

Fall 2003 BMI 226 / CS 426 Notes H- 1

**REVIEW OF PROBLEMS IN *GENETIC
PROGRAMMING* (1992) BOOK**

GENETIC PROGRAMMING

MAJOR TYPES OF TERMINALS

Type of terminals	Examples
Boolean independent variable	Boolean multiplexer Boolean functions of two and three arguments Design of two-bit adder circuit Neural network design Even-4-parity with automatic function definition
Floating-point independent variable	Symbolic regression Symbolic regression with constant creation Trigonometric identities Solving a pair of linear equations Empirical discovery Symbolic integration Symbolic differentiation Solving differential equations Solving integral equations Solving general functional equations Solving quadratic equations Inverse kinematics Fourier series Biathlon (symbolic regression)
Integer independent variable	Sequence induction Randomizer

Multiple independent floating-point variables	Symbolic multiple regression Programmatic image compression
State of the system	Cart centering Broom balancing Truck backer upper Differential pursuer-evader game Discrete non-hamstrung squad car game (see Appendix B.3) One-dimensional cellular automata Two-dimensional cellular automata
Terminals are functions with no arguments	Artificial ant Central place food foraging Emergent collecting behavior for ants Wall following robot Box moving robot Task prioritization (Pac Man) Biathlon (artificial ant)
Class names	Induction of decision trees Grammar induction Intertwined spirals Discrete 32-outcome game Co-evolution of discrete 32-outcome game
The terminals only are ephemeral random constants	Solving equations for numeric roots Finding a global optimum point
Input sensors	Block stacking

Settable variables in addition to the usual terminals	Iterative summation
Recursive reference to previous computation	Local tracking of a dynamical system
Parameters	Optimization — <i>Anolis</i> lizard

MAJOR TYPES OF FUNCTIONS

Type of Function	Examples
Arithmetic operations	Solving a pair of linear equations Sequence induction Programmatic image compression Differential pursuer-evader game Fourier series Biathlon (artificial ant) Local tracking of a dynamical system Finding a global optimum point
Arithmetic operations plus some transcendental functions	Symbolic regression Trigonometric identities Symbolic regression with constant creation Empirical discovery Symbolic integration Symbolic differentiation Solving differential equations Solving integral equations Solving general functional equations Solving equations for numeric roots Multiple symbolic regression Inverse kinematics
Arithmetic operations plus integer modular functions	Randomizer

<p>Arithmetic operations plus some transcendental functions and/or decision making function</p>	<p>Cart centering Broom balancing Truck backer upper Intertwined spirals Optimization — <i>Anolis</i> lizard</p>
<p>Various IF, CASE, and testing functions</p>	<p>Artificial Ant Central place food foraging Emergent collecting behavior for ants Wall following robot Box moving robot Discrete non-hamstrung squad car game (see Appendix B.3) Induction of decision trees Grammar induction Discrete 32-outcome game Co-evolution of discrete 32-outcome game Biathlon (artificial ant)</p>
<p>Boolean functions</p>	<p>Boolean multiplexer Boolean functions of two and three arguments Design of two-bit adder circuit One-dimensional cellular automata Two-dimensional cellular automata</p>
<p>Complex arithmetic</p>	<p>Solving quadratic equations</p>
<p>Problem specific</p>	<p>Neural network design Task prioritization (Pac Man) Block stacking</p>

Automatically defined functions in addition to usual functions	Even-4-parity with automatic function definition
Assignment function in addition to the usual functions	Iterative summation
Combinations	Biathlon (some of the time)

TYPES OF WRAPPERS

Type of wrapper	Examples
Bang-bang force	Cart centering Broom balancing
Saturating value	Truck backer upper
Limited range of integers	Programmatic image compression (i.e., color values)
Binary	Randomizer Intertwined spirals Optimization — <i>Anolis</i> lizard
Complex numbers	Solving quadratic equations

MAJOR TYPES OF FITNESS MEASURES

Type of fitness measure	Examples
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<p>Error</p>	<p> Symbolic regression Symbolic regression with constant creation Trigonometric identities Solving a pair of linear equations Boolean multiplexer Boolean functions of two and three arguments Empirical discovery Symbolic integration Symbolic differentiation Solving differential equations Solving integral equations Solving general functional equations Solving equations for numeric roots Sequence induction Programmatic image compression Multiple symbolic regression Solving quadratic equations Fourier series Design of a two-bit adder circuit Neural network design Biathlon (symbolic regression) Local tracking of a dynamical system Finding a global optimum point Even-4-parity with automatic function definition Iterative summation </p>
<p>Distance shortfall</p>	<p> Inverse kinematics Box moving robot Truck backer upper </p>

Problem specific payoff	Artificial ant Block stacking (correct) Discrete 32-outcome game Central place food foraging Task prioritization (Pac Man) Wall following robot Biathlon (artificial ant) Optimization — <i>Anolis</i> lizard
Time	Cart centering Broom balancing Differential pursuer-evader game Discrete non-hamstrung squad car game (see Appendix B.3)
Instances correctly identified	Induction of decision trees Grammar induction Intertwined spirals
Entropy	Randomizer One-dimensional cellular automata Two-dimensional cellular automata
Center of gravity	Emergent collecting behavior for ants
Combination of factors	Block stacking (correct and efficient) Block stacking (correct, efficient, and parsimonious) Differential equations with initial conditions
Co-Evolution	Co-evolution of discrete 32-outcome game
Changing fitness measure	Biathlon Changing Boolean functions

MAJOR TYPES OF FITNESS CASES

Type of fitness case	Examples
Random floating-point numbers in a specified range for each independent variable	Symbolic regression Symbolic regression with constant creation Trigonometric identities Symbolic integration Symbolic differentiation Solving differential equations Solving integral equations Solving general functional equations Programmatic image compression Multiple symbolic regression Fourier series Biathlon (symbolic regression) Finding a global optimum point Iterative summation
Consecutive integers as independent variable	Sequence induction Randomizer Local tracking of a dynamical system
Regularly chosen sample points	Intertwined spirals Inverse kinematics

<p>Combinations of Boolean values</p>	<p>Boolean multiplexer Boolean functions of two and three arguments Design of two-bit adder circuit Neural network design Even-4-parity with automatic function definition</p>
<p>Randomly chosen initial conditions of a system</p>	<p>Cart centering Broom balancing Truck backer upper Box moving robot Discrete non-hamstrung squad car game (see Appendix B.3) Emergent collecting behavior for ants Differential pursuer-evader game</p>
<p>One fitness case</p>	<p>Artificial ant Biathlon (artificial ant) Central place food foraging Wall following robot Task prioritization (Pac Man) Solving equations for numeric roots</p>
<p>Sets of equations</p>	<p>Solving a pair of linear equations Solving quadratic equations</p>
<p>Temporal sample</p>	<p>One-dimensional cellular automata Two-dimensional cellular automata</p>
<p>Combinations of plays in a game</p>	<p>Discrete 32-outcome game</p>
<p>Co-evolution</p>	<p>Co-evolution of discrete 32-outcome game</p>

Structured sample	Block stacking
Training examples	Induction of decision trees
Sequence of data	Grammar induction
Monte Carlo experiments	Optimization — <i>Anolis</i> lizard
Given data	Empirical discovery

TYPES OF SIMULATIONS OF BEHAVIOR

Type of simulations of behavior	Examples
Simulation involving a number of time steps	Cart centering Broom balancing Differential pursuer-evader game Discrete non-hamstrung squad car game (see Appendix B.3) Emergent collecting behavior for ants Block stacking Artificial ant Biathlon (some of the time) Central place food foraging
Simulation involving a number of time steps and a terminating physical event	Truck backer upper Box moving robot Wall following robot Task prioritization (Pac Man)
Temporal sample	One-dimensional cellular automata Two-dimensional cellular automata
Simulation involving a number of plays or events	Discrete 32-outcome game Optimization — <i>Anolis</i> lizard
Simulation involving co-evolution	Co-evolution of discrete 32-outcome game strategies

Time series	Randomizer
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POPULATION SIZE

Population sizes	Examples
50	Boolean functions of two and three arguments
100	Discrete non-hamstrung squad car game (see Appendix B.3)
300	Co-evolution of discrete 32-outcome game

500	Cart centering Symbolic regression Artificial ant Trigonometric identities Symbolic regression with constant creation Empirical discovery of exchange equation Empirical discovery of Kepler's Law Symbolic integration Symbolic differentiation Solving differential equations Solving integral equations Solving general functional equations Solving equations for numeric roots Sequence induction Broom balancing Central place food foraging Emergent collecting behavior for ants Task prioritization (Pac Man) Box moving robot Randomizer One-dimensional cellular automata Two-dimensional cellular automata Discrete 32-outcome game Induction of decision trees Grammar induction Block stacking Iterative summation Multiple symbolic regression Solving a pair of linear equations Inverse kinematics Neural network design
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1,000	Truck backer upper Wall following robot Design of two-bit adder circuit Biathlon Optimization — <i>Anolis</i> lizard
2,000	Programmatic image compression Box moving robot Solving quadratic equations Fourier series Local tracking of a dynamical system Finding a global optimum point
4,000	Boolean multiplexer Even-4-parity with automatic function definition
10,000	Intertwined spirals