Appendix A: Functions and Terminals

Table A.1 shows the name and a reference for functions and terminals (i.e., functions of arity 0) used in this book.

Table A.1 Functions and terminals

Name	Arity	Full name	Section in this book
+	2	Numeric addition	2.2.1
−	2	Numeric subtraction	2.2.1
*	2	Numeric multiplication	2.2.1
%	2	Protected numeric division	2.2.1
>	2	Greater-than comparative function	7.2.1
<	2	Less-than comparative function	7.2.1
2N3904	0	2N3904 transistor model	10.5.1.4
2N3906	0	2N3906 transistor model	10.5.1.4
ABS_SIGNAL	1	Insert an absolute value block into a controller	3.5.1
ADD_3_SIGNAL	3	Insert a 3-input addition block into a controller	3.5.1
ADD_SIGNAL	2	Insert an addition block into a controller	3.5.1
ADF	Variable	Automatically defined function	3.5.4
AH	0	Connect to Åström-Hägglund controller	13.1.2
B_C_E, …, E_C_B	0	Transistor lead permutation terminals	10.5.1.4
BIFURCATE_POSITIVE	0	Bifurcate positive end of wire in inserting transistor	10.5.1.4

(*Continued*)

Table A.1 (*Continued*)

Name	Arity	Full name	Section in this book
BIFURCATE_NEGATIVE	0	Bifurcate negative end of wire in inserting transistor	10.5.1.4
C	2	Capacitor-inserting function	4.2.1.3
C-LAYOUT	2	Geographically-aware capacitor-inserting function	5.2.1.3
C_NEW	1	Create a capacitor	4.7.1.3
C00002	0	Concentration of cofactor ATP	8.5.3
C00116	0	Concentration of glycerol	8.5.3
C00162	0	Concentration of fatty acid	8.5.3
C00165	0	Concentration of diacyl-glycerol	8.5.3
CAP_LEVEL	0	Represents gene expression level in a genetic network	7.3.3
CONSTANT_0	0	Connect to time-domain signal with constant 0 value	3.5.2
CONTROLLER_OUTPUT	0	Connect to a controller's output	3.5.2
CR_1_1	4	1-subtrate, 1-product reactor block	8.4.1.1
CR_1_2	5	1-subtrate, 2-product reactor block	8.4.1.1
CR_2_1	5	2-subtrate, 1-product reactor block	8.4.1.1
CR_2_2	6	2-subtrate, 2-product reactor block	8.4.1.1
DELAY	1	Insert a delay block into a controller	3.5.1
DIFFERENTIAL_ INPUT_INTEGRATOR	2	Insert a differential input integrator block into a controller	3.5.1
DIFFERENTIATOR	1	Insert a differentiator block into a controller	3.5.1
DIV_NUMERIC	2	Protected numeric division for controllers	9.1.1.3
DIV_SIGNAL	2	Insert a division block into a controller	3.5.1
DOWN_OR_RIGHT	0	Parallel-divide down or right	10.1.2
DRAW	2	Drawing turtle function	6.3.1
END	0	Development-ending function	4.2.1.4
F	0	Free variable representing passband boundary	10.3.1.3
F1	0	Free variable representing passband boundary	11.1.1.3

(*Continued*)

Table A.1 (*Continued*)

Name	Arity	Full name	Section in this book
F2	0	Free variable representing stopband boundary	11.1.1.3
FIRST_PRODUCT	1	Selects the first product produced by a chemical reaction	8.4.1.1
FLIP	1	Flip (polarity-reversing) function	4.2.1.3
GAIN	2	Insert a gain block into a controller	3.5.1
GLUCOSE_LEVEL	0	Represents glucose level in a genetic network	7.3.3
HFA3046	0	HFA3046 transistor model	15.3.3
HFA3128	0	HFA3128 transistor model	15.3.3
IF	3	If operator	7.2.1
IF_POSITIVE	3	Insert an if-positive block into a controller	3.5.1
IFGTZ_DEVELOPMENTAL	3	If greater than zero developmental operator	11.1
INPUT_0	2	Connect to a circuit's input	4.7.1.1
INTEGRATOR	1	Insert an integrator block into a controller	3.5.1
INT1, INT2, INT3	0	Intermediate substance terminals	8.5.3
INVERTER	1	Insert an inverter block into a controller	3.5.1
IRF511	0	IRF511 transistor model	15.3.3
IRF9230	0	IRF9230 transistor model	15.3.3
IRFZ44	0	IRFZ44 transistor model	15.3.3
KU	0	Free variable representing plant's ultimate gain	9.2.1.2
L	0	Free variable representing plant's dead time	9.2.1.2
L	2	Inductor-inserting function	10.3.1.4
L1	0	Free variable representing inductance of a specific inductor	10.1.2.4
L_NEW	1	Create an inductor	4.7.1.3
L-LAYOUT	2	Geographically aware inductor-inserting function	5.2.1.3
LACTOSE_LEVEL	0	Represents lactose level in a genetic circuit	7.3.3
LAG	2	Insert a lag block into a controller	3.5.1
LAG2	3	Insert a second order lag block into a controller	3.5.1
LANDMARK	1	Landmark turtle function	6.3.1
LEAD	2	Insert a lead block into a controller	3.5.1
LEFT_1, …, LEFT_4	0	Takeoff point reference terminals	13.1.2

(*Continued*)

Table A.1 (*Continued*)

Name	Arity	Full name	Section in this book
LIMITER	3	Insert a limiter block into a controller	3.5.1
LOG_F	0	Free variable representing logarithm of passband boundary for filter	10.5.1.4
MTP50P03HDL	0	MTP50P03HDL transistor model	15.3.3
MULT_SIGNAL	2	Insert a multiplication block into a controller	3.5.1
NODE	2	Connect distant points in a circuit	10.1.1
NOP	1	No-operation function	4.2.1.3
OUTPUT_0	2	Connect to a circuit's output	4.7.1.1
PAIR_CONNECT_0	3	Connects a pair of distant points in a circuit	4.2.1.3
PAIR_CONNECT_1	3	Connects a pair of distant points in a circuit	4.2.1.3
PARALLEL-LAYOUT-LEFT	4	Geographically aware parallel division function	5.2.1.3
PARALLEL-LAYOUT-RIGHT	4	Geographically aware parallel division function	5.2.1.3
PARALLEL0	4	Parallel-division function, version 0	4.2.1.3
PARALLEL1	4	Parallel-division function, version 1	4.2.1.3
PARALLEL_NEW	4	New version of parallel division function	10.1.2
PLANT_OUTPUT	0	Connect to a controller's plant output	3.5.2
POW	2	Power function	12.2.3
PROGN	Variable	Connective function	6.3.1
Q	6	Transistor-inserting function	10.1.5
Q_DIODE_NPN	1	Insert an NPN diode into a circuit	4.4.1.4
Q_DIODE_PNP	1	Insert a PNP diode into a circuit	4.4.1.4
Q_GND_EMIT_NPN	1	Insert an NPN transistor whose emitter is connected to ground	4.4.1.4
Q_GND_EMIT_PNP	1	Insert a PNP transistor whose emitter is connected to ground	4.4.1.4
Q_POS5V_COLL_NPN	1	Insert an NPN transistor whose collector is connected to a 5 V power supply	4.4.1.4
Q_POS5V_EMIT_PNP	1	Insert a PNP transistor whose emitter is connected to a 5 V power supply	4.4.1.4
Q_THREE_NPN0, …, Q_THREE_NPN11	3	Insert an NPN transistor into a circuit	4.4.1.4

(*Continued*)

Table A.1 (*Continued*)

Name	Arity	Full name	Section in this book
Q_THREE_PNP0, …, Q_THREE_PNP11	3	Insert a PNP transistor into a circuit	4.4.1.4
R	2	Resistor-inserting function	4.2.1.3
R1	0	Free variable representing inductance of a specific resistor	10.1.2.4
$\Re$	0	Random floating-point constants in specified range	3.5.5.1
$\Re_{\text{integer}}$	0	Random integer constants between 0 and 99	6.3.2
$\Re_{p}$	0	Random perturbable floating-point value in specified range	3.5.5.2
$\Re_{\text{real}}$	0	Random floating-point constants between 0.0 and 1.0	6.3.2
R_NEW	1	Create a resistor	4.7.1.3
REFERENCE_SIGNAL	0	Connect to a controller's reference signal	3.5.2
REPEAT	2	Repeat turtle function	6.3.1
REPRESSOR_LEVEL	0	Represents repressor level in a genetic network	7.3.3
RETAINING_ THREE_GROUND0	3	Connect to ground	4.3.1.4
RETAINING_ THREE_GROUND1	3	Connect to ground	4.3.1.4
RETAINING_ THREE_POS5V_0	3	Connect to 5 V power supply	4.4.1.4
RETAINING_ THREE_POS5V_0	3	Connect to 5 V power supply	4.4.1.4
REXP	1	Protected exponential function	9.2.1.3
RIGHT_1, …, RIGHT_4	0	Takeoff point reference terminals	13.1.2
RLOG	1	Protected natural logarithm function	9.2.1.3
SAFE_CUT	0	Safe-cut developmental function	4.2.1.4
SECOND_PRODUCT	1	Selects the second product produced by a chemical reaction	8.4.1.1
SERIES	3	Series division function	4.2.1.3
SERIES-LAYOUT	3	Geographically aware series division function	5.2.1.3
SIN_THETA	0	Free variable representing sine of a filter's modular angle	10.2.1.4
SUB_SIGNAL	2	Insert a subtraction block into a controller	3.5.1
TAKEOFF	1	New takeoff point function	13.1.1
TARGET	0	Free variable representing identity of target circuit (for squaring/cubing problem and 40/60 dB amplifier problem)	11.3.1.4
TAU	0	Free variable representing plant's time constant	9.1.1.2

(*Continued*)

Table A.1 (*Continued*)

Name	Arity	Full name	Section in this book
THREE_GROUND	3	Three-argument connection to ground	10.2.1.3
TU	0	Free variable representing plant's ultimate period	9.2.1.2
TURN-RIGHT	1	Turn right turtle function	6.3.1
TR	0	Free variable representing plant's rise time	9.2.1.2
TWO_GROUND	2	Two-argument connection to ground	10.2.1.3
TWO_LEAD	3	Two-leaded-component-inserting function	10.1.4
TWO_NEG15V	2	−15 Volt reference voltage source function	11.3.1.3
TWO_POS1V	2	+1 Volt reference voltage source function	11.3.1.3
TWO_POS2V	2	+2 Volt reference voltage source function	11.3.1.3
TWO_POS5V	2	+5 Volt reference voltage source function	11.3.1.3
TWO_POS15V	2	+15 Volt reference voltage source function	11.3.1.3
UP_OR_LEFT	0	Parallel-divide up or left	10.1.2
VIA-TO-GROUND-NEG-LEFT-LAYOUT	3	Geographically aware via to ground function	5.2.1.3
VIA-TO-GROUND-NEG-RIGHT-LAYOUT	3	Geographically aware via to ground function	5.2.1.3
VIA-TO-GROUND-POS-T-LAYOUT	3	Geographically aware via to ground function	5.2.1.3
VIA-TO-GROUND-POS-RIGHT-LAYOUT	3	Geographically aware via to ground function	5.2.1.3
X	0	Represents value on the *X*-axis for symbolic regression problems	2.2.1

Appendix B: Control Parameters

Broadly speaking, we have used substantially the same (almost certainly non-optimal) choices of control parameters from problem to problem over a period of years. Although particular problems in this book could possibly be solved more efficiently by means of a different choice of control parameters, we believe that our policy of substantial consistency in the choice of control parameters helps the reader eliminate superficial concerns that the demonstrated success of genetic programming depends on shrewd or fortuitous choices of the control parameters. That is, the results produced by genetic programming are not the fruit of intricate and astute tailoring of control parameters to a particular problem.

This book continues the policy of *Genetic Programming* (Koza 1992a), *Genetic Programming II* (Koza 1994a), and *Genetic Programming III* (Koza, Bennett, Andre, and Keane 1999a) of using a fixed set of default values for most of the minor control parameters throughout the book. Thus, unless otherwise indicated for a specific problem, the values of all control parameters for all problems in this book are the values specified in *Genetic Programming III* (Koza, Bennett, Andre, and Keane 1999a).

In addition to the values of the control parameters inherited from *Genetic Programming III*, tables B.1 and B.2 present the percentages of genetic operations that are used on or before and after generation 5 of runs of the 10 problems in this book employing the architecture-altering operations. Tables B.3 and B.4 present this information for seven additional problems employing the architecture-altering operations. B.5 presents this information for all the remaining problems. Because the architecture-altering operations were not used on any of the problems in table B.5, one table of percentages is applicable to all generations.

Table B.6 shows the migration strategy (A, B, or C) used for the 41 runs in this book employing a parallel computer system. Strategy A is described in section 17.1.1 and strategies B and C are described in section 17.1.2.

The information in these tables can be summarized as follows: Not noteworthy. Many of the differences simply reflect adjustments necessary to accommodate the presence or absence of the architecture-altering operations. Other differences (such as the migration strategy) arise from some another choice (e.g., the computer system or the population size). Most of the other differences reflect the chronology of our work and the evolution of our thinking on how to maximize the efficiency runs of genetic programming in general (as opposed to any special exigency of a particular problem). At least one of the differences (where the column does not add up to 100%) reflects a typographical error made during programming.

Table B.1 Percentages of operations before generation 5 for 10 problems

	Two-lag plant (section 3.7)	Three-lag plant (section 3.8)	Three-lag plant with five-second delay (section 3.9), non-minimal phase plant (section 3.10), and three-lag plant with a free variable (section 9.1)	Controller for two families of plants (section 9.2)	RC circuit with gain greater than two (section 4.2), Philbrick circuit (section 4.3)	ALU circuit (section 4.5)	Amplifier with layout (section 5.3)
Crossover on internal points	68%	0%	0%	0%	0%	0%	0%
Crossover on terminals	10%	0%	0%	0%	0%	0%	0%
Crossover on non-numeric internal points	0%	45%	45%	46%	50%	50%	50%
Crossover on non-numeric terminals	0%	9%	9%	9%	10%	10%	10%
Crossover on numeric terminals	0%	5%	5%	9%	10%	10%	10%
Reproduction	10%	9%	9%	9%	9%	9%	9%
Subtree mutation	1%	1%	1%	1%	1%	1%	1%
Numeric constant mutation	0%	20%	20%	20%	20%	20%	20%
Subroutine duplication	5%	5%	5%	2%	0%	0%	0%
Argument duplication	0%	0%	0%	0%	0%	0%	0%

Subroutine deletion	1%	1%	1%	2%	0%	0%	0%
Argument deletion	0%	0%	0%	0%	0%	0%	0%
Subroutine creation	5%	5%	5%	2%	0%	0%	0%
Argument creation	0%	0%	0%	0%	0%	0%	0%
Iteration creation	0%	0%	0%	0%	0%	0%	0%
Loop creation	0%	0%	0%	0%	0%	0%	0%
Recursion creation	0%	0%	0%	0%	0%	0%	0%
Storage creation	0%	0%	0%	0%	0%	0%	0%
Max. points for RPB	150	150	150	150	800	300	300
Max. points for ADF	100	100	100	100	NA	NA	NA

Table B.2 Percentages of operations after generation 5 for 10 problems

	Two-lag plant (section 3.7)	Three-lag plant (section 3.8)	Three-lag plant with five-second delay (section 3.9), non-minimal phase plant (section 3.10), and three-lag plant with a free variable (section 9.1)	Controller for two families of plants (section 9.2)	RC circuit with gain greater than two (section 4.2), Philbrick circuit (section 4.3)	ALU circuit (section 4.5)	Amplifier with layout (section 5.3)
Crossover on internal points	76%	0%	0%	0%	0%	0%	0%
Crossover on terminals	10%	0%	0%	0%	0%	0%	0%
Crossover on non-numeric internal points	0%	47%	49%	46%	50%	50%	50%
Crossover on non-numeric terminals	0%	9%	9%	9%	10%	10%	10%
Crossover on numeric terminals	0%	9%	9%	9%	10%	10%	10%
Reproduction	10%	9%	9%	9%	9%	9%	9%
Subtree mutation	1%	1%	1%	1%	1%	1%	1%
Numeric constant mutation	0%	20%	20%	20%	20%	20%	20%
Subroutine duplication	1%	1%	1%	2%	0%	0%	0%
Argument duplication	0%	0%	0%	0%	0%	0%	0%

Subroutine deletion	1%	1%	1%	2%	0%	0%	0%
Argument deletion	0%	0%	0%	0%	0%	0%	0%
Subroutine creation	1%	1%	1%	2%	0%	0%	0%
Argument creation	0%	0%	0%	0%	0%	0%	0%
Iteration creation	0%	0%	0%	0%	0%	0%	0%
Loop creation	0%	0%	0%	0%	0%	0%	0%
Recursion creation	0%	0%	0%	0%	0%	0%	0%
Storage creation	0%	0%	0%	0%	0%	0%	0%
Max. points for RPB	150	150	150	150	800	300	300
Max. points for ADF	100	100	100	100	NA	NA	NA

Table B.3 Percentages of operations before generation 5 for seven problems

	Analog NAND circuit (section 4.4)	Lowpass filter with layout (section 5.2)	Square root computational circuit (section 4.6)	Passive lowpass filter with variable passband boundary (section 10.4)	Lowpass/highpass filter with free variables (section 11.1), Lowpass/highpass filter with variable passband boundary with a free variable (section 11.2)	Yagi-Uda antennas problem (section 6.5)
Crossover on internal points	79%	79%	0%	0%	0%	60%
Crossover on terminals	10%	10%	0%	0%	0%	10%
Crossover on non-numeric internal points	0%	0%	60%	49%	49%	0%
Crossover on non-numeric terminals	0%	0%	10%	10%	10%	0%
Crossover on numeric terminals	0%	0%	0%	0%	0%	0%
Reproduction	10%	10%	9%	9%	9%	9%
Subtree mutation	1%	1%	1%	1%	1%	1%
Numeric constant mutation	0%	0%	20%	20%	20%	20%
Subroutine duplication	0%	0%	0%	5%	5%	0%
Argument duplication	0%	0%	0%	0%	0%	0%

Subroutine deletion	0%	0%	0%	1%	1%	0%
Argument deletion	0%	0%	0%	0%	0%	0%
Subroutine creation	0%	0%	0%	5%	5%	0%
Argument creation	0%	0%	0%	0%	0%	0%
Iteration creation	0%	0%	0%	0%	0%	0%
Loop creation	0%	0%	0%	0%	0%	0%
Recursion creation	0%	0%	0%	0%	0%	0%
Storage creation	0%	0%	0%	0%	0%	0%
Max. points for RPB	300	600	500	300	??	500
Max. points for ADF	NA	NA	NA	100	??	NA

Table B.4 Percentages of operations after generation 5 for seven problems

	Analog NAND circuit (section 4.4)	Lowpass filter with layout (section 5.2)	Square root computational circuit (section 4.6)	Passive lowpass filter with variable passband boundary (section 10.4)	Lowpass/highpass filter with free variables (section 11.1), Lowpass/highpass filter with variable passband boundary with a free variable (section 11.2)	Yagi-Uda antennas problem (section 6.5)
Crossover on internal points	79%	79%	0%	0%	0%	60%
Crossover on terminals	10%	10%	0%	0%	0%	10%
Crossover on non-numeric internal points	0%	0%	60%	57%	57.50%	0%
Crossover on non-numeric terminals	0%	0%	10%	10%	10%	0%
Crossover on numeric terminals	0%	0%	0%	0%	0%	0%
Reproduction	10%	10%	9%	9%	9%	9%
Subtree mutation	1%	1%	1%	1%	1%	1%
Numeric constant mutation	0%	0%	20%	20%	20%	20%
Subroutine duplication	0%	0%	0%	1%	1%	0%
Argument duplication	0%	0%	0%	0%	0%	0%

Subroutine deletion	0%	0%	0%	1%	0.50%	0%
Argument deletion	0%	0%	0%	0%	0%	0%
Subroutine creation	0%	0%	0%	1%	1%	0%
Argument creation	0%	0%	0%	0%	0%	0%
Iteration creation	0%	0%	0%	0%	0%	0%
Loop creation	0%	0%	0%	0%	0%	0%
Recursion creation	0%	0%	0%	0%	0%	0%
Storage creation	0%	0%	0%	0%	0%	0%
Max. points for RPB	300	600	500	300	??	500
Max. points for ADF	NA	NA	NA	100	??	NA

Table B.5 Percentages of operations for the problems not using the architecture-altering operations

	Genetic network for *lac* operon (chapter 7)	Metabolic pathway for phospholipid cycle (section 8.6), Metabolic pathway for ketone bodies (section 8.7)	Lowpass filter without an explicit test fixture (section 4.7), Zobel network problem (two free variables (section 10.2), Third-order elliptic lowpass filter with variable modular angle (section 10.3), Active lowpass filter with variable passband boundary with free variable (section 10.5), Variable Quadratic/ cubic computational circuit (section 11.3), Variable 40–60 dB amplifier (section 11.4), Improved PID tuning rules (four freevariables) (section 12.3), all three runs of non-PID parameterized controller (with four free variables), Problem of reducing amplifier distortion by means of negative feedback (section 14.2), all 11 runs of the six problems involving post-2000 patented inventions in chapter 15
Crossover on internal points	63%	58.50%	63%
Crossover on terminals	7%	6.50%	7%
Crossover on non-numeric internal points	0%	0%	0%
Crossover on non-numeric terminals	0%	0%	0%
Crossover on numeric terminals	0%	0%	0%
Reproduction	9%	9%	9%
Subtree mutation	1%	1%	1%
Numeric constant mutation	20%	20%	20%
Subroutine duplication	0%	0%	0%
Argument duplication	0%	0%	0%
Subroutine deletion	0%	0%	0%
Argument deletion	0%	0%	0%
Subroutine creation	0%	0%	0%
Argument creation	0%	0%	0%
Iteration creation	0%	0%	0%
Loop creation	0%	0%	0%
Recursion creation	0%	0%	0%
Storage creation	0%	0%	0%
Max. points for RPB	1,000	500	500
Max. points for ADF	NA	NA	NA

Table B.6 Migration strategy used on the 41 runs

Migration strategy	Problems
A	Two-lag plant (section 3.7), Three-lag plant (section 3.8), Non-minimal phase plant (section 3.10), RC circuit with gain greater than two (section 4.2), Philbrick circuit (section 4.3), NAND circuit (section 4.4), Arithmetic logic unit (ALU) circuit (section 4.5), Layout of lowpass filter (section 5.2)
B	Three-lag plant with five second delay (section 3.9), Lowpass/highpass filter with free variable (section 11.1), Lowpass/highpass filter with variable passband boundary with a free variable (section 11.2)
C	Three-lag plant with free variable (section 9.1), Controller for two families of plants (section 9.2), Square root computational circuit (section 4.6), Lowpass filter without an explicit test fixture (section 4.7), Layout of amplifier (section 5.3), Yagi–Uda antenna (section 6.5), Metabolic pathway for phospholipid cycle (section 8.6), Metabolic pathway for ketone bodies (section 8.7), Zobel network problem (two free variables) (section 10.2), Third-order elliptic lowpass filter with variable modular angle (section 10.3), Passive lowpass filter with variable passband boundary (section 10.4), Active lowpass filter with variable passband boundary with free variable (section 10.5), Variable Quadratic/cubic computational circuit (section 11.3), Variable 40–60 dB amplifier (section 11.4), Improved PID tuning rules (four free variables) (section 12.3), First non-PID parameterized controller (two free variables) (section 13.2.1), Second non-PID parameterized controller (two free variables) (section13.2.2), Third non-PID parameterized controller (two free variables) (section 13.2.3), Negative feedback (section 14.2), Low-voltage balun circuit (section 15.4.1), Mixed analog-digital variable capacitor circuit (section 15.4.2), High-current load circuit (sections 15.4.3.1 and 15.4.3.2), Voltage–current conversion circuit (section 15.4.4), Cubic function generator (sections 15.4.5 and 15.4.5), Tunable integrated active filter (sections 15.4.6.1, 15.4.6.2. 15.4.6.3, and 15.4.6.4)

The current published literature in the fields of genetic algorithms and genetic programming provides a considerable amount of conflicting advice on the topic of choosing control parameters. Moreover, it is rarely clear how one should go about translating a problem's high-level statement in English into particular choices of control parameters. Thus, it is not clear how a user of genetic programming would go about shrewdly or optimally tailoring the control parameters for a particular problem even if that were the intent. Of course, if one has sufficient understanding of the dynamics of the evolutionary process and sufficient insight concerning the fitness landscape of an unseen new problem, there is nothing wrong with doing such tailoring if the primary objective is to solve the particular problem at hand.

Appendix C: Patented or Patentable Inventions Generated by Genetic Programming

Tables C.1 and C.2 provide additional information on the 23 patent-related results (of the 36 human-competitive results produced by genetic programming in table 1.3).

Table C.1 provides additional information on the 21 results that relate to previously patented inventions. Eleven of the 21 results in table C.1 infringe previously issued patents and 10 duplicate the functionality of previously patented inventions in a non-infringing way. The first 10 entries in table C.1 refer to problems that were solved in *Genetic Programming III: Darwinian Invention and Problem Solving* (Koza, Bennett, Andre, and Keane 1999a). The last 11 entries in table C.1 are described in this book. The last six entries in table C.1 relate to patents for analog circuits that were issued after January 1, 2000.

Four of the 21 entries in the body of table C.1 are marked "See text." These entries relate to groups of previously patented inventions (as opposed to single patents) that are described in detail in *Genetic Programming III: Darwinian Invention and Problem Solving* (Koza, Bennett, Andre, and Keane 1999a). Concerning computational circuits (the 7th entry in table C.1), dozens of different computational circuits have been patented, including, for example, square root circuits (Newbold 1962) and logarithmic circuits (Green 1958). Concerning electronic thermometers (the 8th entry in table C.1), at least two dozen temperature-sensing circuits have been patented, including, for example, ones by Haeusler (1976) and Massey (1970). Concerning voltage reference circuits (the 9th entry in table C.1), Robert C. Dobkin and Robert J. Widlar of National Semiconductor Corporation received U.S. patent 3,617,859 for the voltage reference circuit (Dobkin and Widlar 1971). Subsequent to the renowned Dobkin-Widlar circuit, other patents have been issued for voltage reference circuits, including U.S. patent 3,743,923 to Goetz Wolfgang Steudel of RCA Corporation (Steudel 1973). Hundreds of patents have been issued for amplifiers (the 10th entry in table C.1).

Table C.2 shows the two inventions generated by genetic programming for which a patent application has been filed.

Table C.1 Twenty-one previously patented inventions reinvented by genetic programming

	Invention	Date	Inventor	Place	Patent	Reference
1	Darlington emitter-follower section	1953	Sidney Darlington	Bell Telephone Laboratories	2,663,806	Section 42.3 of *Genetic Programming III*
2	Ladder filter	1917	George Campbell	American Telephone and Telegraph	1,227,113	Section 25.15.1 of *Genetic Programming III* and section 5.2 of this book
3	Crossover filter	1925	Otto Julius Zobel	American Telephone and Telegraph	1,538,964	Section 32.3 of *Genetic Programming III*
4	"*M*-derived half section" filter	1925	Otto Julius Zobel	American Telephone and Telegraph	1,538,964	Section 25.15.2 of *Genetic Programming III*
5	Cauer (elliptic) topology for filters	1934 – 1936	Wilhelm Cauer	University of Gottingen	1,958,742, 1,989,545	Section 27.3.7 of *Genetic Programming III*
6	Sorting network	1962	Daniel G. O'Connor and Raymond J. Nelson	General Precision, Inc.	3,029,413	Sections 21.4.4, 23.6, and 57.8.1 of *Genetic Programming III*
7	Computational circuits	See text	See text	See text	See text	Section 47.5.3 of *Genetic Programming III*
8	Electronic thermometer	See text	See text	See text	See text	Section 49.3 of *Genetic Programming III*
9	Voltage reference circuit	See text	See text	See text	See text	Section 50.3 of *Genetic Programming III*
10	60 and 96 dB amplifiers	See text	See text	See text	See text	Section 45.3 of *Genetic Programming III*
11	Second-derivative controller	1942	Harry Jones	Brown Instrument Company	2,282,726	Section 3.7 of this book
12	Philbrick circuit	1956	George Philbrick	George A. Philbrick Researches	2,730,679	Section 4.3 of this book
13	NAND circuit	1971	David H. Chung and Bill H. Terrell	Texas Instruments Incorporated	3,560,760	Section 4.4 of this book
14	PID (proportional, integrative, and derivative) controller	1939	Albert Callender and Allan Stevenson	Imperial Chemical Limited	2,175,985	Section 9.2 of this book

(*Continued*)

Table C.1 (*Continued*)

	Invention	Date	Inventor	Place	Patent	Reference
15	Negative feedback	1937	Harold S. Black	American Telephone and Telegraph	2,102,670, 2,102,671	Chapter 14 of this book
16	Low-voltage balun circuit	2001	Sang Gug Lee	Information and Communications University	6,265,908	Section 15.4.1 of this book
17	Mixed analog-digital variable capacitor circuit	2000	Turgut Sefket Aytur	Lucent Technologies Inc.	6,013,958	Section 15.4.2 of this book
18	High-current load circuit	2001	Timothy Daun-Lindberg and Michael Miller	International Business Machines Corporation	6,211,726	Section 15.4.3 of this book
19	Voltage-current conversion circuit	2000	Akira Ikeuchi and Naoshi Tokuda	Mitsumi Electric Co., Ltd.	6,166,529	Section 15.4.4 of this book
20	Cubic function generator	2000	Stefano Cipriani and Anthony A. Takeshian	Conexant Systems, Inc.	6,160,427	Section 15.4.5 of this book
21	Tunable integrated active filter	2001	Robert Irvine and Bernd Kolb	Infineon Technologies AG	6,225,859	Section 15.4.6 of this book

Table C.2 Two patentable inventions created by genetic programming

	Claimed invention	Date of patent application	Inventors	Reference
1	Improved general-purpose tuning rules for a PID controller	July 12, 2002	Martin A. Keane, John R. Koza, and Matthew J. Streeter	Section 12.3 of this book
2	Improved general-purpose non-PID controllers	July 12, 2002	Martin A. Keane, John R. Koza, and Matthew J. Streeter	Section 13.2 of this book

Bibliography

Aarts, Emile and Korst, Jan. 1989. *Simulated Annealing and Boltzmann Machines*. Chichester: John Wiley and Sons.

Aaserud, O. and Nielsen, I. Ring. 1995. Trends in current analog design: A panel debate. *Analog Integrated Circuits and Signal-Processing*. 7(1)5–9.

Abelson, Harold and diSessa, Andrea. 1980. *Turtle Geometry*. Cambridge, MA: The MIT Press.

Altshuler, Edward E. and Linden, Derek S. 1998. *Process for the Design of Antennas Using Genetic Algorithm*. U.S. patent 5,719,794. Applied for on July 19, 1995. Issued on February 17, 1998.

Altshuler, Edward E. and Linden, Derek S. 1999. Design of wire antennas using genetic algorithms. In Rahmat-Samii, Yahya and Michielssen, Eric (editors). *Electromagnetic Optimization by Genetic Algorithms*. New York, NY: John Wiley and Sons. Chapter 8. Pages 211–248.

Andersson, Bjorn, Svensson, Per, Nordin, Peter, and Nordahl, Mats. 1999. Reactive and memory-based genetic programming for robot control. In Poli, Riccardo, Nordin, Peter, Langdon, William B., and Fogarty, Terence C. 1999. *Genetic Programming: Second European Workshop. EuroGP'99. Proceedings*. Lecture Notes in Computer Science. Volume 1598. Berlin, Germany: Springer-Verlag. Pages 161–172.

Andre, David, Bennett III, Forrest H, and Koza, John R. 1996. Discovery by genetic programming of a cellular automata rule that is better than any known rule for the majority classification problem. In Koza, John R., Goldberg, David E., Fogel, David B., and Riolo, Rick L. (editors). 1996. *Genetic Programming 1996: Proceedings of the First Annual Conference, July 28–31, 1996, Stanford University*. Cambridge, MA: MIT Press. Pages 3–11.

Andre, David and Koza, John R. 1995. Parallel genetic programming on a network of transputers. In Rosca, Justinian (editor). *Proceedings of the Workshop on Genetic Programming: From Theory to Real World Applications*. University of Rochester. National Resource Laboratory for the Study of Brain and Behavior. Technical Report 95-2. June 1995. Pages 111–120.

Andre, David and Koza, John R. 1996a. Parallel genetic programming: A scalable implementation using the transputer architecture. In Angeline, P. J. and Kinnear, K. E. Jr. (editors). 1996. *Advances in Genetic Programming 2*. Cambridge, MA: The MIT Press.

Andre, David and Koza, John R. 1996b. A parallel implementation of genetic programming that achieves super-linear performance. In Arabnia, Hamid R. (editor). *Proceedings of the International Conference on Parallel and Distributed Processing Techniques and Applications*. Athens, GA: CSREA. Volume III. Pages 1163–1174.

Andre, David and Teller, Astro. 1999. Evolving team Darwin United. In Asada, Minoru and Kitano, Hiroaki (editors). *RoboCup-98: Robot Soccer World Cup II*. Lecture Notes in Computer Science. Volume 1604. Berlin: Springer-Verlag. Pages 346–352.

Angeline, Peter J. and Kinnear, Kenneth E. Jr. (editors). 1996. *Advances in Genetic Programming 2*. Cambridge, MA: The MIT Press.

Angeline, Peter J. 1997. An alternative to indexed memory for evolving programs with explicit state representations. In Koza, John R., Deb, Kalyanmoy, Dorigo, Marco, Fogel, David B., Garzon, Max, Iba, Hitoshi, and Riolo, Rick L. (editors). *Genetic Programming 1997: Proceedings of the Second Annual Conference, July 13–16, 1997, Stanford University*. San Francisco, CA: Morgan Kaufmann. Pages 423–430.

Angeline, Peter J. 1998a. Multiple interacting programs: A representation for evolving complex behaviors. *Cybernetics and Systems*. 29(8)779–806.

Angeline, Peter J. 1998b. Evolving predictors for chaotic time series. In Rogers, S., Fogel, D., Bezdek, J., and Bosacchi, B. (editors). *Proceedings of SPIE (Volume 3390): Application and Science of Computational Intelligence*, Bellingham, WA: The International Society for Optical Engineering. Pages 170–180.

Angeline, Peter J. and Fogel, David B. 1997. An evolutionary program for the identification of dynamical systems. In Rogers, S. (editor). *Proceedings of SPIE (Volume 3077): Application and Science of Artificial Neural Networks III*. Bellingham, WA: The International Society for Optical Engineering. Pages 409–417.

Arkin, Adam, Shen, Peidong, and Ross, John. 1997. A test case of correlation metric construction of a reaction pathway from measurements. *Science*. 277. Pages 1275–1279. August 29, 1997.

Armstrong, Edwin Howard. 1914. *Wireless Receiving System*. U.S. patent 1,113,149. Filed October 29, 1913. Issued October 6, 1914.

Åström, Karl J. and Hägglund, Tore. 1995. *PID Controllers: Theory, Design, and Tuning*. Second Edition. Research Triangle Park, NC: Instrument Society of America.

Aytur, Turgut Sefket. 2000. *Integrated Circuit with Variable Capacitor*. U.S. patent 6,013,958. Filed July 23, 1998. Issued January 11, 2000.

Babanezhad, J. N. and Temes, G. C. 1986. Analog MOS computational circuits. *Proceedings of the IEEE Circuits and System International Symposium*. Piscataway, NJ: IEEE Press. Pages 1156–1160.

Babovic, Vladan. 1996. *Emergence, Evolution, Intelligence: Hydroinformatics*. Rotterdam, The Netherlands: Balkema Publishers.

Bagchi, Tapan P. 1999. *Multiobjective Scheduling by Genetic Algorithms*. Boston: Kluwer Academic Publishers.

Balanis, Constantine A. 1982. *Antenna Theory: Analysis and Design*. New York, NY: John Wiley and Sons.

Banzhaf, Wolfgang, Daida, Jason, Eiben, A. E., Garzon, Max H., Honavar, Vasant, Jakiela, Mark, and Smith, Robert E. (editors). 1999. *GECCO-99: Proceedings of the Genetic and Evolutionary Computation Conference, July 13–17, 1999, Orlando, Florida USA*. San Francisco, CA: Morgan Kaufmann.

Banzhaf, Wolfgang, Nordin, Peter, Keller, Robert E., and Francone, Frank D. 1998. *Genetic Programming: An Introduction*. San Francisco, CA: Morgan Kaufmann and Heidelberg: dpunkt.

Banzhaf, Wolfgang, Nordin, Peter, Keller, Richard, and Olmer, Markus. 1997. Generating adaptive behavior for a real robot using function regression with genetic programming. In Koza, John R., Deb, Kalyanmoy, Dorigo, Marco, Fogel, David B., Garzon, Max, Iba, Hitoshi, and Riolo, Rick L. (editors). *Genetic Programming 1997: Proceedings of the Second Annual Conference, July 13–16, 1997, Stanford University*. San Francisco, CA: Morgan Kaufmann. Pages 35–43.

Banzhaf, Wolfgang, Poli, Riccardo, Schoenauer, Marc, and Fogarty, Terence C. 1998. *Genetic Programming: First European Workshop. EuroGP'98. Paris, France, April 1998 Proceedings*. Lecture Notes in Computer Science. Volume 1391. Berlin, Germany: Springer-Verlag.

Barnum, H., Bernstein, H.J. and Spector, Lee. 2000. Quantum circuits for OR and AND of ORs. *Journal of Physics A: Mathematical and General*. 33(45)8047–8057. November 17, 2000.

Bennett III, Forrest H. and Koza, John R. 2002. *Method and Apparatus for Automatic Synthesis, Placement and Routing of Complex Structures*. U.S. patent 6,424,959. Filed June 17, 1999. Issued July 23, 2002.

Bennett III, Forrest H, Koza, John R., Andre, David, and Keane, Martin A. 1996. Evolution of a 60 decibel op amp using genetic programming. In Higuchi, Tetsuya, Iwata, Masaya, and Lui, Weixin (editors). *Proceedings of International Conference on Evolvable Systems: From Biology to Hardware (ICES-96)*. Lecture Notes in Computer Science, Volume 1259. Berlin: Springer-Verlag. Pages 455–469.

Bennett III, Forrest H, Koza, John R., Yu, Jessen, and Mydlowec, William. 2000. Automatic synthesis, placement, and routing of an amplifier circuit by means of genetic programming. In Miller, Julian, Thompson, Adrian, Thomson, Peter, and Fogarty, Terence C. (editors). 2000. *Evolvable Systems: From Biology to Hardware. Third International Conference, ICES 2000, Edinburgh, Scotland, UK, April 2000 Proceedings*. Lecture Notes in Computer Science. Volume 1801. Berlin, Germany: Springer-Verlag. Pages 1–10.

Bennett III, Forrest H, Koza, John R., Keane, Martin A., Yu, Jessen, Mydlowec, William, and Stiffelman, Oscar. 1999. Evolution by means of genetic programming of analog circuits that perform digital functions. In Banzhaf, Wolfgang, Daida, Jason, Eiben, A. E., Garzon, Max H., Honavar, Vasant, Jakiela, Mark, and Smith, Robert E. (editors). 1999. *GECCO-99: Proceedings of the Genetic and Evolutionary Computation Conference, July 13–17, 1999, Orlando, Florida USA*. San Francisco, CA: Morgan Kaufmann. Pages 1477–1483.

Bennett III, Forrest H, Koza, John R., Shipman, James, and Stiffelman, Oscar. 1999. Building a parallel computer system for $18,000 that performs a half peta-flop per day. In Banzhaf, Wolfgang, Daida, Jason, Eiben, A. E., Garzon, Max H., Honavar, Vasant, Jakiela, Mark, and Smith, Robert E. (editors). 1999. *GECCO-99: Proceedings of the Genetic and Evolutionary Computation Conference, July 13–17, 1999, Orlando, Florida USA*. San Francisco, CA: Morgan Kaufmann. Pages 1484–1490.

Black, Harold S. 1928. *Translating System*. U.S. patent 1,686,792. Filed February 3, 1925. Issued October 9, 1928.

Black, Harold S. 1935. *Wave Translation System*. U.S. patent 2,003,282. Filed August 8, 1928. Issued June 4, 1935.

Black, Harold S. 1937a. *Wave Translation System*. U.S. patent 2,102,670. Filed August 8, 1928. Issued December 21, 1937.

Black, Harold S. 1937b. *Wave Translation System*. U.S. patent 2,102,671. Filed April 22, 1932. Issued December 21, 1937.

Black, Harold S. 1977. Inventing the negative feedback amplifier. *IEEE Spectrum*. December 1977. Pages 55–60.

Blickle, Tobias. 1997. *Theory of Evolutionary Algorithms and Application to System Synthesis*. TIK-Schriftenreihe Nr. 17. Zurich, Switzerland: vdf Hochschul Verlag AG an der ETH Zuerich.

Boutin, Noel. 2002. Use time-domain analysis of Zobel network. *EDN*. July 27, 2002. Page 86.

Bower, James M. and Bolouri, Hamid. 2000. *Computational Modeling of Genetic and Biochemical Networks*. Cambridge, MA: MIT Press.

Boyd, S. P. and Barratt, C. H. 1991. *Linear Controller Design: Limits of Performance*. Englewood Cliffs, NJ: Prentice Hall.

Bryson, Arthur E., and Ho, Yu-Chi. 1975. *Applied Optimal Control*. New York: Hemisphere Publishing.

Burke, Gerald J. 1992. *Numerical Electromagnetics Code—NEC-4: Method of Moments—User*'s *Manual*. Lawrence Livermore National Laboratory report UCRL-MA-109338. Livermore, CA: Lawrence Livermore National Laboratory.

Callender, Albert and Stevenson, Allan Brown. 1939. *Automatic Control of Variable Physical Characteristics*. U.S. patent 2,175,985. Filed February 17, 1936 in the United States. Filed February 13, 1935 in Great Britain. Issued October 10, 1939 in the United States.

Campbell, George A. 1917. *Electric Wave Filter*. Filed July 15, 1915. U.S. patent 1,227,113. Issued May 22, 1917.

Cantu-Paz, Erick. 2000. *Efficient and Accurate Parallel Genetic Algorithms*. Boston: Kluwer Academic Publishers.

Cauer, Wilhelm. 1934. *Artificial Network*. U.S. patent 1,958,742. Filed June 8, 1928 in Germany. Filed December 1, 1930 in the United States. Issued May 15, 1934.

Cauer, Wilhelm. 1935. *Electric Wave Filter*. U.S. patent 1,989,545. Filed June 8, 1928. Filed December 6, 1930 in the United States. Issued January 29, 1935.

Cauer, Wilhelm. 1936. *Unsymmetrical Electric Wave Filter*. U.S. patent 2,048,426. Filed November 10, 1932 in Germany. Filed November 23, 1933 in the United States. Issued July 21, 1936.

Chung, David H. and Terrell, Bill H. 1971. *Logic NAND Gate Circuits*. U.S. patent 3,560,760. Filed February 2, 1970. Issued February 2, 1971.

Cipriani, Stefano and Takeshian, Anthony A. 2000. *Compact Cubic Function Generator*. U.S. patent 6,160,427. Filed September 4, 1998. Issued December 12, 2000.

Coello Coello, Carlos A., Van Veldhuizen, David A., and Lamont, Gary B. 2002. *Evolutionary Algorithms for Solving Multi-Objective Problems*. Boston: Kluwer Academic Publishers.

Cohn, John M., Garrod, David J., Rutenbar, Rob A., and Carley, L. Richard. 1994. *Analog Device-Level Layout Automation*. Boston: Kluwer.

Collado-Vides, Julio and Hofestadt, Ralf. 2002. *Gene Regulation and Metabolism*. Cambridge, MA: The MIT Press.

Comisky, William, Yu, Jessen, and Koza, John. 2000. Automatic synthesis of a wire antenna using genetic programming. *Late Breaking Papers at the 2000 Genetic and Evolutionary Computation Conference, Las Vegas, Nevada*. Pages 179–186.

Crawford, L. S., Cheng, V. H. L., and Menon, P. K. 1999. Synthesis of flight vehicle guidance and control laws using genetic search methods. *Proceedings of 1999 Conference on Guidance, Navigation, and Control*. Reston, VA: American Institute of Aeronautics and Astronautics. Paper AIAA-99-4153.

Darlington, Sidney. 1953. *Semiconductor Signal Translating Device*. U.S. patent 2,663,806. Filed May 9, 1952. Issued December 22, 1953.

Daun-Lindberg, Timothy Charles and Miller, Michael Lee. 2001. *Low Voltage High-Current Electronic Load*. U.S. patent 6,211,726. Filed June 28, 1999. Issued April 3, 2001.

Deb, Kalyanmoy. 2001. *Multi-Objective Optimization using Evolutionary Algorithms*. Boston: Kluwer Academic Publishers.

Dewell, Larry D. and Menon, P. K. 1999. Low-thrust orbit transfer optimization using genetic search. *Proceedings of 1999 Conference on Guidance, Navigation, and Control*. Reston, VA: American Institute of Aeronautics and Astronautics. Paper AIAA-99-4151.

D'haeseleer, Patrik, Wen, Xiling, Fuhrman, Stefanie, and Somogyi, Roland. 1999. Linear modeling of mRNA expression levels during CNS development and injury. In Altman, Russ B. Dunker, A. Keith, Hunter, Lawrence, Klein, Teri E., and Lauderdale, Kevin (editors). *Pacific Symposium on Biocomputing '99*. Singapore: World Scientific. Pages 41–52.

Dobkin, Robert C. and Widlar, Robert J. 1971. *Electrical Regulator Apparatus Including a Zero-Temperature Coefficient Voltage Reference Circuit*. U.S. patent 3,617,859. Filed May 23, 1970. Issued November 2, 1971.

Dorf, Richard C. and Bishop, Robert H. 1998. *Modern Control Systems*. Eighth edition. Menlo Park, CA: Addison-Wesley.

Drechsler, Rolf. 1998. *Evolutionary Algorithms for VLSI CAD*. Boston: Kluwer Academic Publishers.

Foster, James A., Lutton, Evelyne, Miller, Julian, Ryan, Conor, and Tettamanzi, Andrea G. B. (editors). 2002. *Genetic Programming: 5th European Conference, EuroGP 2002, Kinsale, Ireland, April 2002 Proceedings*. Berlin: Springer-Verlag.

Garey, Michael R. and Johnson, David S. 1979. *Computers and Intractability: A Guide to the Theory of NP-Completeness*. New York, NY: W. H. Freeman.

Getreu, Ian. 2002. Productivity tools for analog/mixed-signal designs: Ready for prime time? *Electronic Design*. June 10, 2002. Page 40.

Gilbert, Barrie. 1968. A precise four-quadrant multiplier with subnanosecond response. *IEEE Journal of Solid-State Circuits*. Volume SC-3. Number 4. December 1968. Pages 365–373.

Gilbert, Barrie. 1979. *Multiplier Circuit*. U.S. patent 4,156,283. Filed October 3, 1977. Issued May 22, 1979.

Goddard, Robert. 1915. *Method of and Apparatus for Producing Electrical Impulses or Oscillations*. U.S. patent 1,159,209. Filed August 1, 1912. Issued November 2, 1915.

Goldberg, David E. 1989. *Genetic Algorithms in Search, Optimization, and Machine Learning*. Reading, MA: Addison-Wesley.

Goldberg, David E. 1990. A note on Boltzmann tournament selection for genetic algorithms and population-oriented simulated annealing. *Complex Systems*. 4(4)445–460.

Goldberg, David E. 2002. *The Design of Innovation: Lessons from and for Competent Genetic Algorithms*. Boston: Kluwer Academic Publishers.

Green, Milton. 1958. *Logarithmic Converter Circuit*. U.S. patent 2,861,182. Filed June 16, 1953. Issued November 18, 1958.

Grimbleby, J. B. 1995. Automatic analogue network synthesis using genetic algorithms. *Proceedings of the First International Conference on Genetic Algorithms in Engineering Systems: Innovations and Applications (GALESIA)*. London: Institution of Electrical Engineers. Pages 53–58.

Gruau, Frederic. 1992a. *Cellular Encoding of Genetic Neural Networks*. Technical report 92–21. Laboratoire de l'Informatique du Parallélisme. Ecole Normale Supérieure de Lyon. May 1992.

Gruau, Frederic. 1992b. Genetic synthesis of Boolean neural networks with a cell rewriting developmental process. In Schaffer, J. D. and Whitley, Darrell (editors). *Proceedings of the Workshop on Combinations of Genetic Algorithms and Neural Networks 1992*. Los Alamitos, CA: The IEEE Computer Society Press.

Haeusler, Jochen, 1976. *Arrangement for Measuring Temperatures*. U.S. patent 3,943,434. Filed February 6, 1974. Issued March 9, 1976.

Haupt, Randy L. 1994. Thinned arrays using genetic algorithms. *IEEE Transactions on Antennas and Propagation*. Volume 42: Pages 993–999.

Higuchi, Tetsuya, Iwata, Masaya, and Lui, Weixin (editors). 1997. *Evolvable Systems: From Biology to Hardware: First International Conference, ICES-96, Tsukuba, Japan, October 1996 Proceedings*. Lecture Notes in Computer Science, Volume 1259. Berlin: Springer-Verlag.

Higuchi, Tetsuya, Niwa, Tatsuya, Tanaka, Toshio, Iba, Hitoshi, de Garis, Hugo, and Furuya, Tatsumi. 1993a. Evolving hardware with genetic learning: A first step towards building a Darwin machine. In Meyer, Jean-Arcady, Roitblat, Herbert L. and Wilson, Stewart W. (editors). *From Animals to Animats 2: Proceedings of the Second International Conference on Simulation of Adaptive Behavior*. Cambridge, MA: The MIT Press. 1993. Pages 417–424.

Higuchi, Tetsuya, Niwa, Tatsuya, Tanaka, Toshio, Iba, Hitoshi, de Garis, Hugo, and Furuya, Tatsumi. 1993b. *Evolvable Hardware–Genetic-Based Generation of Electric Circuitry at Gate and Hardware Description Language (HDL) Levels*. Electrotechnical Laboratory technical report 93-4. Tsukuba, Japan: Electrotechnical Laboratory.

Holland, John H. 1975. *Adaptation in Natural and Artificial Systems: An Introductory Analysis with Applications to Biology, Control, and Artificial Intelligence*. Ann Arbor, MI: University of Michigan Press. Second edition. Cambridge, MA: The MIT Press 1992.

Hsu, Feng-Hsiung. 2002. *Behind Deep Blue: Building the Computer That Defeated the World Chess Champion*. Princeton, NJ: Princeton University Press.

Iba, Hitoshi. 1996. *Genetic Programming*. Tokyo: Tokyo Denki University Press. In Japanese.

Ikeuchi, Akira and Tokuda, Naoshi. 2000. *Voltage-Current Conversion Circuit*. U.S. patent 6,166,529. Filed February 24, 2000 in the United States. Issued December 26, 2000 in the United States. Filed March 10, 1999 in Japan.

Ince, D. C. (editor). 1992. *Mechanical Intelligence: Collected Works of A. M. Turing*. Amsterdam: North Holland.

Irvine, Robert and Kolb, Bernd. 2001. *Integrated Low-Pass Filter*. U.S. patent 6,225,859. Filed September 14, 1998. Issued May 1, 2001.

Jacob, Christian. 1997. *Principia Evolvica: Simulierte Evolution mit Mathematica*. Heidelberg, Germany: dpunkt.verlag.

Jacob, Christian. 2001. *Illustrating Evolutionary Computation with Mathematica*. San Francisco: Morgan Kaufmann.

Jamshidi, Mo, Coelho, Leandro dos Santos, Krohling, Renato A., and Fleming, Peter J. 2003. *Robust Control Systems with Genetic Algorithms*. Boca Raton, FL: CRC Press.

Johnson, Kenneth S. 1926. *Electric-Wave Transmission*. U.S. patent 1,611,916. Filed March 9, 1923. Issued December 28, 1926.

Johnson, Walter C. 1950. *Transmission Lines and Networks*. New York: NY: McGraw-Hill.

Johnson, J. Michael and Rahmat-Samii, Yahya. 1999. Genetic algorithms and method of moments (GA/MOM) for the design of integrated antennas. *IEEE Transactions on Antennas and Propagation*. 47(10)1606–1614. October 1999.

Jones, Eric A. 1999. *Genetic Design of Antennas and Electronic Circuits*. Ph.D. Thesis. Department of Electrical and Computer Engineering. Duke University.

Jones, Harry S. 1942. *Control Apparatus*. U.S. patent 2,282,726. Filed October 25, 1939. Issued May 12, 1942.

Keane, Martin A., Koza, John R., and Rice, James P. 1993. Finding an impulse response function using genetic programming. *Proceedings of the 1993 American Control Conference*. Evanston, IL: American Automatic Control Council. Volume III. Pages 2345–2350.

Keane, Martin A., Koza, John R., and Streeter, Matthew J. 2002a. *Improved General-Purpose Controllers*. U.S. patent application filed July 12, 2002.

Keane, Martin A., Koza, John R., and Streeter, Matthew J. 2002b. Automatic synthesis using genetic programming of an improved general-purpose controller for industrially representative plants. In Stoica, Adrian, Lohn, Jason, Katz, Rich, Keymeulen, Didier and Zebulum, Ricardo (editors) 2002. *Proceedings of 2002 NASA/DoD Conference on Evolvable Hardware*. Los Alamitos, CA: IEEE Computer Society. Pages 113–122.

Keane, Martin A., Yu, Jessen, and Koza, John R. 2000. Automatic synthesis of both the topology and tuning of a common parameterized controller for two families of plants using genetic programming. In Whitley, Darrell, Goldberg, David, Cantu-Paz, Erick, Spector, Lee, Parmee, Ian, and Beyer, Hans-Georg (editors). *GECCO-2000: Proceedings of the Genetic and Evolutionary Computation Conference, July 10–12, 2000, Las Vegas, Nevada*. San Francisco: Morgan Kaufmann. Pages 496–504.

Keymeulen, Didier, Stoica, Adrian, Lohn, Jason, and Zebulum, Ricardo Salem (editors). 2001. *Proceedings of the Third NASA/DOD Workshop on Evolvable Hardware, Pasadena, California, July 12–14, 2001*. Los Alamitos, CA. IEEE Computer Society.

Kinnear, Kenneth E. Jr. (editor). 1994. *Advances in Genetic Programming*. Cambridge, MA: MIT Press.

Kirkpatrick, S., Gelatt, C. D., and Vecchi, M. P. 1983. Optimization by simulated annealing. *Science* 220. Pages 671–680.

Kitano, Hiroaki. 1990. Designing neural networks using genetic algorithms with graph generation system. *Complex Systems*. 4 (1990) 461–476.

Kitano, Hiroaki. 2001. *Foundations of Systems Biology*. Cambridge, MA: The MIT Press.

Koza, John R. 1988. *Nonlinear Genetic Algorithms for Solving Problems*. U.S. patent application filed May 20, 1988.

Koza, John R. 1989. Hierarchical genetic algorithms operating on populations of computer programs. In *Proceedings of the 11th International Joint Conference on Artificial Intelligence*. San Mateo, CA: Morgan Kaufmann. Volume I. Pages 768–774.

Koza, John R. 1990a. *Genetic Programming: A Paradigm for Genetically Breeding Populations of Computer Programs to Solve Problems*. Stanford University Computer Science Department technical report STAN-CS-TR-90-1314. June 1990.

Koza, John R. 1990b. *Non-Linear Genetic Algorithms for Solving Problems*. U.S. patent 4,935,877. Filed May 20, 1988. Issued June 19, 1990.

Koza, John R. 1992a. *Genetic Programming: On the Programming of Computers by Means of Natural Selection*. Cambridge, MA: MIT Press.

Koza, John R. 1992b. *Non-Linear Genetic Algorithms for Solving Problems by Finding a Fit Composition of Functions*. U. S. patent 5,136,686. Filed March 28, 1990. Issued August 4, 1992.

Koza, John R. 1992c. Hierarchical automatic function definition in genetic programming. In Whitley, Darrell (editor). 1993. *Foundations of Genetic Algorithms 2*. San Mateo, CA: Morgan Kaufmann Publishers. Pages 297–318.

Koza, John R. 1992d. A genetic approach to finding a controller to back up a tractor-trailer truck. In *Proceedings of the 1992 American Control Conference*. Evanston, IL: American Automatic Control Council. Volume III. Pages 2307–2311.

Koza, John R. 1993. Discovery of rewrite rules in Lindenmayer systems and state transition rules in cellular automata via genetic programming. *Symposium on Pattern Formation (SPF-93), Claremont, California. February 13, 1993*. A copy of this presented, but otherwise unpublished, paper is available at `http://www.smi.stanford.edu/people/koza`.

Koza, John R. 1994a. *Genetic Programming II: Automatic Discovery of Reusable Programs*. Cambridge, MA: MIT Press.

Koza, John R. 1994b. *Genetic Programming II Videotape: The Next Generation*. Cambridge, MA: MIT Press.

Koza, John R. 1994c. *Architecture-Altering Operations for Evolving the Architecture of a Multi-Part Program in Genetic Programming*. Stanford University Computer Science Department technical report STAN-CS-TR-94-1528. October 21, 1994.

Koza, John R. 1995a. Evolving the architecture of a multi-part program in genetic programming using architecture-altering operations. In McDonnell, John R., Reynolds, Robert G., and Fogel, David B. (editors). 1995. *Evolutionary Programming IV: Proceedings of the Fourth Annual Conference on Evolutionary Programming*. Cambridge, MA: The MIT Press. Pages 695–717.

Koza, John R. 1995b. Gene duplication to enable genetic programming to concurrently evolve both the architecture and work-performing steps of a computer program. *Proceedings of the 14th International Joint Conference on Artificial Intelligence*. San Francisco: Morgan Kaufmann. Pages 734–740.

Koza, John R. 1995c. Two ways of discovering the size and shape of a computer program to solve a problem. In Eshelman, Larry J. (editor). *Proceedings of the Sixth International Conference on Genetic Algorithms*. San Francisco: Morgan Kaufmann. Pages 287–294.

Koza, John R. and Andre, David. 1995. *Parallel Genetic Programming on a Network of Transputers*. Stanford University Computer Science Department technical report STAN-CS-TR-95-1542. January 30, 1995.

Koza, John R., Andre, David, and Tackett, Walter Alden. 1994. *Simultaneous Evolution of the Architecture of a Multi-Part Program to Solve a Problem Using Architecture Altering Operations*. U.S. patent application filed August 4, 1994.

Koza, John R., Andre, David, and Tackett, Walter Alden. 1998. *Simultaneous Evolution of the Architecture of a Multi-Part Program to Solve a Problem Using Architecture Altering Operations*. U. S. patent 5,742,738. Filed August 4, 1994. Issued April 21, 1998.

Koza, John R., Andre, David, and Tackett, Walter Alden. 2000. *Simultaneous Evolution of the Architecture of a Multi-Part Program to Solve a Problem Using Architecture Altering Operations*. U. S. patent 6,058,385. Filed March 7, 1997. Issued May 2, 2000.

Koza, John R., Banzhaf, Wolfgang, Chellapilla, Kumar, Deb, Kalyanmoy, Dorigo, Marco, Fogel, David B., Garzon, Max H., Goldberg, David E., Iba, Hitoshi, and Riolo, Rick. (editors). 1998. *Genetic Programming 1998: Proceedings of the Third Annual Conference*. San Francisco, CA: Morgan Kaufmann.

Koza, John R., and Bennett III, Forrest H. 1999. Automatic synthesis, placement, and routing of electrical circuits by means of genetic programming. In Spector, Lee, Langdon, William B., O'Reilly, Una-May, and Angeline, Peter (editors). *Advances in Genetic Programming 3*. Cambridge, MA: MIT Press. Chapter 6. Pages 105–134.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1996a. Automated design of both the topology and sizing of analog electrical circuits using genetic programming. In Gero, John S. and Sudweeks, Fay (editors). *Artificial Intelligence in Design '96*. Dordrecht: Kluwer Academic Publishers. Pages 151–170.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1996b. Automated WYWIWYG design of both the topology and component values of analog electrical circuits using genetic programming. In Koza, John R., Goldberg, David E., Fogel, David B., and Riolo, Rick L. (editors). *Genetic Programming 1996: Proceedings of the First Annual Conference, July 28–31, 1996, Stanford University*. Cambridge, MA: The MIT Press. Pages 123–131.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1996c. Reuse, parameterized reuse, and hierarchical reuse of substructures in evolving electrical circuits using genetic programming. In Higuchi, Tetsuya, Iwata, Masaya, and Liu, Weixin (editors). 1997. *Proceedings of International Conference on Evolvable Systems: From Biology to Hardware (ICES-96)*. Lecture Notes in Computer Science, Volume 1259. Berlin: Springer-Verlag. Berlin: Springer-Verlag. Pages 312–326.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1996d. Toward evolution of electronic animals using genetic programming. In Langton, Christopher G. and Shimohara, Katsunori (editors). 1997. *Artificial Life V: Proceedings of the Fifth International Workshop on the Synthesis and Simulation of Living Systems*. Cambridge, MA: The MIT Press. Pages 327–334.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1996e. Four problems for which a computer program evolved by genetic programming is competitive with human performance. *Proceedings of the 1996 IEEE International Conference on Evolutionary Computation*. IEEE Press. Pages 1–10.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1996f. *Method and Apparatus for Automated Design of Electrical Circuits Using Genetic Programming*. U.S. patent application filed February 20, 1996.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1999a. *Genetic Programming III: Darwinian Invention and Problem Solving*. San Francisco, CA: Morgan Kaufmann.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1999b. *Method and Apparatus for Automated Designs of Complex Structures using Genetic Programming*. Filed February 20. 1996. U. S. patent 5,867,397. Issued February 2, 1999.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 1999c. *Genetic Programming Problem Solver with Automatically Defined Stores, Loops, and Recursions*. U.S. patent application filed April 12, 1999.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 2002. *Method and Apparatus for Automated Design of Complex Structures using Genetic Programming*. U.S. patent 6,360,191. Filed February 20, 1996 and January 5, 1999. Issued March 19, 2002.

Koza, John R., Bennett III, Forrest H, Andre, David, and Keane, Martin A. 2003. *Genetic Programming Problem Solver with Automatically Defined Stores, Loops, and Recursions*. U.S. patent 6,532,453. Filed April 12, 1999. Issued March 11, 2003.

Koza, John R., Bennett III, Forrest H, Andre, David, Keane, Martin A., and Brave, Scott. 1999. *Genetic Programming III Videotape: Human-Competitive Machine Intelligence*. San Francisco, CA: Morgan Kaufmann.

Koza, John R., Bennett III, Forrest H, Andre, David, Keane, Martin A., and Dunlap, Frank. 1997. Automated synthesis of analog electrical circuits by means of genetic programming. *IEEE Transactions on Evolutionary Computation*. 1(2). Pages 109–128.

Koza, John R., Bennett, Forrest H, III, Hutchings, Jeffrey L., Bade, Stephen L., Keane, Martin A., and Andre, David. 1997. Evolving sorting networks using genetic programming and the rapidly reconfigurable Xilinx 6216 field-programmable gate array. *Proceedings of the 31st Asilomar Conference on Signals, Systems, and Computers*. Piscataway, NJ: IEEE Press. Pages 404–410.

Koza, John R., Bennett, Forrest H, III, Hutchings, Jeffrey L., Bade, Stephen L., Keane, Martin A., and Andre, David. 1998. Evolving computer programs using rapidly reconfigurable field-programmable gate arrays and genetic programming. *Proceedings of the ACM Sixth International Symposium on Field Programmable Gate Arrays*. New York: ACM Press. Pages 209–219.

Koza, John R., Bennett III, Forrest H, Keane, Martin A., and Andre, David. 1997. Automatic programming of a time-optimal robot controller and an analog electrical circuit to implement the robot controller by means of genetic programming. In *Proceedings of 1997 IEEE International Symposium on Computational Intelligence in Robotics and Automation*. Los Alamitos, CA: Computer Society Press. Pages 340–346.

Koza, John R., Bennett III, Forrest H, Keane, Martin A., Yu, Jessen, Mydlowec, William, and Stiffelman, Oscar. 1999. Searching for the impossible using genetic programming. In Banzhaf, Wolfgang, Daida, Jason, Eiben, A. E., Garzon, Max H., Honavar, Vasant, Jakiela, Mark, and Smith, Robert E. (editors). 1999. *GECCO-99: Proceedings of the Genetic and Evolutionary Computation Conference, July 13–17, 1999, Orlando, Florida USA*. San Francisco, CA: Morgan Kaufmann. Pages 1083–1091.

Koza, John R., Bennett III, Forrest H, and Stiffelman, Oscar. 1999a. Genetic programming as a Darwinian invention machine. In Poli, Riccardo, Nordin, Peter, Langdon, William B., and Fogarty, Terence C. 1999. *Genetic Programming: Second European Workshop. EuroGP'99. Proceedings*. Lecture Notes in Computer Science. Volume 1598. Berlin, Germany: Springer-Verlag. Pages 93–108.

Koza, John R., Bennett III, Forrest H, and Stiffelman, Oscar. 1999b. *An Invention Machine that Automatically Creates Novel Designs*. U.S. patent application filed April 13, 2000.

Koza, John R., Deb, Kalyanmoy, Dorigo, Marco, Fogel, David B., Garzon, Max, Iba, Hitoshi, and Riolo, Rick L. (editors). 1997. *Genetic Programming 1997: Proceedings of the Second Annual Conference, July 13–16, 1997, Stanford University*. San Francisco, CA: Morgan Kaufmann.

Koza, John R., Goldberg, David E., Fogel, David B., and Riolo, Rick L. (editors). 1996. *Genetic Programming 1996: Proceedings of the First Annual Conference, July 28–31, 1996, Stanford University*. Cambridge, MA: MIT Press.

Koza, John R., and Keane, Martin A. 1990a. Cart centering and broom balancing by genetically breeding populations of control strategy programs. In *Proceedings of International Joint Conference on Neural Networks, Washington, January 15–19, 1990*. Hillsdale, NJ: Lawrence Erlbaum. Volume I, Pages 198–201.

Koza, John R., and Keane, Martin A. 1990b. Genetic breeding of nonlinear optimal control strategies for broom balancing. In *Proceedings of the Ninth International Conference on Analysis and Optimization of Systems. Antibes, France, June, 1990*. Berlin: Springer-Verlag. Pages 47–56.

Koza, John R., Keane, Martin A., Bennett III, Forrest H, Yu, Jessen, Mydlowec, William, and Stiffelman, Oscar. 1999. Automatic creation of both the topology and parameters for a robust controller by means of genetic programming. *Proceedings of the 1999 IEEE International Symposium on Intelligent Control, Intelligent Systems, and Semiotics*. Piscataway, NJ: IEEE. Pages 344–352.

Koza, John R., Keane, Martin A., and Streeter, Matthew J. 2003. Evolving inventions. *Scientific American*. February 2003. 288(2) 52–59.

Koza, John R., Keane, Martin A., Yu, Jessen, Bennett III, Forrest H, and Mydlowec, William. 2000. Automatic creation of human-competitive programs and controllers by means of genetic programming. *Genetic Programming and Evolvable Machines*. Volume 1. Number 1/2. Pages 121–164.

Koza, John R., Keane, Martin A., Yu, Jessen, Bennett III, Forrest H, Mydlowec, William, and Stiffelman, Oscar. 1999. Automatic synthesis of both the topology and parameters for a robust controller for a non-minimal phase plant and a three-lag plant by means of genetic programming. *Proceedings of 1999 IEEE Conference on Decision and Control*. Pages 5292–5300.

Koza, John R., Keane, Martin A., Yu, Jessen, Bennett III, Forrest H, and Mydlowec, William. 2003. *Method and Apparatus for Automatic Synthesis of Controllers*. U.S. patent application filed September 10, 1999. Application number 09/393,863. Allowed October 30, 2002.

Koza, John R., Keane, Martin A., Yu, Jessen, and Mydlowec, William. 2000. Automatic synthesis of electrical circuits containing a free variable using genetic programming. In Whitley, Darrell, Goldberg, David, Cantu-Paz, Erick, Spector, Lee, Parmee, Ian, and Beyer, Hans-Georg (editors). *GECCO-2000: Proceedings of the Genetic and Evolutionary Computation Conference, July 10–12, 2000, Las Vegas, Nevada*. San Francisco: Morgan Kaufmann. Pages 551–557.

Koza, John R., Keane, Martin A., Yu, Jessen, Mydlowec, William, and Bennett, Forrest H III. 2000a. Automatic synthesis of both the topology and parameters for a controller for a three-lag plant with a five-second delay using genetic programming. In Cagnoni, Stafano et al. (editors). *Real World Applications of Evolutionary Computing. EvoWorkshops 2000. EvoIASP, Evo SCONDI, EvoTel, EvoSTIM, EvoRob, and EvoFlight, Edinburgh, Scotland, UK, April 2000, Proceedings*. Lecture Notes in Computer Science. Volume 1803. Berlin, Germany: Springer-Verlag. Pages 168–177.

Koza, John R., Keane, Martin A., Yu, Jessen, Mydlowec, William, and Bennett, Forrest H III. 2000b. Automatic synthesis of both the control law and parameters for a controller for a three-lag plant with five-second delay using genetic programming and simulation techniques. In *Proceedings of the 2000 American Control Conference, Chicago, Illinois, June 28–30, 2000*. Evanston, IL: American Automatic Control Council. Pages 453–459.

Koza, John R., Mydlowec, William, Lanza, Guido, Yu, Jessen, and Keane, Martin A. 2000a. *Reverse Engineering and Automatic Synthesis of Metabolic Pathways from Observed Data Using Genetic Programming*. Stanford Medical Informatics Technical Report SMI-2000-0851. November 7, 2000. `http://smi-web.stanford.edu/pubs/SMI_Abstracts/SMI-2000-0851.html`

Koza, John R., Mydlowec, William, Lanza, Guido, Yu, Jessen, and Keane, Martin A. 2000b. Reverse engineering of metabolic pathways from observed data using genetic programming. In Altman, Russ B. Dunker, A. Keith, Hunter, Lawrence, Lauderdale, Kevin, and Klein, Teri (editors). *Pacific Symposium on Biocomputing'99*. Singapore: World Scientific. Pages 434–445.

Koza, John R., Mydlowec, William, Lanza, Guido, Yu, Jessen, and Keane, Martin A. 2001a. Automated reverse engineering of metabolic pathways by means of genetic programming. In

Kitano, Hiroaki. 2001. *Foundations of Systems Biology*. Cambridge, MA: The MIT Press. Pages 95–121.

Koza, John R., Mydlowec, William, Lanza, Guido, Yu, Jessen, and Keane, Martin A. 2001b. Automatic synthesis of both the topology and sizing of metabolic pathways using genetic programming. In Spector, Lee, Goodman, E., Wu, A., Langdon, William B., Voigt, H.-M., Gen, M., Sen, S., Dorigo, Marco, Pezeshk, S., Garzon, Max, and Burke, E. (editors). 2001. *Proceedings of the Genetic and Evolutionary Computation Conference, GECCO-2001*. San Francisco, CA: Morgan Kaufmann. Pages 57–65.

Koza, John R., and Rice, James P. 1991. Genetic generation of both the weights and architecture for a neural network. In *Proceedings of International Joint Conference on Neural Networks, Seattle, July 1991*. Los Alamitos, CA: IEEE Press. Volume II. Pages 397–404.

Koza, John R., and Rice, James P. 1992a. *Genetic Programming: The Movie*. Cambridge, MA: MIT Press.

Koza, John R., and Rice, James P. 1992b. *A Non-Linear Genetic Process for Data Encoding and for Solving Problems Using Automatically Defined Functions*. U.S. patent application filed May 11, 1992.

Koza, John R., and Rice, James P. 1992c. *A Non-Linear Genetic Process for Use with Plural Co-Evolving Populations*. U. S. patent No. 5,148,513. Filed September 18, 1990. Issued September 15, 1992.

Koza, John R., and Rice, James P. 1994a. *A Non-Linear Genetic Process for Data Encoding and for Solving Problems Using Automatically Defined Functions*. U. S. patent application filed May 11, 1992. U. S. patent No. 5,343,554. Issued August 30, 1994.

Koza, John R., and Rice, James P. 1994b. *A Non-Linear Genetic Process for Data Encoding and for Solving Problems Using Automatically Defined Functions*. U.S. patent 5,343,554. Filed May 11, 1992. Issued August 30, 1994.

Koza, John R., and Rice, James P. 1995. *Process for Problem Solving Using Spontaneously Emergent Self-Replicating and Self-Improving Entities*. U. S. patent application filed June 16, 1992. U. S. patent No. 5,390,282. Issued February 14, 1995.

Koza, John R., Rice, James P., and Roughgarden, Jonathan. 1992. Evolution of food foraging strategies for the Caribbean *Anolis* lizard using genetic programming. *Adaptive Behavior*. Volume 1, number 2, pages 47–74.

Koza, John R., Yu, Jessen, Keane, Martin A., and Mydlowec, William. 2000a. Evolution of a controller with a free variable using genetic programming. In Poli, Riccardo, Banzhaf, Wolfgang, Langdon, William B., Miller, Julian, Nordin, Peter, and Fogarty, Terence C. 2000. *Genetic Programming: European Conference, EuroGP 2000, Edinburgh, Scotland, UK, April 2000, Proceedings*. Lecture Notes in Computer Science. Volume 1802. Berlin, Germany: Springer-Verlag. Pages 91–105.

Koza, John R., Yu, Jessen, Keane, Martin A., and Mydlowec, William. 2000b. Use of conditional developmental operators and free variables in automatically synthesizing generalized circuits using genetic programming. *Proceedings of the Second NASA/DoD Workshop on Evolvable Hardware, July 13–15 2000, Palo Alto, California*. Los Alamitos, CA: IEEE Computer Society Press. Pages 5–15.

Kruiskamp, Marinum Wilhelmus. 1996. *Analog Design Automation using Genetic Algorithms and Polytopes*. Eindhoven, The Netherlands: Data Library Technische Universiteit Eindhoven.

Kruiskamp, Marinum Wilhelmus and Leenaerts, Domine. 1995. DARWIN: CMOS opamp synthesis by means of a genetic algorithm. *Proceedings of the 32nd Design Automation Conference*. New York, NY: Association for Computing Machinery. Pages 433–438.

Laing, Shoudan, Fuhrman, Stefanie, and Somogyi, Roland. 1998. REVEAL: A general reverse engineering algorithm for inference of genetic network architecture. In Altman, Russ B.

Dunker, A. Keith, Hunter, Lawrence, and Klein, Teri E. (editors). *Pacific Symposium on Biocomputing '98*. Singapore: World Scientific. Pages 18–29.

Langdon, William B. 1998. *Genetic Programming and Data Structures: Genetic Programming + Data Structures = Automatic Programming!* Amsterdam: Kluwer.

Langdon, W. B., Cantu-Paz, E., Mathias, K., Roy, R., Davis, D., Poli, R., Balakrishnan, K., Honavar, V., Rudolph, G., Wegener, J., Bull, L., Potter, M. A., Schultz, A. C., Miller, J. F., Burke, E., and Jonoska, N. (editors). 2002. *Proceedings of the 2002 Genetic and Evolutionary Computation Conference*. San Francisco, CA: Morgan Kaufmann.

Langdon, William B. and Poli, Riccardo. 2002. *Foundations of Genetic Programming*. Berlin: Springer-Verlag.

Lanza, Guido, Mydlowec, William, and Koza, John R. 2000. Automatic creation of a genetic network for the *lac* operon from observed data by means of genetic programming. Poster paper accepted at First International Conference on Systems Biology in Tokyo on November 14–16, 2000.

Lee, Sang Gug. 2001. *Low Voltage Balun Circuit*. U.S. patent 6,265,908. Filed December 15, 1999. Issued July 24, 2001.

Lee, Thomas H. 1998. *The Design of CMOS Radio-Frequency Integrated Circuits*. Cambridge: Cambridge University Press.

Linden, Derek S. 1997. *Automated Design and Optimization of Wire Antennas Using Genetic Algorithms*. Ph.D. Thesis. Department of Electrical Engineering and Computer Science. Massachusetts Institute of Technology.

Lindenmayer, Aristid. 1968. Mathematical models for cellular interactions in development, I & II. *Journal of Theoretical Biology*. Volume 18. Pages 280–315.

Liu, Yong, Tanaka, Kiyoshi, Iwata, Masaya, Higuchi, Tetsuya, and Yasunaga, Moritoshi (editors). 2001. *Evolvable Systems: From Biology to Hardware, 4th International Conference, ICES 2001, Tokyo, Japan, October 2001 Proceedings*. Lecture Notes in Computer Science, Volume 2210. Berlin: Springer-Verlag.

Lohn, Jason, Stoica, Adrian, Keymeulen, Didier, and Colombano, Silvano (editors). 2000. *Proceedings of the Second NASA/DoD Workshop on Evolvable Hardware, July 13–15 2000, Palo Alto, California*. Los Alamitos, CA: IEEE Computer Society Press.

Loomis, William F. and Sternberg, Paul W. 1995. Genetic networks. *Science*. Pages 269–649. August 4, 1995.

Luke, Sean. 1998. Genetic programming produced competitive soccer softbot teams for RoboCup97. In Koza, John R., Banzhaf, Wolfgang, Chellapilla, Kumar, Deb, Kalyanmoy, Dorigo, Marco, Fogel, David B., Garzon, Max H., Goldberg, David E., Iba, Hitoshi, and Riolo, Rick. (editors). *Genetic Programming 1998: Proceedings of the Third Annual Conference, July 22–25, 1998, University of Wisconsin, Madison, Wisconsin*. San Francisco, CA: Morgan Kaufmann. Pages 214–222.

Macbeth, Ian. 2002. FPAAs: Synthesis by construction. *EDN*. November 28, 2002. Pages 44.

Mahfoud, S. W. and Goldberg, David E. 1995. Parallel recombinative simulated annealing: A genetic algorithm. *Parallel Computing*. Amsterdam: Elsevier Science. Volume 21. Pages 1–28.

Man, K. F., Tang, K. S., Kwong, S., and Halang, W. A. 1997. *Genetic Algorithms for Control and Signal-Processing*. London: Springer-Verlag.

Man, K. F., Tang, K. S., Kwong, S., and Halang, W. A. 1999. *Genetic Algorithms: Concepts and Designs*. London: Springer-Verlag.

Marcano, Diogenes and Duran, Filinto. 1999. Synthesis of linear and planar arrays using genetic algorithms. In Rahmat-Samii, Yahya and Michielssen, Eric (editors). *Electromagnetic Optimization by Genetic Algorithms*. New York, NY: John Wiley and Sons. Chapter 6. Pages 157–179.

Marenbach, Peter, Bettenhausen, Kurt D., and Freyer, Stephan. 1996. Signal path oriented approach for generation of dynamic process models. In Koza, John R., Goldberg, David E., Fogel, David B., and Riolo, Rick L. (editors). *Genetic Programming 1996: Proceedings of the First Annual Conference, July 28–31, 1996, Stanford University*. Cambridge, MA: MIT Press. Pages 327–332.

Massey, John. 1970. *Compensated Resistance Bridge-Type Electrical Thermometer*. U.S. patent 3,541,857. Filed November 27, 1968. Issued November 24, 1970.

Maziasz, Robert L. and Hayes, John P. 1992. *Layout Minimization of CMOS Cells*. Boston: Kluwer.

Mazumder, Pinaki and Rudnick, Elizabeth M. (editors). 1999. *Genetic Algorithms for VLSI Design, Layout and Test Automation*. Upper Saddle River, NJ: Prentice Hall.

McAdams, Harley H. and Shapiro, Lucy. 1995. Circuit simulation of genetic networks. *Science*. Volume 269. Pages 650–656. August 4, 1995.

Mendes, Pedro and Kell, Douglas B. 1998. Nonlinear optimization of biochemical pathways: Applications to metabolic engineering and parameter estimation. *Bioinformatics*. 14(10)869–883.

Menon, P. K., Yousefpor, M., Lam, T., and Steinberg, M. L. 1995. Nonlinear flight control system synthesis using genetic programming. *Proceedings of 1995 Conference on Guidance, Navigation, and Control*. Reston, VA: American Institute of Aeronautics and Astronautics. Pages 461–470.

Messina, Paul, Sterling, Thomas, and Smith, Paul H. (editors). 1999. *Petaflops II: Second Conference on Enabling Technologies for Peta(fl)ops Computing, February 15–19, 1999, Santa Barbara*.

Miller, Julian, Thompson, Adrian, Thomson, Peter, and Fogarty, Terence C. (editors). 2000. *Evolvable Systems: From Biology to Hardware. Third International Conference, ICES 2000, Edinburgh, Scotland, UK, April 2000 Proceedings*. Lecture Notes in Computer Science. Volume 1801. Berlin, Germany: Springer-Verlag.

Miller, Julian, Tomassini, Marco, Lanzi, Pier Luca, Ryan, Conor, Tettamanzi, Andrea G. B., and Langdon, William B. (editors). 2001. *Genetic Programming: 4th European Conference, EuroGP 2001, Lake Como, Italy, April 2001 Proceedings*. Berlin: Springer.

Mittenthal, Jay E., Ao Yuan, Bertrand Clarke, and Scheeline, Alexander. 1998. Designing metabolism: Alternative connectivities for the pentose phosphate pathway. *Bulletin of Mathematical Biology*. Volume 60. Pages 815–856.

Moore, Gordon E. 1996. Can Moore's law continue indefinitely? *Computerworld Leadership Series*. 2(6)2–7. July 15, 1996.

Moretti, Gabe. 2002. The next wave: Synthesis tools help with mixed-signal designs. *EDN*. November 28, 2002. Pages 43–50.

Mydlowec, William and Koza, John. 2000. Use of time-domain simulations in automatic synthesis of computational circuits using genetic programming. *Late Breaking Papers at the 2000 Genetic and Evolutionary Computation Conference, Las Vegas, Nevada*. Pages 187–197.

Newbold, William F. 1962. *Square Root Extracting Integrator*. U.S. patent 3,016,197. Filed September 15, 1958. Issued January 9, 1962.

Newborn, Monty. 2002. *Deep Blue: An Artificial Intelligence Milestone*. New York: Springer.

Nordin, Peter. 1997. *Evolutionary Program Induction of Binary Machine Code and Its Application*. Munster, Germany: Krehl Verlag.

O'Connor, Daniel G. and Nelson, Raymond J. 1962. *Sorting System with N-Line Sorting Switch*. U.S. patent 3,029,413. Issued April 10, 1962.

Ogata, Katsuhiko. 1997. *Modern Control Engineering*. Third edition. Upper Saddle River, NJ: Prentice Hall.

Ohr, Stephan. 2002. Anadigm fields reconfigurable analog device. *EE Times*. September 2, 2002.

Olsson, Jan Roland. 1994a. Inductive functional programming using incremental program transformation. *Artificial Intelligence*. Volume 74. Pages 55–81.

Olsson, Jan Roland. 1994b. *Inductive Functional Programming Using Incremental Program Transformation*. Dr. Scient. thesis. University of Oslo.

O'Neill, Michael and Ryan, Conor. 2003. *Grammatical Evolution: Evolutionary Automatic Programming in an Arbitrary Language*. Boston: Kluwer Academic Publishers.

Osyczka, A. 1984. *Multicriterion Optimization in Engineering with FORTRAN programs*. Ellis Horwood Limited.

Pease, Robert. 1992. What's all this Muntzing stuff, anyhow? *Electronic Design*. July 23, 1992.

Pease, Robert. 1996. What's all this R-C filter stuff, anyhow? *Electronic Design*. March 18, 1996.

Pease, Robert. 1999. What's all this logarithmic stuff, anyhow? *Electronic Design*. August 19, 1999.

Philbrick, George A. 1956. *Delayed Recovery Electric Filter Network*. Filed May 18, 1951. U.S. patent 2,730,679. Issued January 10, 1956.

Poli, Riccardo, Nordin, Peter, Langdon, William B., and Fogarty, Terence C. 1999. *Genetic Programming: Second European Workshop, EuroGP'99. Proceedings*. Lecture Notes in Computer Science. Volume 1598. Berlin, Germany: Springer-Verlag.

Poli, Riccardo, Banzhaf, Wolfgang, Langdon, William B., Miller, Julian, Nordin, Peter, and Fogarty, Terence C. 2000. *Genetic Programming: European Conference, EuroGP 2000, Edinburgh, Scotland, UK, April 2000, Proceedings*. Lecture Notes in Computer Science. Volume 1802. Berlin, Germany: Springer-Verlag.

Prusinkiewicz, Przemyslaw and Hanan, James. 1980. *Lindenmayer Systems, Fractals, and Plants*. New York: Springer-Verlag.

Prusinkiewicz, Przemyslaw, and Lindenmayer, Aristid. 1990. *The Algorithmic Beauty of Plants*. New York: Springer-Verlag.

Ptashne, Mark. 1992. *A Genetic Switch: Phage λ and Higher Organisms*. Second Edition. Cambridge, MA: Cell Press and Blackwell Scientific Publications.

Quarles, Thomas, Newton, A. R., Pederson, D. O., and Sangiovanni-Vincentelli, A. 1994. *SPICE 3 Version 3F5 User*'s *Manual*. Department of Electrical Engineering and Computer Science, University of California. Berkeley, CA. March 1994.

Rahmat-Samii, Yahya and Michielssen, Eric (editors). 1999. *Electromagnetic Optimization by Genetic Algorithms*. New York, NY: John Wiley and Sons.

Rechenberg, Ingo. 1965. *Cybernetic solution path of an experimental problem*. Royal Aircraft Establishment, Ministry of Aviation, Library Translation 1112. Farnborough.

Rechenberg, Ingo. 1973. *Evolutionsstrategie: Optimierung Technischer Systeme nach Prinzipien der Biolgischen Evolution*. Stuttgart-Bad Cannstatt: Verlag Frommann-Holzboog.

Riolo, Rich and Worzel, William. 2003. *Genetic Programming: Theory and Practice*. Boston: Kluwer Academic Publishers.

Robertson, George. 1987. Parallel implementation of genetic algorithms in a classifier system. In Davis, Lawrence (editor). *Genetic Algorithms and Simulated Annealing* London: Pittman.

Ryan, Conor. 1999. *Automatic Re-engineering of Software Using Genetic Programming*. Amsterdam: Kluwer Academic Publishers.

Salamon, Peter, Sibani, Paolo, and Frost, Richard. 2002. *Facts, Conjectures, and Improvements for Simulated Annealing*. Philadelphia: Society for Industrial and Applied Mathematics.

Samuel, Arthur L. 1983. AI: Where it has been and where it is going. *Proceedings of the Eighth International Joint Conference on Artificial Intelligence*. Los Altos, CA: Morgan Kaufmann. Pages 1152–1157.

Sanchez, Eduardo and Tomassini, Marco (editors). 1996. *Towards Evolvable Hardware*. Lecture Notes in Computer Science, Volume 1062. Berlin: Springer-Verlag.

Schaeffer, Jonathan. 1997. *One Jump Ahead: Challenging Human Supremacy in Checkers*. New York: Springer.

Sechen, Carl. 1988. *VLSI Placement and Global Routing using Simulated Annealing*. Boston, MA: Kluwer.

Sheingold, Daniel H. (editor). 1976. *Nonlinear Circuits Handbook*. Norwood, MA: Analog Devices, Inc.

Sipper, Moshe, Mange, Daniel, and Perez-Uribe, Andres (editors). 1998. *Evolvable Systems: From Biology to Hardware. Second International Conference, ICES 98, Lausanne, Switzerland, September 1998 Proceedings*. Lecture Notes in Computer Science 1478. Berlin: Springer-Verlag.

Smith, Steven F. 1980. *A Learning System Based on Genetic Adaptive Algorithms*. Ph.D. dissertation. Pittsburgh, PA: University of Pittsburgh.

Song, Bang-Sup and Harjani, Ramesh. 1995. In Chen, Wai-Kai (editor). *The Circuits and Filters Handbook*. Boca Raton, FL: CRC Press. Pages 2072–2127.

Spector, Lee, Barnum, Howard, and Bernstein, Herbert J. 1998. Genetic programming for quantum computers. In Koza, John R., Banzhaf, Wolfgang, Chellapilla, Kumar, Deb, Kalyanmoy, Dorigo, Marco, Fogel, David B., Garzon, Max H., Goldberg, David E., Iba, Hitoshi, and Riolo, Rick. (editors). *Genetic Programming 1998: Proceedings of the Third Annual Conference*. San Francisco, CA: Morgan Kaufmann. Pages 365–373.

Spector, Lee, Barnum, Howard, and Bernstein, Herbert J. 1999. Quantum computing applications of genetic programming. In Spector, Lee, Langdon, William B., O'Reilly, Una-May, and Angeline, Peter (editors). *Advances in Genetic Programming 3*. Cambridge, MA: The MIT Press. Pages 135–160.

Spector, Lee, Barnum, Howard, Bernstein, Herbert J., and Swamy, N. 1999. Finding a better-than-classical quantum AND/OR algorithm using genetic programming. In IEEE. *Proceedings of 1999 Congress on Evolutionary Computation*. Piscataway, NJ: IEEE Press. Pages 2239–2246.

Spector, Lee, and Bernstein, Herbert J. 2003. Communication capacities of some quantum gates, discovered in part through genetic programming. In Shapiro, Jeffrey H. and Hirota, Osamu (editors). *Proceedings of the Sixth International Conference on Quantum Communication, Measurement, and Computing*. Paramus, NJ: Rinton Press.

Spector, Lee, Goodman, E., Wu, A., Langdon, William B., Voigt, H. -M., Gen, M., Sen, S., Dorigo, Marco, Pezeshk, S., Garzon, Max, and Burke, E. (editors). 2001. *Proceedings of the Genetic and Evolutionary Computation Conference, GECCO-2001*. San Francisco, CA: Morgan Kaufmann.

Spector, Lee, Langdon, William B., O'Reilly, Una-May, and Angeline, Peter (editors). 1999. *Advances in Genetic Programming 3*. Cambridge, MA: The MIT Press.

Spector, Lee and Stoffel, Kilian. 1996a. Ontogenetic programming. In Koza, John R., Goldberg, David E., Fogel, David B., and Riolo, Rick L. (editors). 1996. *Genetic Programming 1996: Proceedings of the First Annual Conference, July 28–31, 1996, Stanford University*. Cambridge, MA: MIT Press. Pages 394–399.

Spector, Lee and Stoffel, Kilian. 1996b. Automatic generation of adaptive programs. In Maes, Pattie, Mataric, Maja J., Meyer, Jean-Arcady, Pollack, Jordan, and Wilson, Stewart W. (editors). 1996. *From Animals to Animats 4: Proceedings of the Fourth International Conference on Simulation of Adaptive Behavior*. Cambridge, MA: The MIT Press. Pages 476–483.

Sripramong, Thanwa and Toumazou, Christofer. 2002. The invention of CMOS amplifiers using genetic programming and current-flow analysis. *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*. 21(11). November 2002. Pages 1237–1252.

Stender, Joachim (editor). 1993. *Parallel Genetic Algorithms*. Amsterdam: IOS Publishing.

Stephens, C. R. and Waelbroeck, H. 1997. Effective degrees of freedom in genetic algorithms and the block hypothesis. In Back, Thomas (editor). 1997. *Genetic Algorithms: Proceedings of the Seventh International Conference*. San Francisco, CA: Morgan Kaufmann. Pages 34–40.

Sterling, Thomas L. 1998a. Beowulf-class clustered computing: Harnessing the power of parallelism in a pile of PCs. In Koza, John R., Banzhaf, Wolfgang, Chellapilla, Kumar, Deb, Kalyanmoy, Dorigo, Marco, Fogel, David B., Garzon, Max H., Goldberg, David E., Iba, Hitoshi, and Riolo, Rick L. (editors). *Genetic Programming 1998: Proceedings of the Third Annual Conference, July 22–25, 1998, University of Wisconsin, Madison, Wisconsin*. San Francisco, CA: Morgan Kaufmann. Pages 883–887.

Sterling, Thomas L. 1998b. *Proceedings of Petaflops-Systems Operations Working Review, Bodega Bay, California, June 1–5, 1998*.

Sterling, Thomas L. and Foster, Ian. 1996a. *Proceedings of Petaflops Architecture Workshop (PAWS '96), April 22–25, 1996*.

Sterling, Thomas L. and Foster, Ian. 1996b. *Proceedings of Petaflops System Software Summer Study (Peta Soft '96), June 17–21, 1996*.

Sterling, Thomas L., Salmon, John, and Becker, Donald J., and Savarese, Daniel F. 1999. *How to Build a Beowulf: A Guide to Implementation and Application of PC Clusters*. Cambridge, MA: MIT Press.

Steudel, Goetz Wolfgang. 1973. *Reference Voltage Generator and Regulator*. U.S. patent 3,743,923. Filed December 2, 1971. Issued July 3, 1973.

Stoica, Adrian, Keymeulen, Didier, and Lohn, Jason (editors). 1999. *Proceedings of the First NASA/DOD Workshop on Evolvable Hardware, Pasadena, California, July 19–21, 1999*. Los Alamitos, CA. IEEE Computer Society.

Stoica, Adrian, Lohn, Jason, Katz, Rich, Keymeulen, Didier and Zebulum, Ricardo Salem (editors). 2002. *Proceedings of 2002 NASA/DoD Conference on Evolvable Hardware*. Los Alamitos, CA: IEEE Computer Society.

Stoica, Adrian, Zebulum, Ricardo, and Keymeulen, Didier. 2001. Polymorphic electronics. In Liu, Yong, Tanaka, Kiyoshi, Iwata, Masaya, Higuchi, Tetsuya, and Yasunaga, Moritoshi (editors). *Evolvable Systems: From Biology to Hardware, 4th International Conference, ICES 2001, Tokyo, Japan, October 2001 Proceedings*. Lecture Notes in Computer Science, Volume 2210. Berlin: Springer-Verlag. Pages 291–302.

Streeter, Matthew J., Keane, Martin A., and Koza, John R. 2002a. Iterative refinement of computational circuits using genetic programming. In Langdon, W. B., Cantu-Paz, E., Mathias, K., Roy, R., Davis, D., Poli, R., Balakrishnan, K., Honavar, V., Rudolph, G., Wegener, J., Bull, L., Potter, M. A., Schultz, A. C., Miller, J. F., Burke, E., and Jonoska, N. (editors). 2002. *Proceedings of the 2002 Genetic and Evolutionary Computation Conference*. San Francisco, CA: Morgan Kaufmann. Pages 877–884.

Streeter, Matthew J., Keane, Martin A., and Koza, John R. 2002b. Routine duplication of post-2000 patented inventions by means of genetic programming. In Foster, James A., Lutton, Evelyne, Miller, Julian, Ryan, Conor, and Tettamanzi, Andrea G. B. (editors). 2002. *Genetic Programming: 5th European Conference, EuroGP 2002, Kinsale, Ireland, April 2002 Proceedings*. Berlin: Springer. Pages 26–36.

Streeter, Matthew J., Keane, Martin A., and Koza, John R. 2003. Automatic synthesis using genetic programming of both the topology and sizing for five post-2000 patented analog and mixed analog-digital circuits. *Proceedings of 2003 Southwest Symposium on Mixed-Signal Design, February 23–25, 2003, Las Vegas, Nevada, U.S.A.* Pages 5–10.

Stutzman, Warren. L. and Thiele, Gary A. 1998. *Antenna Theory and Design*. Second edition. New York, NY: John Wiley and Sons.

Sweriduk, G. D., Menon, P. K., and Steinberg, M. L. 1998. Robust command augmentation system design using genetic search methods. *Proceedings of 1998 Conference on Guidance, Navigation, and Control*. Reston, VA: American Institute of Aeronautics and Astronautics. Pages 286–294.

Sweriduk, G. D., Menon, P. K., and Steinberg, M. L. 1999. Design of a pilot-activated recovery system using genetic search methods. *Proceedings of 1998 Conference on Guidance, Navigation, and Control*. Reston, VA: American Institute of Aeronautics and Astronautics.

Tanese, Reiko. 1989. *Distributed Genetic Algorithm for Function Optimization*. Ph.D. dissertation. Department of Electrical Engineering and Computer Science. University of Michigan.

Teller, Astro. 1996a. *Evolving Programmers: SMART Mutation*. Technical Report CMU-CS-96. Computer Science Department, Carnegie Mellon University.

Teller, Astro. 1996b. Evolving programmers: The co-evolution of intelligent recombination operators. In Angeline, Peter J. and Kinnear, Kenneth E. Jr. (editors). *Advances in Genetic Programming 2*. Cambridge, MA: The MIT Press.

Teller, Astro. 1998. *Algorithm Evolution with Internal Reinforcement for Signal Understanding*. Ph.D. Thesis. Computer Science Department. Carnegie Mellon University. Pittsburgh, Pennsylvania.

Teller, Astro. 1999. The internal reinforcement of evolving algorithms. In Spector, Lee, Langdon, William B., O'Reilly, Una-May, and Angeline, Peter (editors). 1999. *Advances in Genetic Programming 3*. Cambridge, MA: The MIT Press.

Teller, Astro, and Veloso, Manuela. 1995a. *Learning Tree Structured Algorithms for Orchestration into an Object Recognition System*. Technical Report CMU-CS-95-101. Computer Science Department, Carnegie Mellon University.

Teller, Astro, and Veloso, Manuela. 1995b. Program evolution for data mining. In Louis, Sushil (editor). Special Issue on Genetic Algorithms and Knowledge Bases. *The International Journal of Expert Systems*. JAI Press. (3)216–236.

Teller, Astro, and Veloso, Manuela. 1995c. A controlled experiment: evolution for learning difficult problems. *Proceedings of Seventh Portuguese Conference on Artificial Intelligence*. Springer-Verlag. Pages 165–76.

Teller, Astro, and Veloso, Manuela. 1995d. Algorithm Evolution for Face Recognition: What Makes a Picture Difficult? *Proceedings of the IEEE International Conference on Evolutionary Computation*. IEEE Press.

Teller, Astro, and Veloso, Manuela. 1995e. Language Representation Progression in PADO. *Proceedings of AAAI Fall Symposium on Artificial Intelligence*. Menlo Park, CA: AAAI Press.

Teller, Astro and Veloso, Manuela. 1996. PADO: A new learning architecture for object recognition. In Ikeuchi, Katsushi and Veloso, Manuela (editors). *Symbolic Visual Learning*. Oxford University Press. Pages 81–116.

Teller, Astro, and Veloso, Manuela. 1997. Neural programming and an internal reinforcement policy. In Yao, Xin, Kim, Jong-Hwan, and Furuhashi, T. (editors). *Simulated Evolution and Learning*. Lecture Notes in Artificial Intelligence. Volume 1285. Heidelberg, Germany: Springer-Verlag. Pages 279–286.

Thompson, Adrian. 1996. Silicon evolution. In Koza, John R., Goldberg, David E., Fogel, David B., and Riolo, Rick L. (editors). 1996. *Genetic Programming 1996: Proceedings of the First Annual Conference, July 28–31, 1996, Stanford University*. Cambridge, MA: MIT Press. Pages 444–452.

Thompson, Adrian. 1998. *Hardware Evolution: Automatic Design of Electronic Circuits in Reconfigurable Hardware by Artificial Evolution*. Conference of Professors and Heads of Computing / British Computer Society Distinguished Dissertation series. Berlin: Springer-Verlag.

Tomita, Masaru, Hashimoto, Kenta, Takahashi, Kouichi, Shimizu, Thomas Simon, Matsuzaki, Yuri, Miyoshi, Fumihiko, Saito, Kanako, Tanida, Sakura, Yugi, Katsuyuki, Venter, J. Craig, Hutchison, Clyde A. III. 1999. E-CELL: Software environment for whole cell simulation. *Bioinformatics*. Volume 15 (1)72–84.

Turing, Alan M. 1948. Intelligent machinery. Reprinted in Ince, D. C. (editor). 1992. *Mechanical Intelligence: Collected Works of A. M. Turing*. Amsterdam: North Holland. Pages 107–127. Also reprinted in Meltzer, B. and Michie, D. (editors). 1969. *Machine Intelligence 5*. Edinburgh: Edinburgh University Press.

Turing, Alan M. 1950. Computing machinery and intelligence. *Mind*. 59(236)433–460. Reprinted in Ince, D. C. (editor). 1992. *Mechanical Intelligence: Collected Works of A. M. Turing*. Amsterdam: North Holland. Pages 133–160.

Uda, S. 1926. Wireless beam of short electric waves. *Journal of the IEE (Japan)*. March 1926. Pages 273–282.

Uda, S. 1927. Wireless beam of short electric waves. *Journal of the IEE (Japan)*. March 1927. Pages 1209–1219.

Ullman, Jeffrey D. 1984. *Computational Aspects of VLSI*. Rockville, MD: Computer Science Press.

Van Valkenburg, M. E. 1982. *Analog Filter Design*. Fort Worth, TX: Harcourt Brace Jovanovich.

Villagran, Victor and Sbarbaro, Daniel. 1998. A new approach for turning PID controller based on iterative learning. *Proceedings of the 1998 IEEE International Conference on Control Applications*. Volume I. Pages 139–143.

Vladimirescu, Andrei. 1994. *The SPICE Book*. New York, NY: John Wiley and Sons.

Voit, Eberhard O. 2000. *Computational Analysis of Biochemical Systems*. Cambridge: Cambridge University Press.

Wakerly, John F. 1990. *Digital Design Principles and Practices*. Englewood Cliffs, NJ: Prentice Hall.

Webb, Edwin C. 1992. *Enzyme Nomenclature 1992: Recommendations of the Nomenclature Committee of the International Union of Biochemistry and Molecular Biology*. San Diego, CA: Academic Press.

Whitley, Darrell, Goldberg, David, Cantu-Paz, Erick, Spector, Lee, Parmee, Ian, and Beyer, Hans-Georg (editors). 2000. *GECCO-2000: Proceedings of the Genetic and Evolutionary Computation Conference, July 10–12, 2000, Las Vegas, Nevada*. San Francisco: Morgan Kaufmann.

Whitley, Darrell, Gruau, Frederic, and Preatt, Larry. 1995. Cellular encoding applied to neurocontrol. In Eshelman, Larry J. (editor). *Proceedings of the Sixth International Conference on Genetic Algorithms*. San Francisco, CA: Morgan Kaufmann. Pages 460–467.

Whitley, Darrell. 2000. Functions as permutations: Regarding no free lunch, Walsh analysis and summary statistics. In Schoenauer, Marc, Deb, Kalyanmoy, Gunter, Rudolph, Yao, Xin, Lutton, Evelyne, Merelo, Juan Julian, and Schwefel, Hans-Paul (editors). 2000. *Parallel Problem Solving from Nature: 6th International Conference, Paris, France, September 2000 Proceedings*. Berlin: Springer. Page 169–178.

Williams, Arthur B. and Taylor, Fred J. 1995. *Electronic Filter Design Handbook*. Third Edition. New York, NY: McGraw-Hill.

Witczak, Marcin. 2003. *Identification and Fault Detection of Non-Linear Dynamic Systems*. University of Zielona Gora Press.

Wolpert, D. H. and Macready, W. G. 1997. No free lunch theorems for optimization. *IEEE Transactions on Evolutionary Computation*. 1(1) 67– 82. April 1997.

Wong, D. F., Leong, H. W., and Liu. C. L. 1988. *Simulated Annealing for VLSI Design*. Boston, MA: Kluwer.

Wong, Man Leung and Leung, Kwong Sak. 2000. *Data Mining Using Grammar Based Genetic Programming and Applications*. Amsterdam: Kluwer Academic Publishers.

Yagi, H. 1928. Beam transmission of ultra short waves. *Proceedings of the IRE*. Volume 26: Pages 714–741. June 1928.

Yu, Jessen, Keane, Martin A., and Koza, John R. 2000. Automatic design of both topology and tuning of a common parameterized controller for two families of plants using genetic programming. In *Proceedings of Eleventh IEEE International Symposium on Computer-Aided Control System Design (CACSD) Conference and Ninth IEEE International Conference on Control Applications (CCA) Conference, Anchorage, Alaska, September 25–27, 2000.*

Yuh, Chiou-Hwa, Bolouri, Hamid, and Davidson, Eric H. 1998. Genomic cis-regulatory logic: Experimental and computational analysis of a sea urchin gene. *Science*. 279. Pages 1896–1902.

Zebulum, Ricardo Salem, Pacheco, Marco Aurelio C., and Vellasco, Marley Maria B. R. 2002. *Evolutionary Electronics: Automatic Design of Electronic Circuits and Systems by Genetic Algorithms*. Boca Raton, FL: CRC Press.

Ziegler, J. G. and Nichols, N. B. 1942. Optimum settings for automatic controllers. *Transactions of ASME*. (64) 759–768.

Zitzler, Eckart, Deb, Kalyanmoy, Thiele, Lothar, Coello Coello, Carlos A., and Corne, David (editors). 2001. *Evolutionary Multi-Criterion Optimization, First International Conference, EMO 2001, Zurich, Switzerland, March 2001, Proceedings*. Lecture Notes in Computer Science. Volume 1993. Berlin, Germany: Springer-Verlag.

Zobel, Otto Julius. 1926. *Electrical Network and Method of Transmitting Electric Currents*. Filed August 9, 1922. U.S. patent 1,603,305. Issued October 19, 1926.

Zobel, Otto Julius. 1925. *Wave Filter*. Filed January 15, 1921. U.S. patent 1,538,964. Issued May 26, 1925.

Zobel, Otto Julius. 1928. Distortion correction in electrical circuits with constant resistance networks. *Bell Systems Technical Journal*. July 1928. Page 438.

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