Applying Genetic Programming to Bytecode and Assembly

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The big picture

- Evolving whole programs is hard to do with source code.
- Evolving whole programs with bytecode and assembly is not as hard.

Outline

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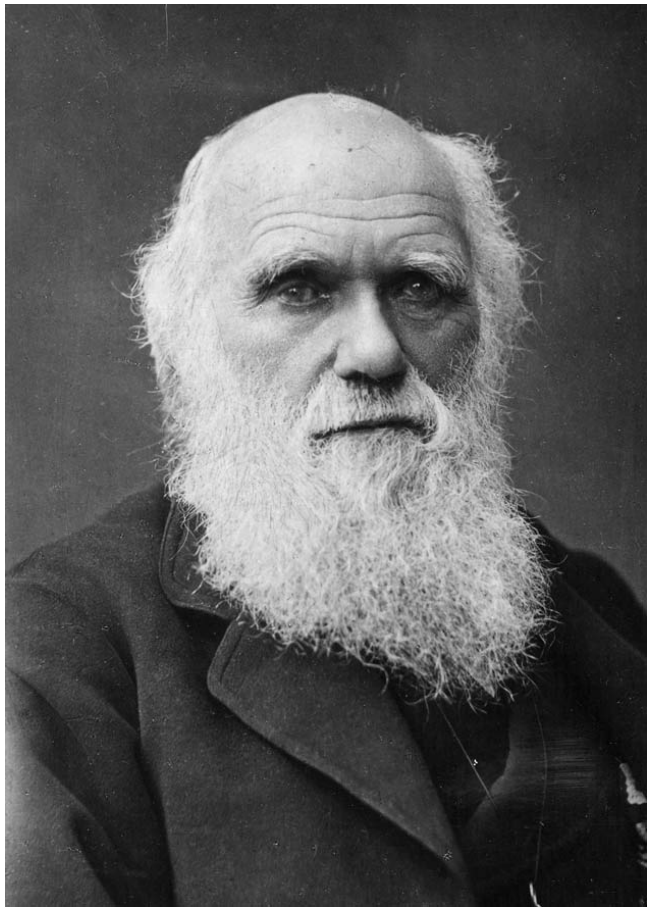
What is Evolutionary Computation?

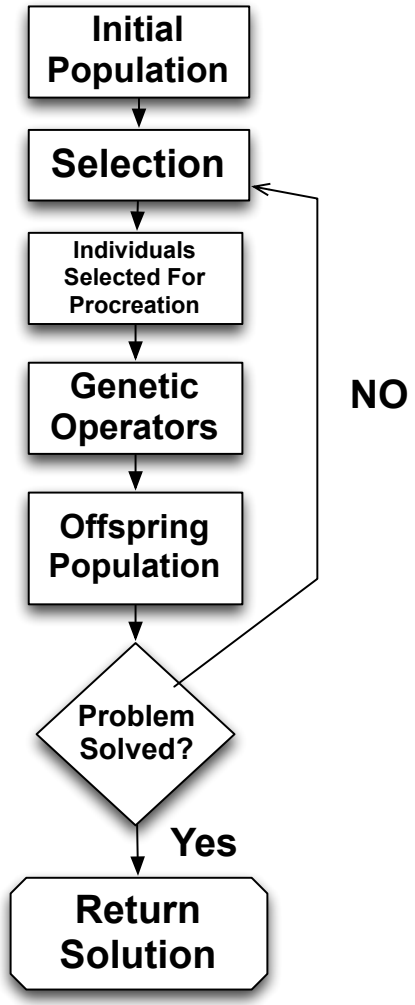
- EC is a a technique that is used to automate computer problem solving.
- Loosely emulates evolutionary biology.



Charles Darwin
http://tinyurl.com/lqwj3wt

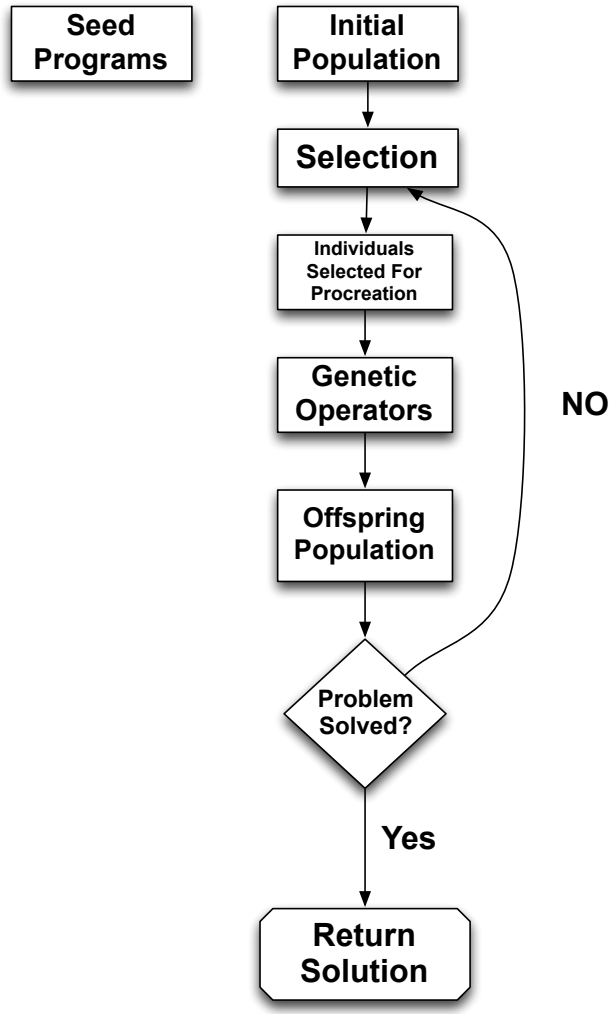
How does it work

- Continuous Optimization
- Selection is driven by the *fitness* of individuals
- Genetic Operators mimic sexual reproduction and mutation



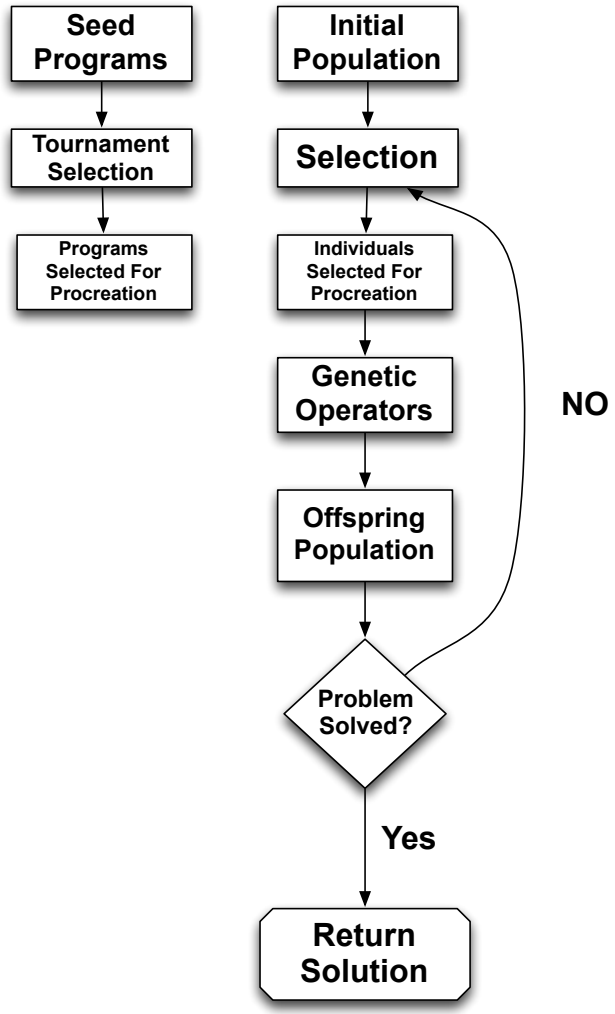
Genetic Programming

- Uses the EC technique to evolve programs
- The population is programs



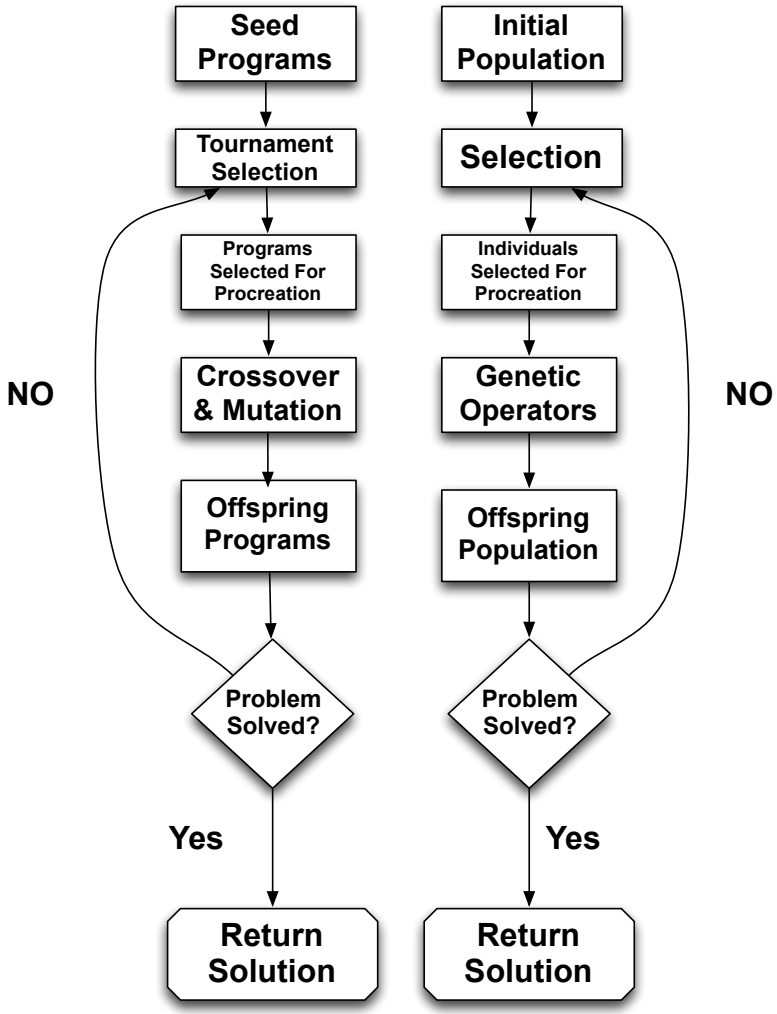
Genetic Programming

- Tournament Selection

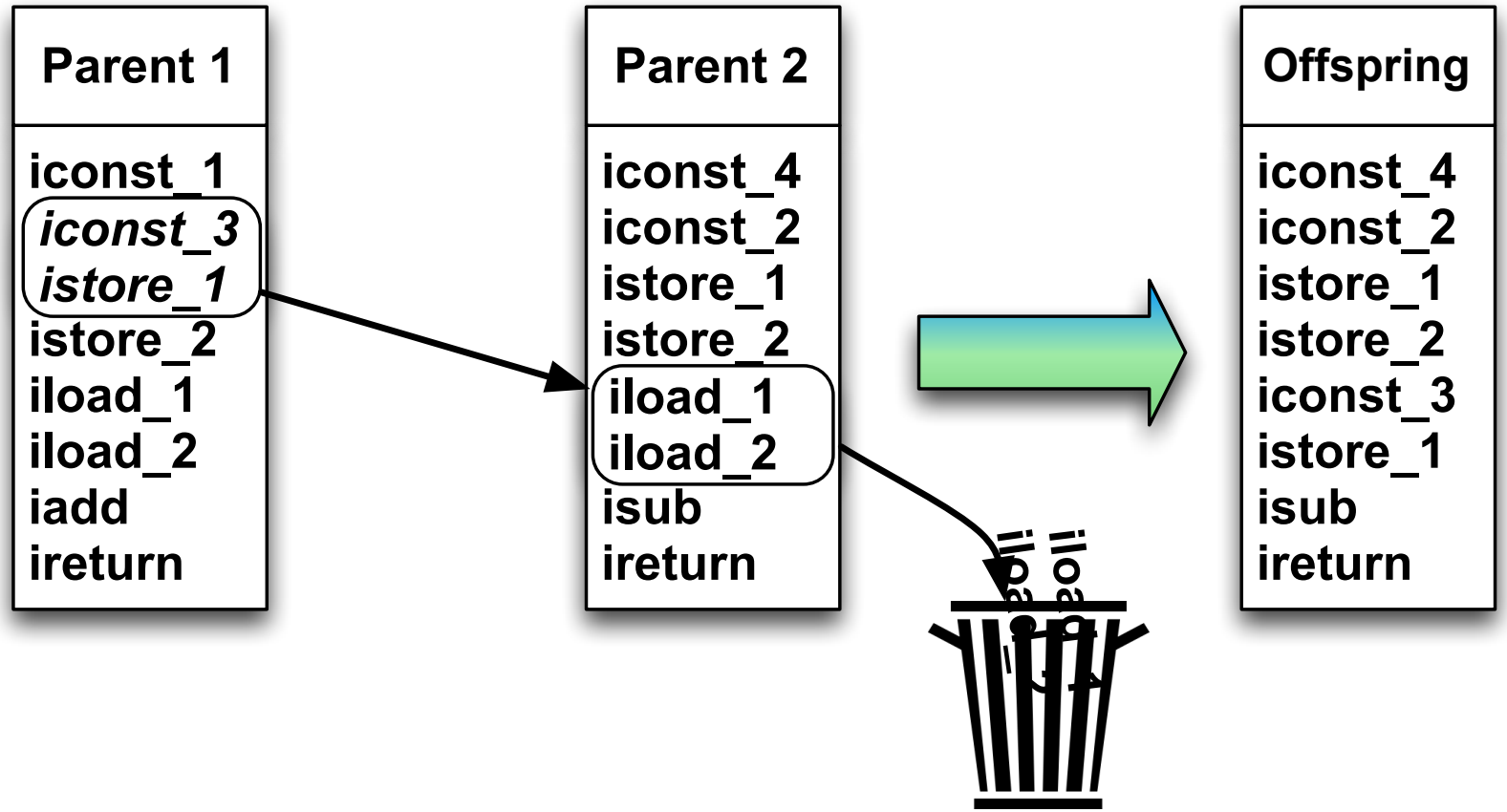


Genetic Programming

- Crossover
- Mutation

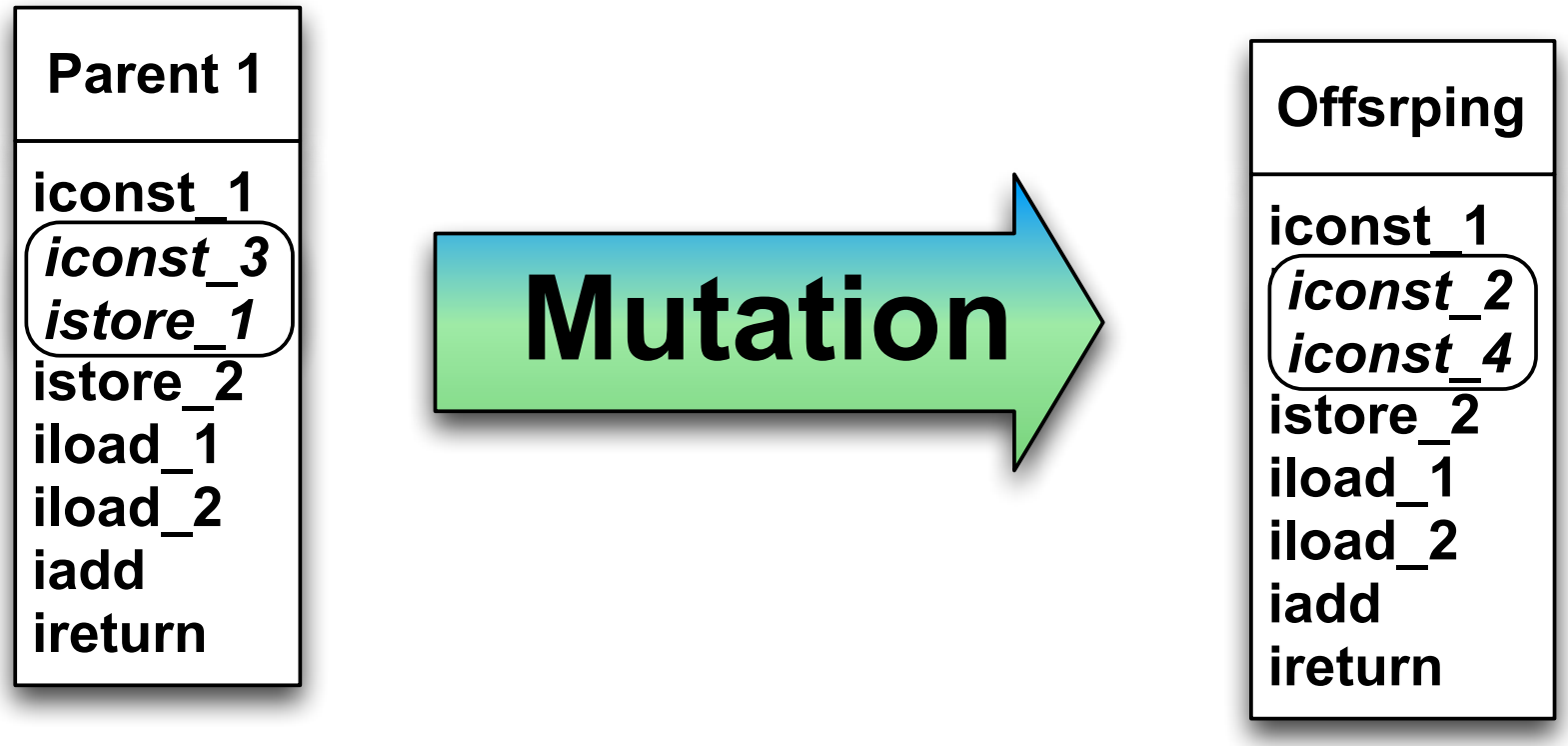


Crossover



Crossover with Java Bytecode

Mutation



Crossover with Java Bytecode

Outline

Source Code Constraints

- While it would be useful, it is difficult to apply evolution to an entire program in source code
  - Source code is made to simplify reading and writing programs
  - Source code does not represent the semantic constraints of the program.

Source Code Constraints

```
float x;  int y = 7;
if (y >= 0)
   x = y;
else
   x = -y;
System.out.println(x);
```

(a)

```
int x = 7;  float y;
if (y >= 0) {
   y = x;
   x = y;
}
System.out.println(z);
```

(b)

Both (a) and (b) are valid syntactically. However (b) is invalid semantically.

Source Code Constraints

- EAs are usually designed to avoid dealing with semantic constraints

```
class Robot{
...
  double robotSpeed(){
      double evolvedVariable = valueFromEA;
      return (robot.location + evolvedVariable)/2;
  }
...
}
```

Instruction-Level Code Constraints

- Consists of a smaller alphabets
- Simpler syntactically
- Less semantic constraints to violate

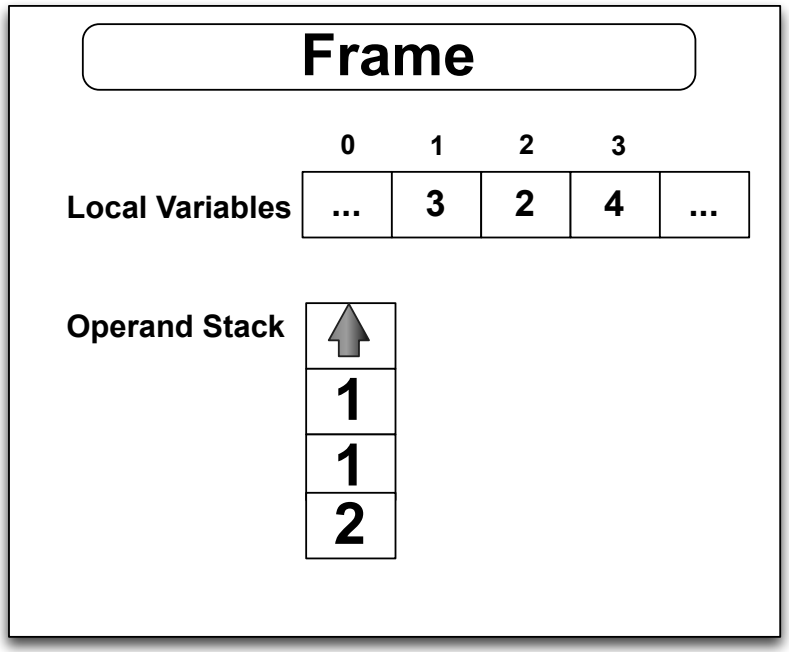
Instruction-level Code Benefits

- Do not need to understand the structure of the program being evolved
- Can evolve a lot from a little
- If there is a compiler for it we can evolve it

Outline

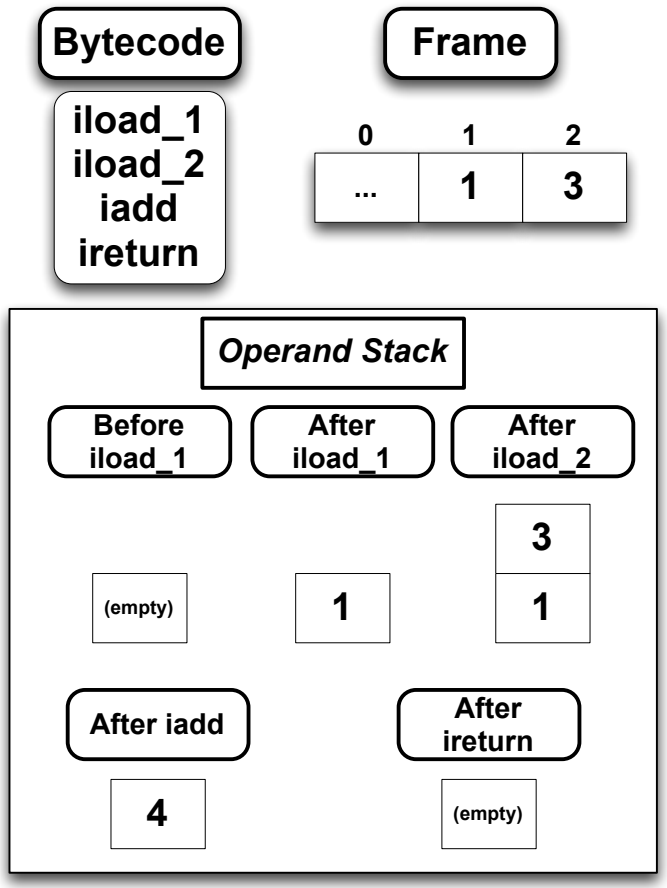
Java Virtual Machine

- Frames
- Array of local variables
- Operand Stack



Java Bytcode and Frames

- Opcodes
- Prefix indicates type



Outline

What is FINCH?

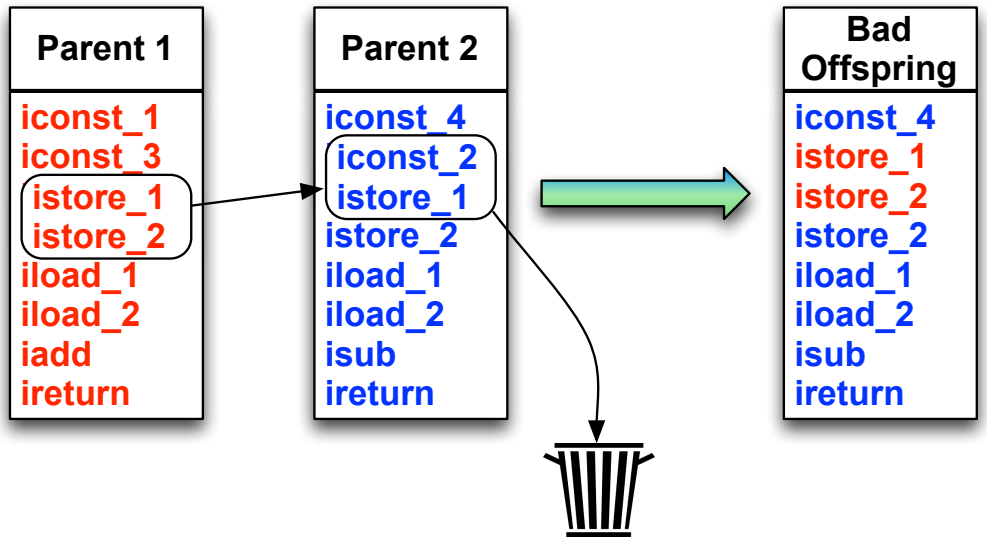
- FINCH is an EA developed by M. Orlov and M. Sipper
- It evolves Java bytecode using crossover
- It is a good example of dealing with semantic constraints

Selecting Offspring

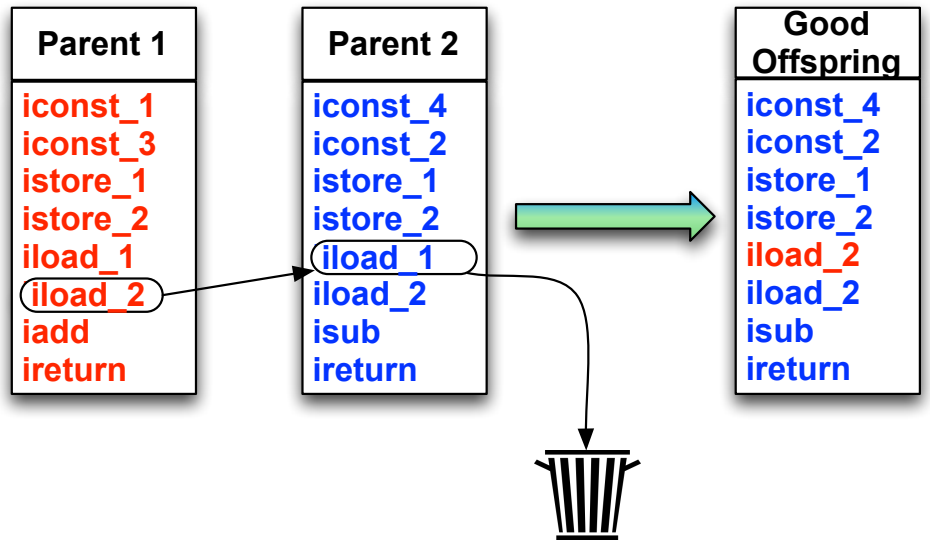
- There is still a chance to produce non-compilable code
- Solution: check if offspring follows semantic constraints
  - Stack and Frame Depth
  - Variable Types
  - Control Flow

1. Apply crossover to two parents
2. Check if they comply to semantic constraints
3. If the program passes the constraint test then it proceeds to offspring generation
4. If it fails the constrain check then another attempt is made with the same parents

Bad Crossover



Good Crossover



Array Sum

- The array sum problem
  - Started with a zero fitness seed program
  - Counted function calls to check for a non-halting state

```
int sumlistrec(List list){
    int sum = 0;
    if(list.isEmpty())
        sum *= sumlistrec(list);
    else
        sum += list.get(0)/2 + sumlistrec(
              list.subList(1, list.size()));
    return sum;
}
```

Array Sum

```
int sumlistrec(List list) {
  int sum = 0;
  if (list.isEmpty())
    sum = sum;
  else
    sum += ((Integer)list.get(0)).intValue() +
        sumlistrec(list.subList(1,
            list.size()));
  return sum;
}
```

Outline

Selecting Offspring

- Debugging programs that consist of thousands of lines of code
- Uses a weighted path due to size of programs
- No checks if executable instruction-level code is produced

Selecting Offspring

- Each instruction is given a weight
- The weight is determined by what tests execute that instruction
- Each experiment started with one negative test case and multiple positive test cases

Instruction Weight

- Only executed by failing test: weight = 1.0
- Executed by negative test and one positive: weight = 0.1
- Not executed by negative test case: weight = 0

Bugs Fixed

- Buffer overflow
- Infinite loops

Outline

Conclusions

References