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

### MAJOR TYPES OF TERMINALS

<table>
<thead>
<tr>
<th>Type of terminals</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean independent variable</td>
<td>Boolean multiplexer</td>
</tr>
<tr>
<td></td>
<td>Boolean functions of two and three arguments</td>
</tr>
<tr>
<td></td>
<td>Design of two-bit adder circuit</td>
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<tr>
<td></td>
<td>Neural network design</td>
</tr>
<tr>
<td></td>
<td>Even-4-parity with automatic function definition</td>
</tr>
<tr>
<td>Floating-point independent variable</td>
<td>Symbolic regression</td>
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<tr>
<td></td>
<td>Symbolic regression with constant creation</td>
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<tr>
<td></td>
<td>Trigonometric identities</td>
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<tr>
<td></td>
<td>Solving a pair of linear equations</td>
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<tr>
<td></td>
<td>Empirical discovery</td>
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<td>Symbolic integration</td>
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<td>Symbolic differentiation</td>
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<tr>
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<td>Solving general functional equations</td>
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<td>Fourier series</td>
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<td>Biathlon (symbolic regression)</td>
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<tr>
<td>Integer independent variable</td>
<td>Sequence induction</td>
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<td>Randomizer</td>
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<tr>
<td>Multiple independent floating-point variables</td>
<td>Symbolic multiple regression</td>
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<tr>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td></td>
<td>Programmatic image compression</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>State of the system</th>
<th>Cart centering</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Broom balancing</td>
</tr>
<tr>
<td></td>
<td>Truck backer upper</td>
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<tr>
<td></td>
<td>Differential pursuer-evader game</td>
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<td></td>
<td>Discrete non-hamstrung squad car game (see Appendix B.3)</td>
</tr>
<tr>
<td></td>
<td>One-dimensional cellular automata</td>
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<td></td>
<td>Two-dimensional cellular automata</td>
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</table>

<table>
<thead>
<tr>
<th>Terminals are functions with no arguments</th>
<th>Artificial ant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central place food foraging</td>
</tr>
<tr>
<td></td>
<td>Emergent collecting behavior for ants</td>
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<td>Wall following robot</td>
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<td>Task prioritization (Pac Man)</td>
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<td>Biathlon (artificial ant)</td>
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<table>
<thead>
<tr>
<th>Class names</th>
<th>Induction of decision trees</th>
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<tbody>
<tr>
<td></td>
<td>Grammar induction</td>
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<tr>
<td></td>
<td>Intertwined spirals</td>
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<td></td>
<td>Discrete 32-outcome game</td>
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<td></td>
<td>Co-evolution of discrete 32-outcome game</td>
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</table>

<table>
<thead>
<tr>
<th>The terminals are only ephemeral random constants</th>
<th>Solving equations for numeric roots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Finding a global optimum point</td>
</tr>
</tbody>
</table>

<p>| Input sensors                                   | Block stacking                   |</p>
<table>
<thead>
<tr>
<th>Settable variables in addition to the usual terminals</th>
<th>Iterative summation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recursive reference to previous computation</td>
<td>Local tracking of a dynamical system</td>
</tr>
<tr>
<td>Parameters</td>
<td>Optimization — <em>Anolis</em> lizard</td>
</tr>
</tbody>
</table>
## MAJOR TYPES OF FUNCTIONS

<table>
<thead>
<tr>
<th>Type of Function</th>
<th>Examples</th>
</tr>
</thead>
</table>
| 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 |
| Arithmetic operations plus some transcendental functions and/or decision making function | Cart centering  
Broom balancing  
Truck backer upper  
Intertwined spirals  
Optimization — *Anolis* lizard |
|---|---|
| Various IF, CASE, and testing functions | 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) |
| Boolean functions | Boolean multiplexer  
Boolean functions of two and three arguments  
Design of two-bit adder circuit  
One-dimensional cellular automata  
Two-dimensional cellular automata |
| Complex arithmetic | Solving quadratic equations |
| Problem specific | Neural network design  
Task prioritization (Pac Man)  
Block stacking |
<table>
<thead>
<tr>
<th>Automatically defined functions in addition to usual functions</th>
<th>Even-4-parity with automatic function definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assignment function in addition to the usual functions</td>
<td>Iterative summation</td>
</tr>
<tr>
<td>Combinations</td>
<td>Biathlon (some of the time)</td>
</tr>
</tbody>
</table>
### TYPES OF WRAPPERS

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

**MAJOR TYPES OF FITNESS MEASURES**
<table>
<thead>
<tr>
<th>Error</th>
<th>Symbolic regression</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Symbolic regression with constant creation</td>
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<td>Trigonometric identities</td>
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<td>Solving general functional equations</td>
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<td>Solving equations for numeric roots</td>
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<td>Sequence induction</td>
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<td>Programmatic image compression</td>
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<td>Solving quadratic equations</td>
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<td>Fourier series</td>
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<td>Design of a two-bit adder circuit</td>
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<td>Biathlon (symbolic regression)</td>
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<td>Finding a global optimum point</td>
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<td>Even-4-parity with automatic function definition</td>
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<tr>
<td></td>
<td>Iterative summation</td>
</tr>
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<table>
<thead>
<tr>
<th>Distance shortfall</th>
<th>Inverse kinematics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Box moving robot</td>
</tr>
<tr>
<td></td>
<td>Truck backer upper</td>
</tr>
</tbody>
</table>
| 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 — Anolis 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

<table>
<thead>
<tr>
<th>Type of fitness case</th>
<th>Examples</th>
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</table>
| 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 |
| Combinations of Boolean values | 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 |
|---------------------------------|------------------------------------------------|
| Randomly chosen initial conditions of a system | 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 |
| One fitness case | Artificial ant  
Biathlon (artificial ant)  
Central place food foraging  
Wall following robot  
Task prioritization (Pac Man)  
Solving equations for numeric roots |
| Sets of equations | Solving a pair of linear equations  
Solving quadratic equations |
| Temporal sample | One-dimensional cellular automata  
Two-dimensional cellular automata |
<p>| Combinations of plays in a game | Discrete 32-outcome game |
| Co-evolution | Co-evolution of discrete 32-outcome game |</p>
<table>
<thead>
<tr>
<th>Structured sample</th>
<th>Block stacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training examples</td>
<td>Induction of decision trees</td>
</tr>
<tr>
<td>Sequence of data</td>
<td>Grammar induction</td>
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<tr>
<td>Monte Carlo experiments</td>
<td>Optimization — <em>Anolis</em> lizard</td>
</tr>
<tr>
<td>Given data</td>
<td>Empirical discovery</td>
</tr>
</tbody>
</table>
## TYPES OF SIMULATIONS OF BEHAVIOR

<table>
<thead>
<tr>
<th>Type of simulations of behavior</th>
<th>Examples</th>
</tr>
</thead>
</table>
| **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 — *Anolis* lizard |
| **Simulation involving co-evolution** | Co-evolution of discrete 32-outcome game strategies |
| Time series | Randomizer |
### POPULATION SIZE

<table>
<thead>
<tr>
<th>Population sizes</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Boolean functions of two and three arguments</td>
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<tr>
<td>100</td>
<td>Discrete non-hamstrung squad car game (see Appendix B.3)</td>
</tr>
<tr>
<td>300</td>
<td>Co-evolution of discrete 32-outcome game</td>
</tr>
<tr>
<td>500</td>
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<td>-----</td>
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</tr>
<tr>
<td>Cart centering</td>
<td></td>
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<tr>
<td>Symbolic regression</td>
<td></td>
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<tr>
<td>Artificial ant</td>
<td></td>
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<td>Trigonometric identities</td>
<td></td>
</tr>
<tr>
<td>Symbolic regression with constant creation</td>
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<tr>
<td>Empirical discovery of exchange equation</td>
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<tr>
<td>Empirical discovery of Kepler's Law</td>
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<tr>
<td>Symbolic integration</td>
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<td>Symbolic differentiation</td>
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<td>Box moving robot</td>
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<td>Two-dimensional cellular automata</td>
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<td>Discrete 32-outcome game</td>
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<td>Induction of decision trees</td>
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<td>Neural network design</td>
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| 1,000 | Truck backer upper  
Wall following robot  
Design of two-bit adder circuit  
Biathlon  
Optimization — *Anolis* 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 |