore's CGP Program (in Java)	339
Index	341



<http://www.springer.com/978-3-642-17309-7>

Cartesian Genetic Programming

Miller, J.F. (Ed.)

2011, XXII, 346 p., Hardcover

ISBN: 978-3-642-17309-7