Applying Genetic Programming to Bytecode and Assembly

Eric Collom

Division of Science and Mathematics
University of Minnesota, Morris
Morris, Minnesota, USA

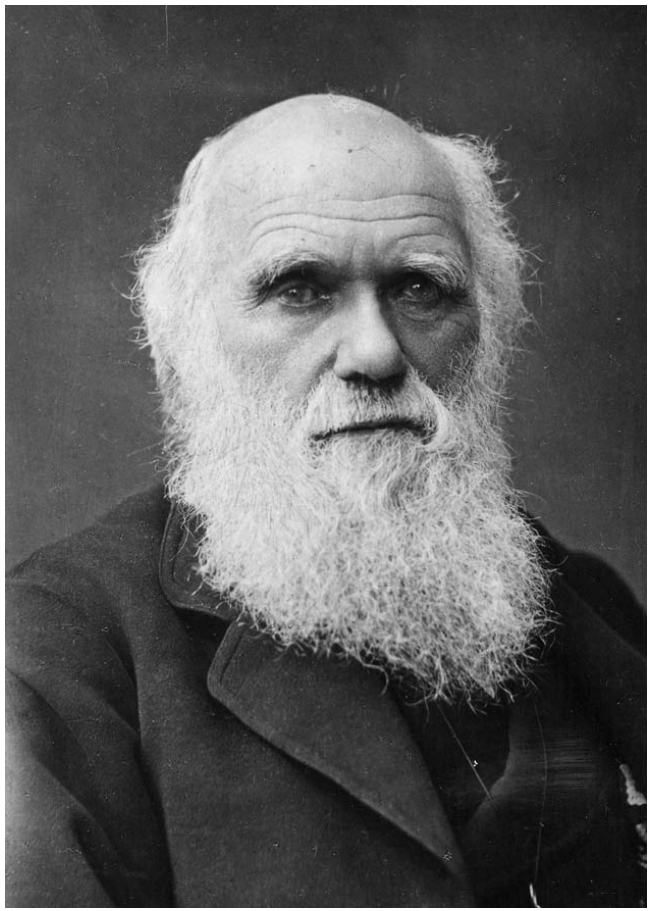
29 April '14,
UMM Senior Seminar

Outline

Outline

What is Evolutionary Computation?

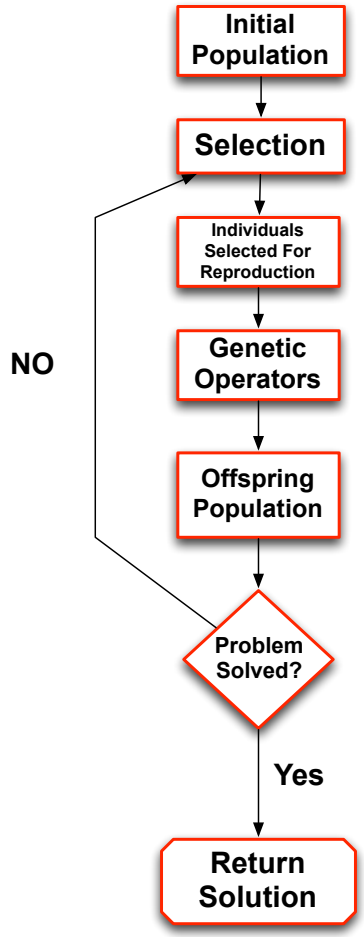
- Evolutionary Computation (EC) is a a technique that is used to automate computer problem solving.
- Loosely emulates evolutionary biology.



Charles Darwin
http://tinyurl.com/lqwj3wt

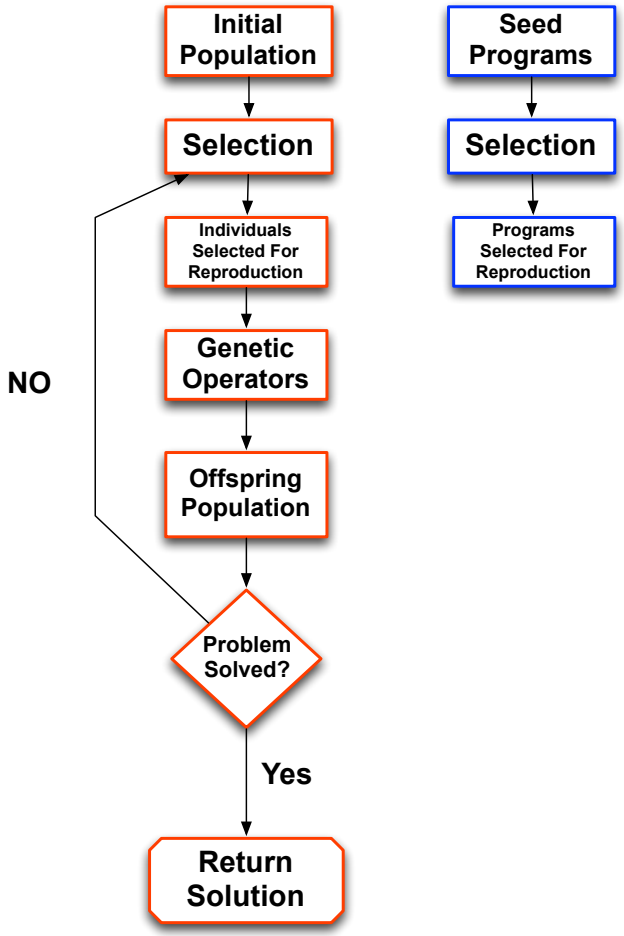
How does it work?

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



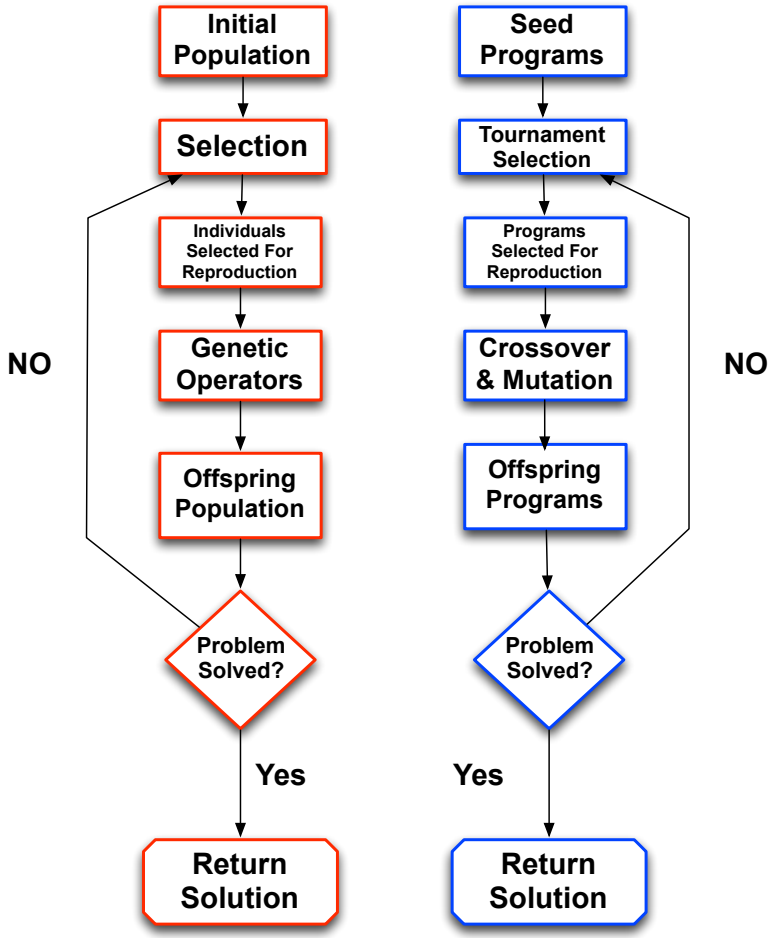
Genetic Programming

- Genetic programming (GP) uses the EC process to evolve **programs**
- This done by using an Evolutionary Algorithm (EA)

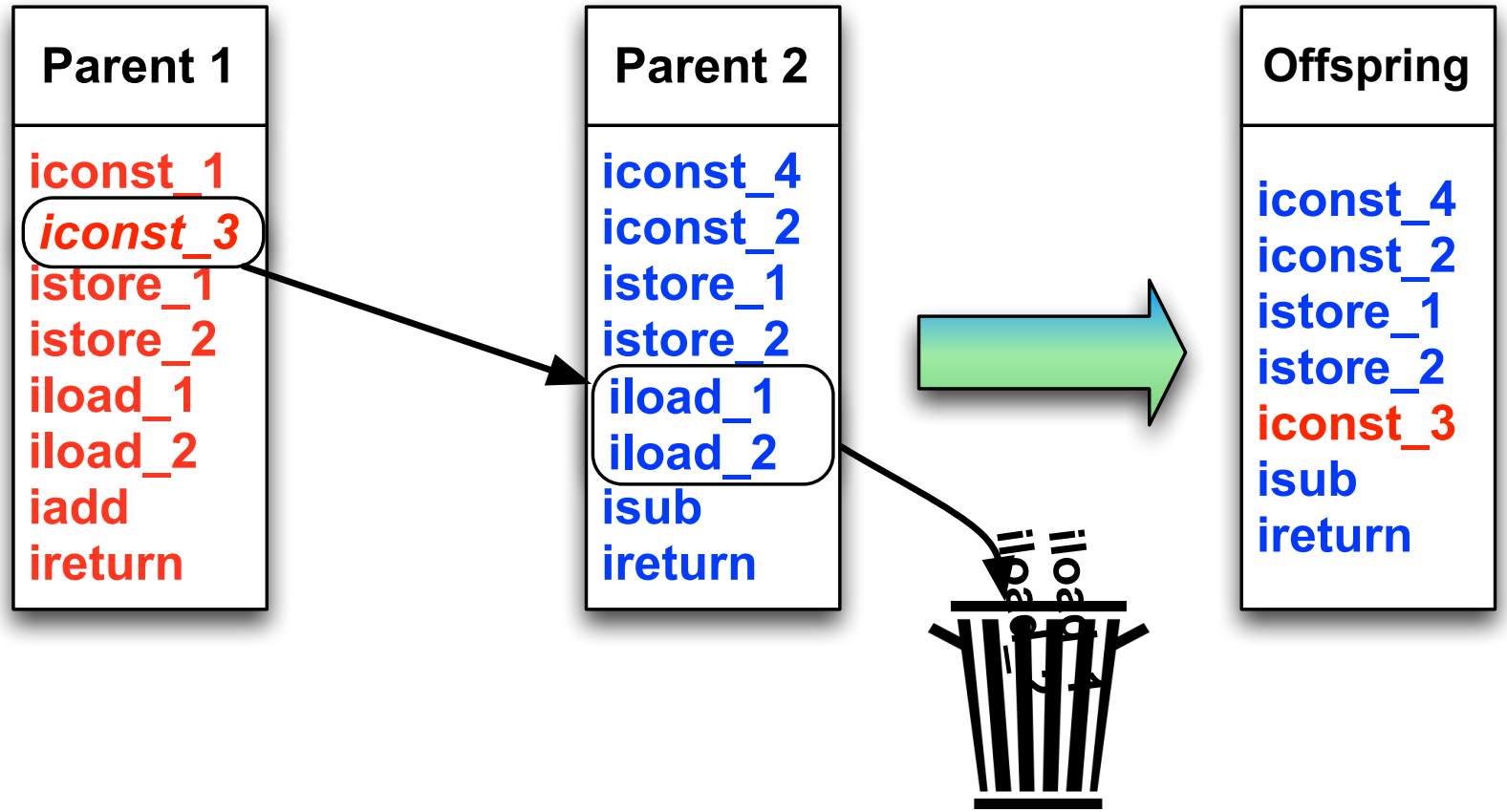


Genetic Programming

Two genetic operators used in GP are *crossover* and *mutation*

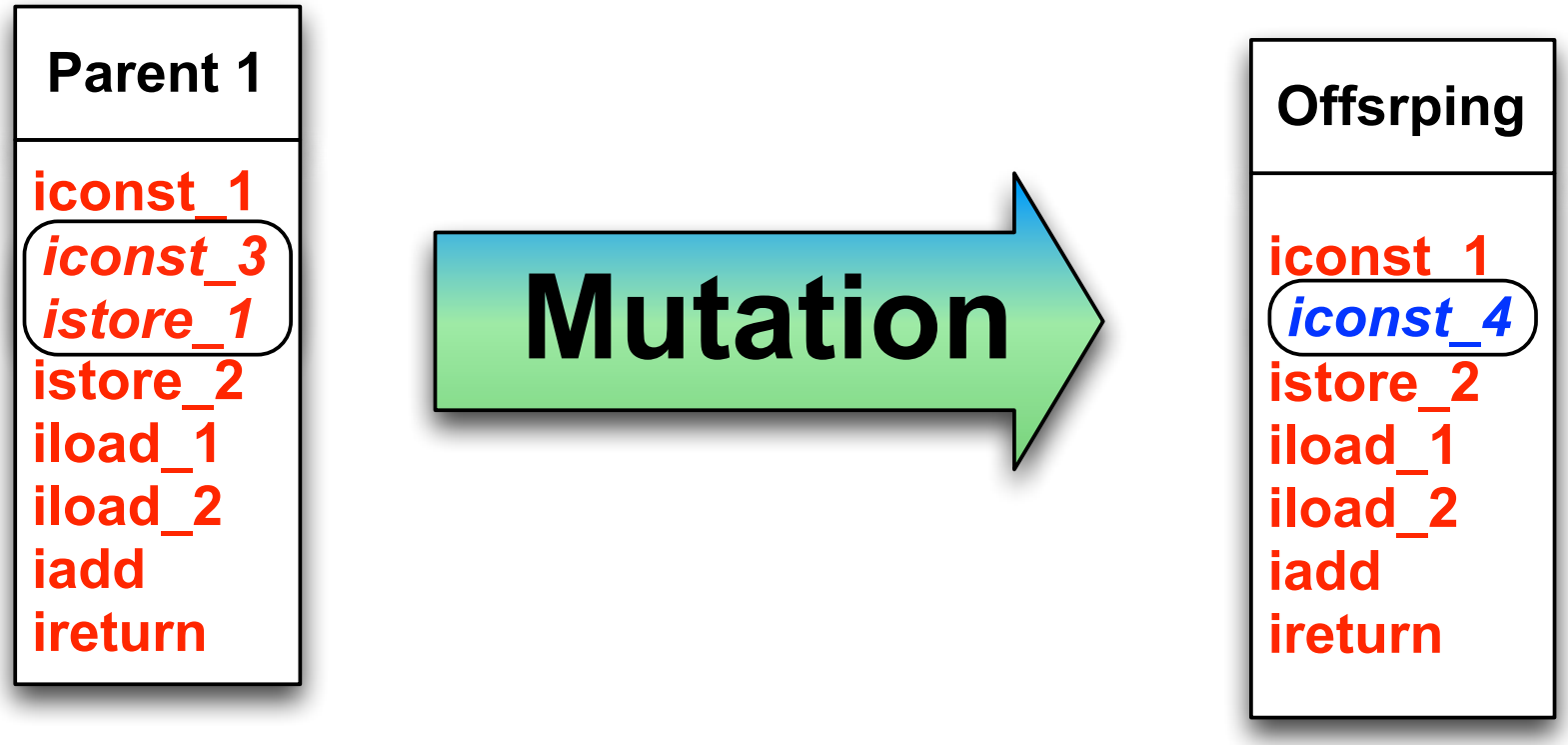


Crossover



Crossover with Java Bytecode

Mutation



Crossover with Java Bytecode

Outline

Source Code Semantic Constraints

- 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.

Syntax vs Semantics

- Syntax represents structure
- Semantics represent meaning

Semantically Wrong: The sun rises in the West.
Semantically Correct: The sun rises in the East.

Syntax vs Semantics

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

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

(a)

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

(b)

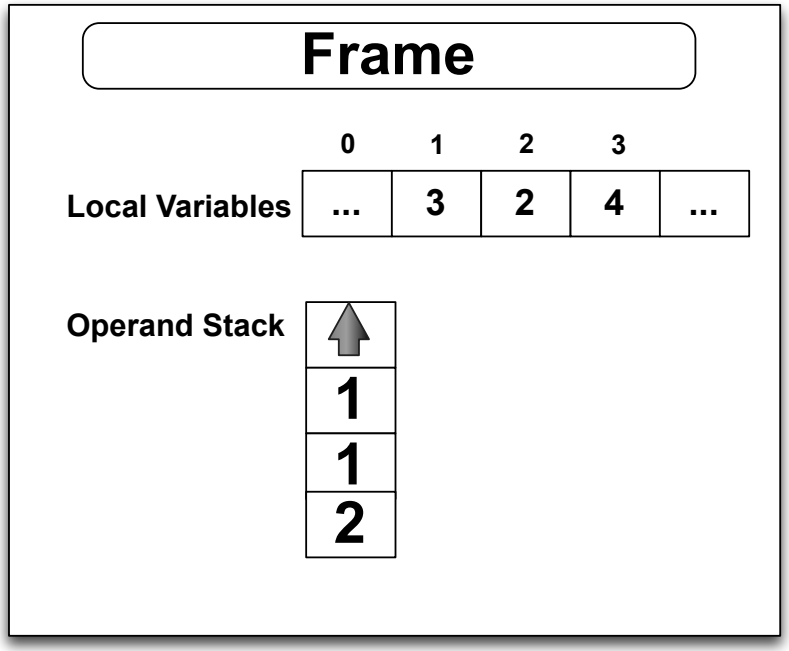
Instruction-Level Code Constraints

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

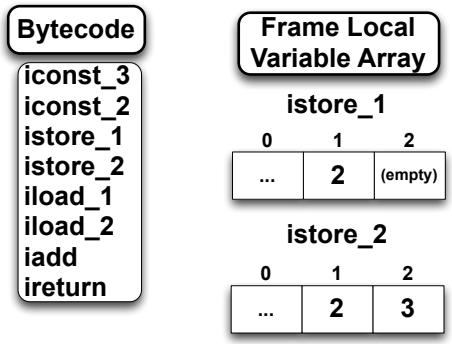
Outline

Java Virtual Machine

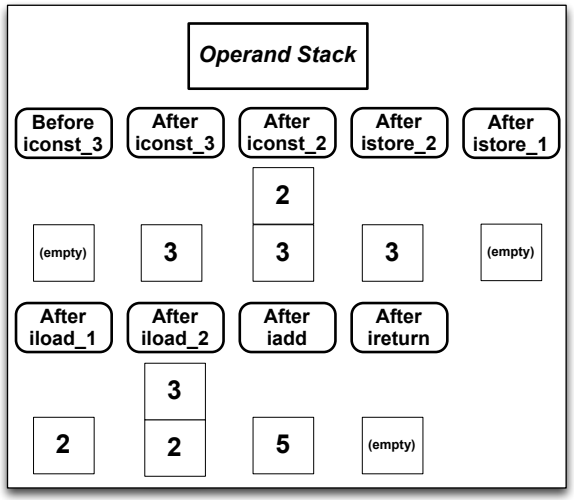
- A frame stores data and partial results as well as return values for methods
- Each method call has a frame



Java Bytcode and Frames



- Opcodes
- The prefix indicates type



Outline

What is FINCH?

- FINCH is an EA developed by Orlov and Sipper
- It evolves Java bytecode
- It deals with semantic constraints

Dealing With Semantic Constraints

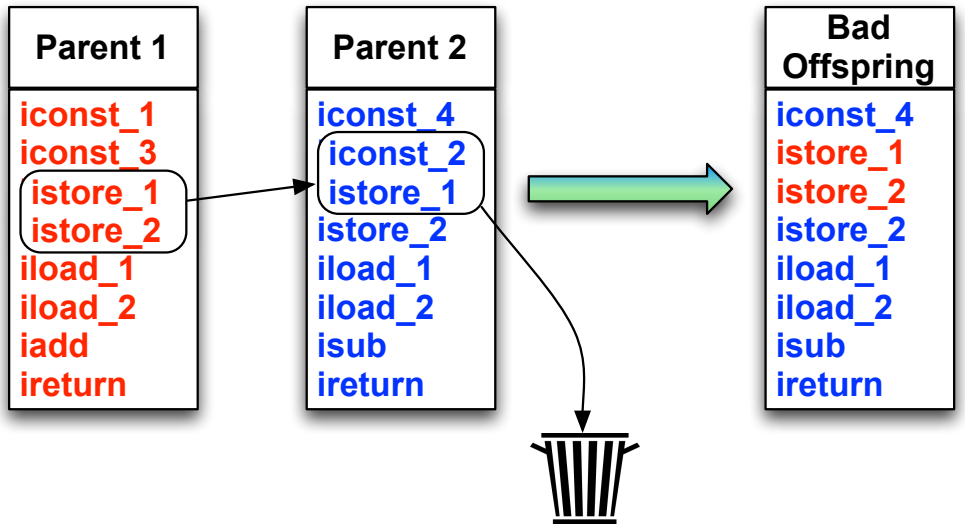
The semantic constraints that are checked for are

- Stack and Frame Depth
- Variable Types
- Control Flow

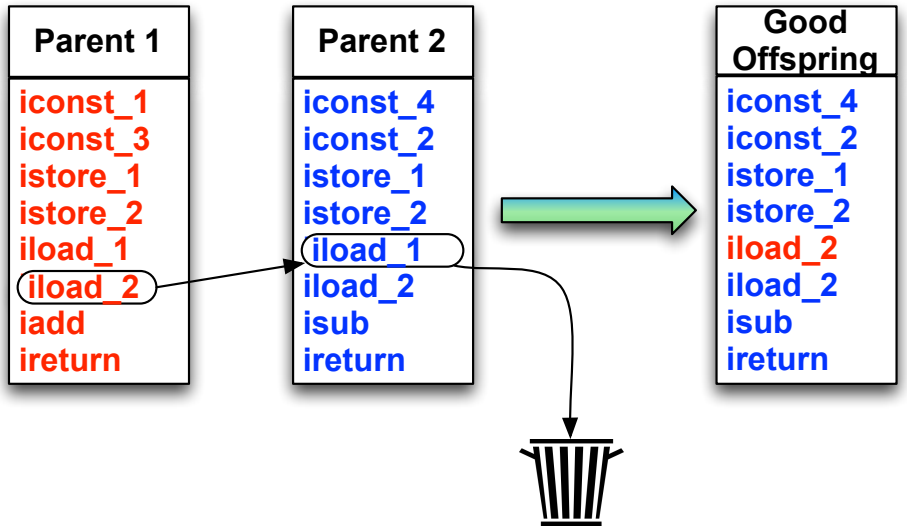
Dealing With Semantic Constraints

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 constraint 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

Decompiled Solution

```
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

Automating Bug Repair

- Schulte et al., automated bug repair by evolving Java bytecode and x86 assembly
- Fixed bugs in real code
- Does not check for semantic constraints

Tests and Fitness

- Fitness was determined by tests
- Test consisted of one *negative* test and multiple *positive* tests
- The negative test was used to check if the bug was fixed

- Programs at times consist of thousands of lines of code
- Uses a weighted path due to size of programs
- The weighted path was determined by what tests execute that instruction

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

What was debugged?

Schulte et al., were able to debug:

- Infinite loops
- Buffer overflows
- Incorrect type declarations

Outline

Conclusions

coll0474@morris.umn.edu

Questions?

References


M. Orlov and M. Sipper.
Flight of the FINCH Through the Java Wilderness.
Evolutionary Computation, IEEE Transactions on, 15(2):166–182, April 2011.


E. Schulte, S. Forrest, and W. Weimer.
Automated Program Repair Through the Evolution of Assembly Code.
In *Proceedings of the IEEE/ACM International Conference on Automated Software Engineering*, ASE '10, pages 313–316, New York, NY, USA, 2010. ACM.