Genetic Programming Part 1

Evolutionary Computation
Lecture 11
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Previous Lecture

- Multi-objective Optimization
  - Pareto optimality
  - Hyper-volume based indicators
- Recent lectures about
  - Constraint handling
  - Niching
  - Population dynamics

Genetic Programming

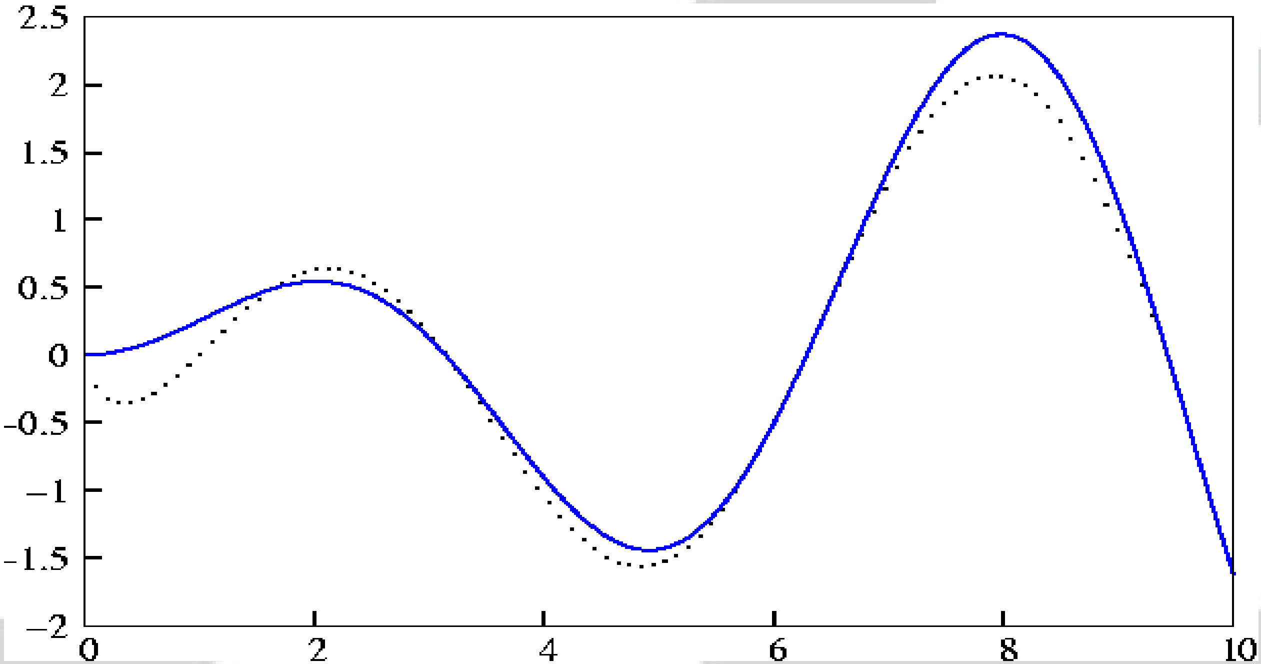
- Two different view of what GP means:
- Content view:
  - Automatic Programming
  - Creation of programs by artificial evolution
  - Different representations
- Representation view:
  - anything using tree representation
  - May be programs, may be other things

Representing Programs in EC

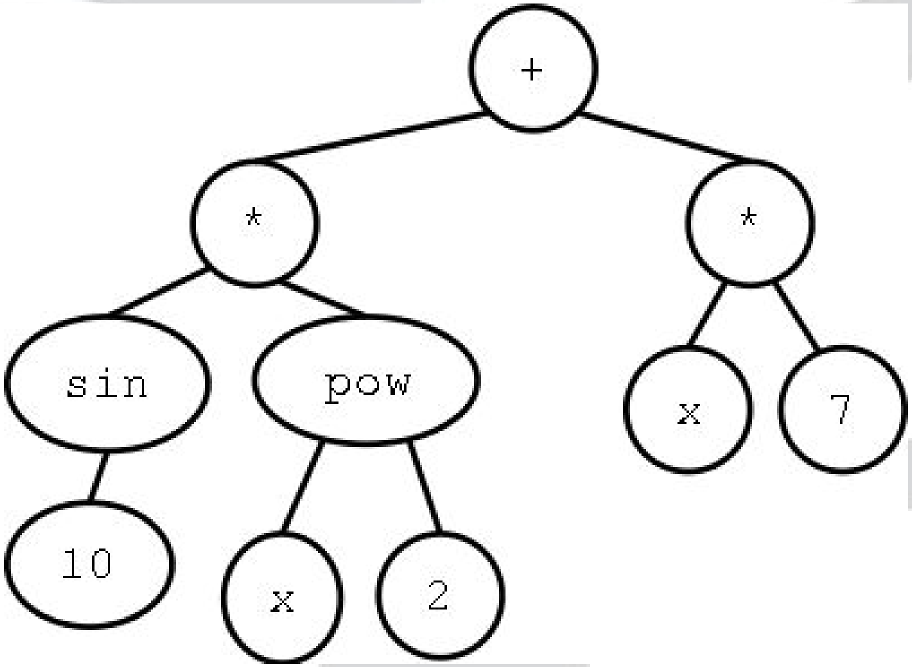
- Tree representation
  - LISP-like expression
  - Local data storage
  - Tree Genotypes
  - Tree genetic operators
  - Stack for data storage
- Linear representation
  - Series of instructions
  - Registers for data storage
- Graph representation
  - Nodes contain instructions
  - Edges control program flow
  - Stack for data storage

Example Problem: Symbolic Regression

- Given: a set of function points
- Problem: find a function that fits the points as closely as possible
- Common problem in stats, process engineering, ...



Tree Representation for Symbolic Regression



- Function Set and Terminal Set

The Terminal Set

- Anything with arity 0 and one output
  - Arity: number of inputs (unary, binary, ...)
- Inputs
  - Sensors
  - Function variables
- Constants
  - Numbers

Do we need to supply all possible constants?

The Function Set

- n-ary functions
  - E.g. mathematical functions +, -, *, /, log, sum, ...
  - E.g. boolean functions and, or, not, xor, ...
  - E.g. memory functions store, read
  - E.g. control structures if..then..else, for, ...
  - E.g. side-effect functions move, pen up, turn, ...

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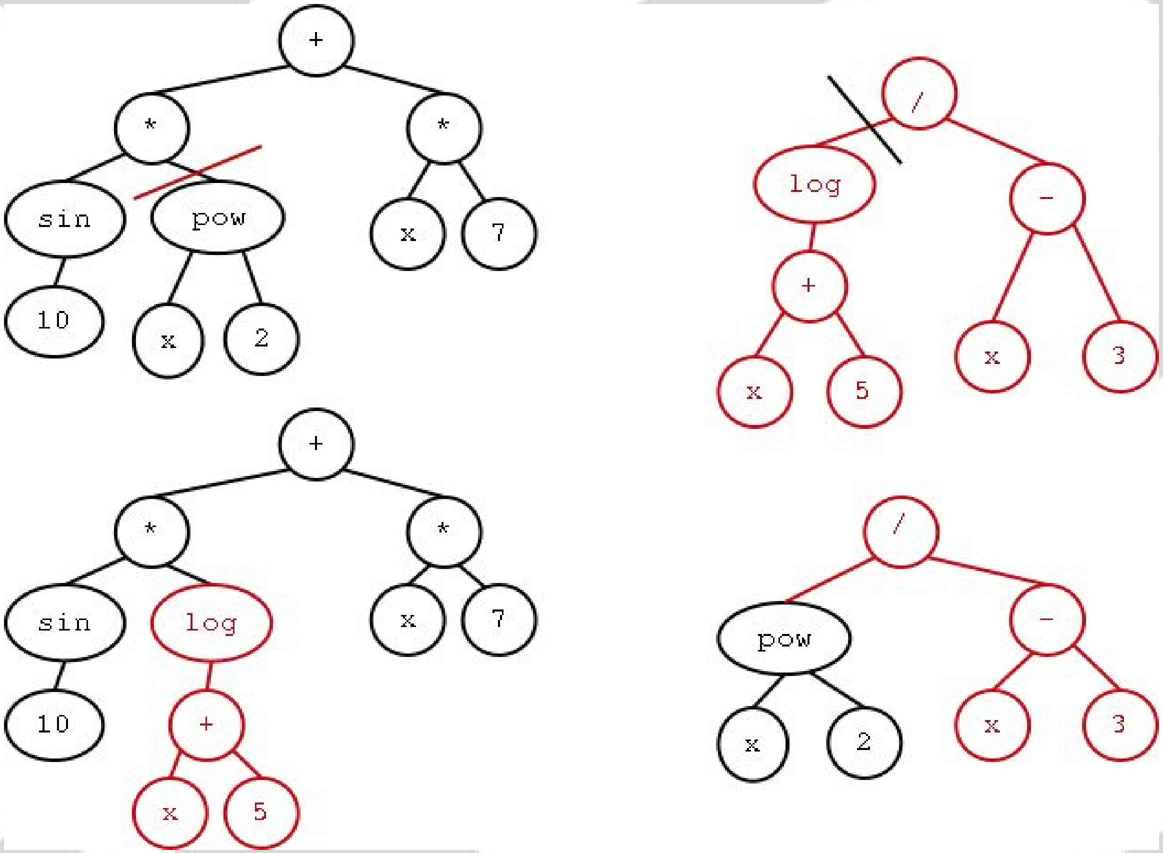
- Coverage
  - Functions need to be defined over all inputs
  - E.g. division needs to be defined for input 0

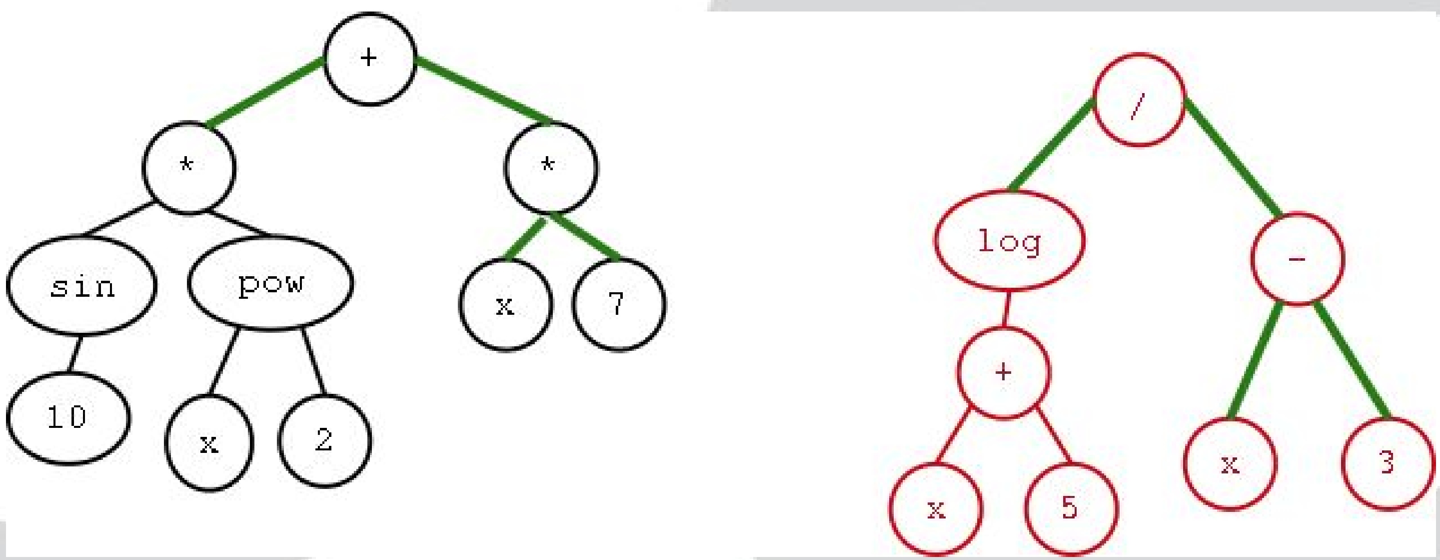
Crossover

- Branch Swap
  - Pick random branch at each parent
  - Swap branches



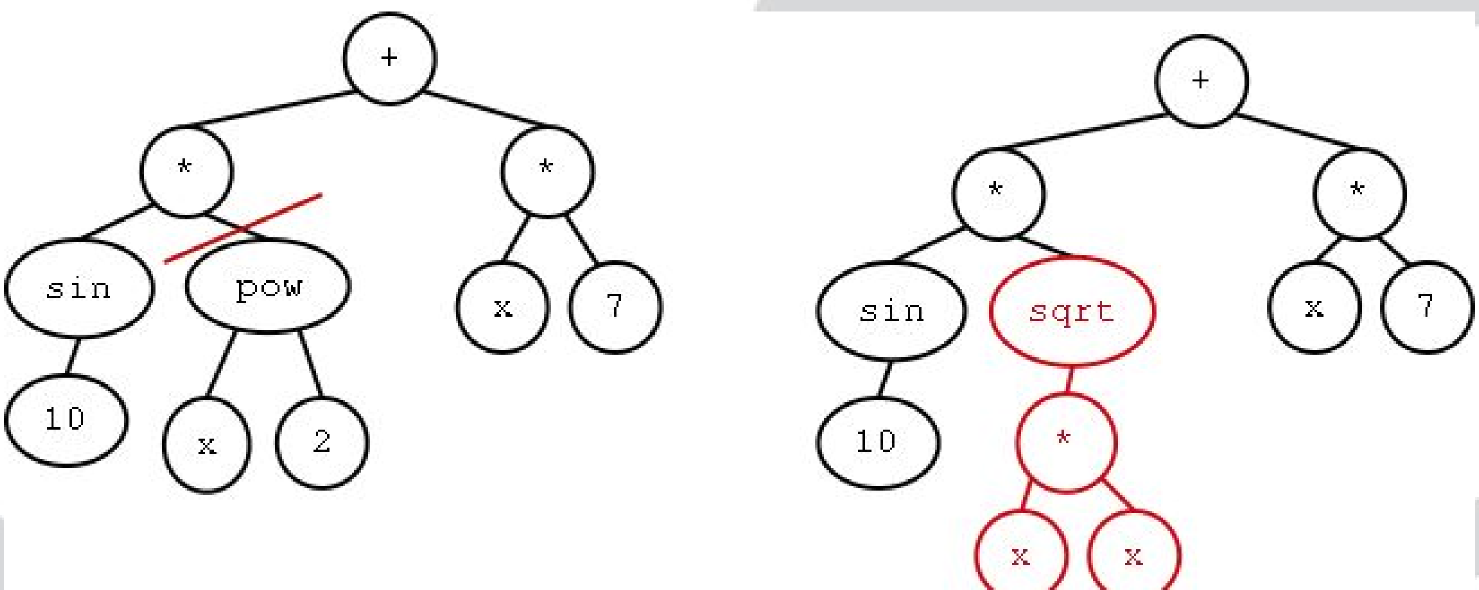
Matched 1-point Tree Crossover

- From root follow branches
- As long as nodes have same arity
- Same crossover point for both parents, within matched branches
- n-point crossover possible, too



Mutation

- Branch replacement
  - Pick random branch from parent
  - Delete branch
  - Replace with random new branch
  - (New branch created as in initial population creation)



Creation of Initial Population (1)

- Full Method
  - with fixed tree depth treeDepth:
  - 1. do add random function nodes until all branches have (treeDepth -1) depth
  - 2. add random terminal nodes to all branches

Creation of Initial Population (2)

- Growth Method
  - with fixed maximum tree depth maxDepth:
  - 1. do add random function or terminal nodes until all branches have terminals or are (maxDepth -1) depth
  - 2. add random terminal nodes to all branches without terminals

Creation of Initial Population (3)

- Ramped half-and-half
  - with fixed maximum tree depth maxDepth and population size popSize:
  - for n=2..maxDepth create:
    - (popSize/2*(maxDepth -1)) individuals using growth with maxDepth=n
    - (popSize/2*(maxDepth -1)) individuals using full with treeDepth=n

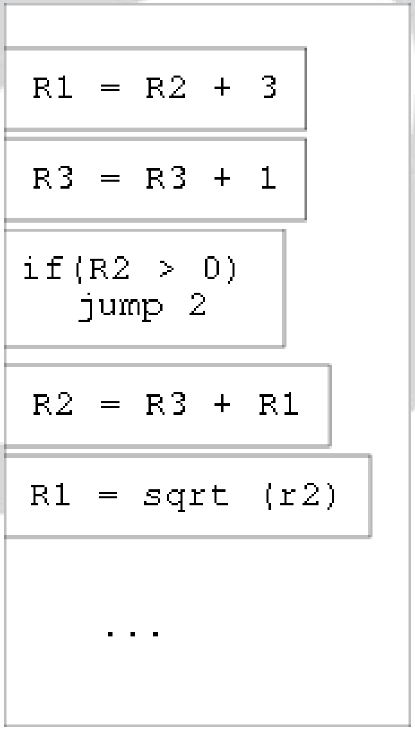
Bloat

- Program size grows
  - As a result of uneven crossover
  - Unused code
  - Slows down runs
  - More space, cpu time required
  - Mutation, crossover of unused code - offspring behaviour is identical
- Countermeasures
  - Incorporate program size into fitness
  - Use special crossover (e.g. matched one-point crossover)

Linear Representation Genetic Programming

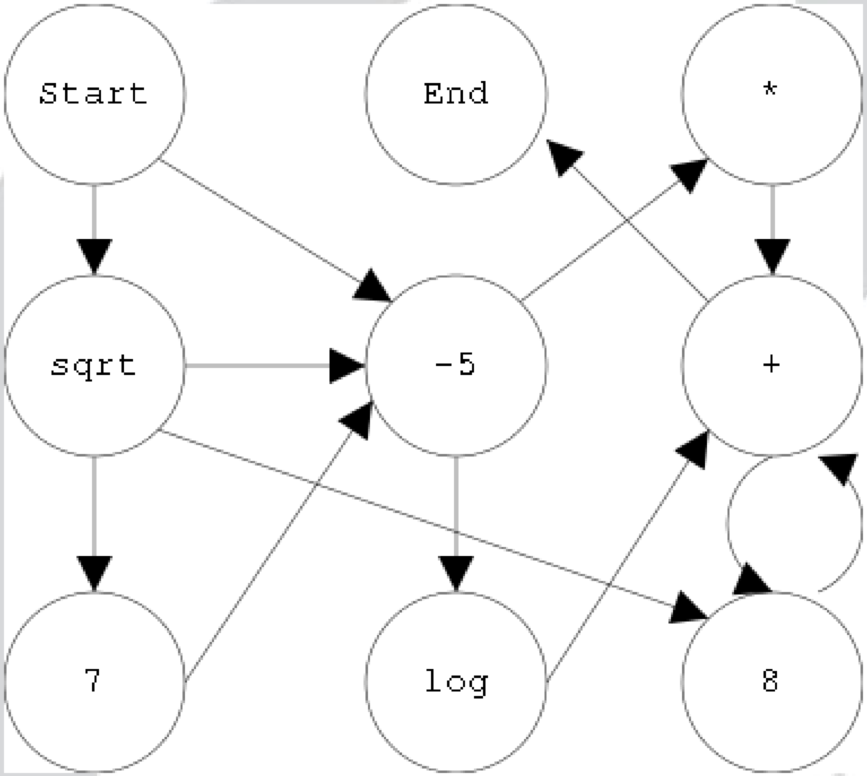
Register Machine

- Van-Neuman Architecture
- String of instructions and data
- Functions get arguments from registers
- String Representation
- Usually variable-length
- Crossover: variable-length versions of one-pint, two-point
- Mutation: 'usual' random gene replacement, but also add, delete operations



Graph Representation Genetic Programming

- Nodes define operations
  - Operands come from stack
  - Result will be put onto the stack
  - Edges define control flow
  - Control mechanism controls which edge to follow
  - E.g. depends on value written to stack {<0, =0, >0}
  - Loops and recursion common
  - Specialized Crossover and Mutation operators



Genetic Programming == Automatic Programming?

- Does it start from a high level specification ?
- Does it produce an executable program ?
- Does it automatically determine the number of steps a program should take ?
- Does it produce results that are competitive with human programmers, engineers, mathematicians and designers ?

Genetic Programming Applications

- Regression
  - Chemistry,Engineering
  - Statistics
  - Classification etc.
  - Data Mining
  - Intrusion Detection
  - Image classification
- Control
  - Plants
  - Robots
  - Spacecraft altitude manoeuvres
  - Animation
- Design
  - Neural Networks
  - Electronic Circuits

Summary

- Automatic Generation of Programs
  - within limits...
- Tree Representation
  - Tree crossover
  - Branch replacement mutation
- Other Representations
  - Linear
  - Graph

References

- Basic Reading:
  - Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, and Frank D. Francone Genetic Programming: An Introduction Morgan Kaufmann Publishers (In the Library): Chapter 5
- Advanced Reading
  - Other chapters in Banzhaf et. al
  - John R. Koza: Genetic Programming: On the Programming of Computers by Means of Natural Selection (In the library - don't be put off by the volume of the book, you can skim over a lot of the material quickly, just pick interesting applications.)
- Websites
  - http://www.geneticprogramming.com/