Flight of the FINCH through the Java Wilderness

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GP: Programs or Representations?

> "While it is common to describe GP as evolving **programs**, GP is not typically used to evolve programs in the familiar Turing-complete languages humans normally use for software development. It is instead more common to evolve programs (or expressions or formulae) in a **more constrained** and often **domain-specific language**."

A Field Guide to Genetic Programming
[Poli, Langdon, and McPhee, 2008]

Our Goals

From programs. . .

Evolve actual programs
written in Java

. . . to software!

Improve (existing) software
written in unrestricted Java

FINCH:
Fertile Darwinian Bytecode Harvester

- A system for evolving Java (bytecode).
- Employs a sophisticated compatible crossover operator.
- **Always** produces correct (compilable) bytecode.
- Which we can deploy directly or decompile back to Java for perusal.
- All you need: A seed and a wish (= fitness function).
- If the wish is good—even a **bad** seed will eventually blossom!

Darwinian Software Development

Michael Orlov
Moshe Sipper

> “On two occasions I have been asked, ‘Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?’ I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a question.”

Charles Babbage

Garbage in—Garbage out. . .

Or maybe not?

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Garbage in. . .

Sample seed supplied to FINCH:

```
class SimpleSymbolicRegression {
  Number simpleRegression(Number num) {
    double x     = num.doubleValue();
    double llsq  = Math.log(Math.log(x*x));
    double dv    = x / (x - Math.sin(x));
    double worst = Math.exp(dv - llsq);
    return Double.valueOf(worst + Math.cos(1));
  }

  /* Rest of class omitted */
}
```

Goody out!

Evolved program computing $x^4 + x^3 + x^2 + x$:

```
class SimpleSymbolicRegression_0_7199 {
  Number simpleRegression(Number num) {
    double d = num.doubleValue();
    d = num.doubleValue();
    double d1 = d; d = Double.valueOf(d + d * d *
          num.doubleValue()).doubleValue();
    return Double.valueOf(d +
          (d = num.doubleValue()) * num.doubleValue());
  }

  /* Rest of class unchanged */
}
```

. . . and out

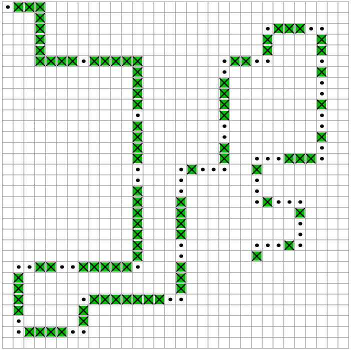
Evolved program computing $x^9 + x^8 + \cdots + x^2 + x$**:**

```
Number simpleRegression(Number num) {
  double d = num.doubleValue();
  return Double.valueOf(d + (d * (d * (d +
      ((d = num.doubleValue()) +
        (((num.doubleValue() * (d = d) + d) *
          d + d) * d + d) * d)
      * d) + d) + d) * d);
}
```

. . . and out

Evolved program solving Artificial Ant problem:

```
void step() {
  if (foodAhead()) {
    move(); right();
  }
  else {
    right(); right();
    if (foodAhead())
      left();
    else {
      right(); move();
      left();
    }
    left(); left();
  }
}
```



Interlude: Important Note

We're not simply solving Ants or Spirals again (yawn).

We're taking a **bad program** and **improving** it, outputting in the end a **perfect** program.

Thus, we're solving one of the most complex problems known to man. Indeed, we're solving a problem that currently falls exclusively within the domain of humans—
machines don't do this.

. . . and out

Evolved program solving Intertwined Spirals problem:

uses sign of $\sin\left(\frac{9}{4}\pi^2\sqrt{x^2+y^2} - \tan^{-1}\frac{y}{x}\right)$

```
boolean isFirst(double x, double y) {
  double a, b, c, e;
  a = Math.hypot(x, y);  e = y;
  c = Math.atan2(y, b = x) +
    -(b = Math.atan2(a, -a))
    * (c = a + a) * (b + (c = b));
  e = -b * Math.sin(c);
  if (e < -0.0056126487018762772) {
    b = Math.atan2(a, -a);
    b = Math.atan2(a * c + b, x);  b = x;
    return false;
  }
  else
    return true;
}
```

Tree GP

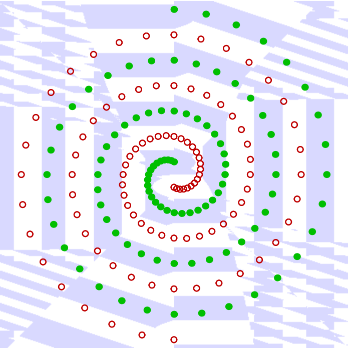
Compare with Koza's best-of-run:

```
(sin (iflte (iflte (+ Y Y) (+ X Y) (- X Y) (+ Y Y)) (* X X)
(sin (iflte (% Y Y) (% (sin (sin (% Y 0.30400002))) X) (% Y
0.30400002) (iflte (iflte (% (sin (% (% Y (+ X Y))
0.30400002)) (+ X Y)) (% X -0.10399997) (- X Y) (* (+
-0.12499994 -0.15999997) (- X Y))) 0.30400002 (sin (sin
(iflte (% (sin (% (% Y 0.30400002) 0.30400002)) (+ X Y))
(% (sin Y) Y) (sin (sin (sin (% (sin X) (+ -0.12499994
-0.15999997))))) (% (+ (+ X Y) (+ Y Y)) 0.30400002))))
(+ (+ X Y) (+ Y Y))))) (sin (iflte (iflte Y (+ X Y) (- X Y)
(+ Y Y)) (* X X) (sin (iflte (% Y Y) (% (sin (sin (% Y
0.30400002))) X) (% Y 0.30400002) (sin (sin (iflte (iflte
(sin (% (sin X) (+ -0.12499994 -0.15999997))) (% X
-0.10399997) (- X Y) (+ X Y)) (sin (% (sin X) (+
-0.12499994 -0.15999997))) (sin (sin (% (sin X) (+
-0.12499994 -0.15999997)))) (+ (+ X Y) (+ Y Y))))))) (%
Y 0.30400002)))))
```

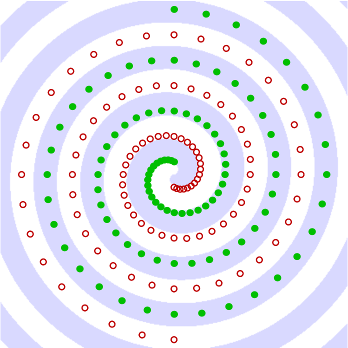
Tree GP vs. FINCH

And compare the phenotypes:

Koza's:



Ours:



. . . and out

Evolved program computing sum of values in array: (loop solution)

```
int sumlist(int list[]) {
  int sum  = 0;
  int size = list.length;
  for (int tmp = 0; tmp < list.length; tmp++) {
    size = tmp;
    sum = sum - (0 - list[tmp]);
  }
  return sum;
}
```

Yes, FINCH can handle loops. . .

. . . and out

Evolved program computing sum of values in array: (List solution)

```
int sumlist(List list) {
  int sum = 0;
  int size = list.size();
  for (Iterator iterator = list.iterator();
                    iterator.hasNext(); ) {
    int tmp = ((Integer) iterator.next())
                    .intValue();
    tmp = tmp + sum;
    if (tmp == list.size() + sum)
      sum = tmp;
    sum = tmp;
  }
  return sum;
}
```

Yes, FINCH can handle Java 5.0 constructs. . .

. . . and out

Evolved program computing sum of values in array: (recursive 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;
}
```

Yes, FINCH can handle recursion. . .

Enough Garbage In!

- We can turn bad (seeds) into good (programs)

- Input: **Good** program implementing sophisticated Minimax algorithm to play Tic-Tac-Toe.
- Problem: Programmer made a small, insidious, very hard-to-detect error.
- Can FINCH save the day?

- We implemented four errors:
All were easily swept away by FINCH.

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The Insidious Errors

```
int negamaxAB(TicTacToeBoard board,
      int alpha, int beta, boolean save) {
  Position[] free = getFreeCells(board);
  // utility is derived from the number of free cells left
  if (board.getWinner() != null)
    alpha = utility(board, free);
  else if (free.length == 0)
    ~~alpha = 0~~ save = false ;
  else for (Position move: free) {
    TicTacToeBoard copy = board.clone();
    copy.play(move.row(), move.col(),
                    copy.getTurn());
    int utility = - (removed) negamaxAB(copy,
                    -beta, -alpha, ~~false~~ save );
    if (utility > alpha) {
      alpha = utility;
      if (save)
        // save the move into a class instance field
        chosenMove = move;
      if ( ~~alpha >= beta~~ beta >= alpha )
        break;
    }
  }
  return alpha;
}
```

Result is Human-Competitive

(G) The result solves a problem of indisputable difficulty in its field.

- There is a widely recognized need for automatic improvement of existing software.
- Improving software is indisputably difficult (G)
  (Did anybody say 'difficult'? Merely 'difficult'?)
- No technique previously existed that allowed the automatic improvement of **unrestricted** software written in a **widely used**, real-life programming language.
- And along came FINCH. . .

Result is Human-Competitive (cont'd)

(D) The result is publishable in its own right as a new scientific result independent of the fact that the result was mechanically created.

- The evolved programs are fully functional Java programs solving hard problems.
- The FINCH system itself is of indisputable interest to the software industry at large.

Why is Result Best?

- Our work aims at one of the hardest problems known to (and created by) man: software design.

- Given the size and importance of the software industry, any step taken toward automating the programmer's task could impact society in ways far outreaching the boundaries of evolutionary computation.

Why is Result Best? (cont'd)

- Very little work within the field of search-based software engineering tackles the issue of evolving **actual** software written in **mainstream** languages.
- The work of Weimer and Forrest on automatically evolving patches to fix buggy C programs is probably the most worthy of mention.
- However, their system is currently limited to evolving small patches in predetermined source locations.
- Works when fixing bugs with known positive and negative test cases, which afford the ability to focus the search using standard software engineering techniques.

Why is Result Best? (cont'd)

- We have taken another major step forward.
- Ours is the first approach that allows viable evolution of extant, real-world software in a mainstream programming language (Java is one of the 2 most popular programming languages).
- Moreover, FINCH is not limited to Java:
  Scala, Groovy, Jython, Kawa, JavaFX Script, Clojure.

Why is Result Best? (cont'd)

- "Judiciously used, digital evolution can substantially augment the cognitive limits of human designers and can find novel (possibly counterintuitive) solutions to complex . . . system design problems."

  (Recent study by US DoD on futuristic systems)

- FINCH represents a significant step on the (long) path toward full-fledged **Darwinian Software Development**.

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1950

"I believe that in about fifty years' time it will be possible, to programme computers . . . to make them play the imitation game so well that an average interrogator will not have more than 70 per cent. chance of making the right identification after five minutes of questioning."

A. M. Turing, "Computing machinery and intelligence," Mind, 59(236), 433-460, Oct. 1950

2010

"... despite its current widespread use, there was, within living memory, equal skepticism about whether compiled code could be trusted. If a similar change of attitude to evolved code occurs over time ..."

M. Harman, "Automated patching techniques: The fix is in,"
Communications of the ACM, 53(5), 108, May 2010

2060

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Not merely **possible** but indeed **prevalent**.

Turing was wrong—will we be?

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2060 (cont'd)

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To find out, please register for GECCO 2060.

References

M. Orlov and M. Sipper. **Genetic programming in the wild: Evolving unrestricted bytecode.** Proceedings of GECCO 2009.

M. Orlov and M. Sipper. **Flight of the FINCH through the Java wilderness.** IEEE Transactions on Evolutionary Computation, 2010 (in press).