Landscape of the Triangle Program

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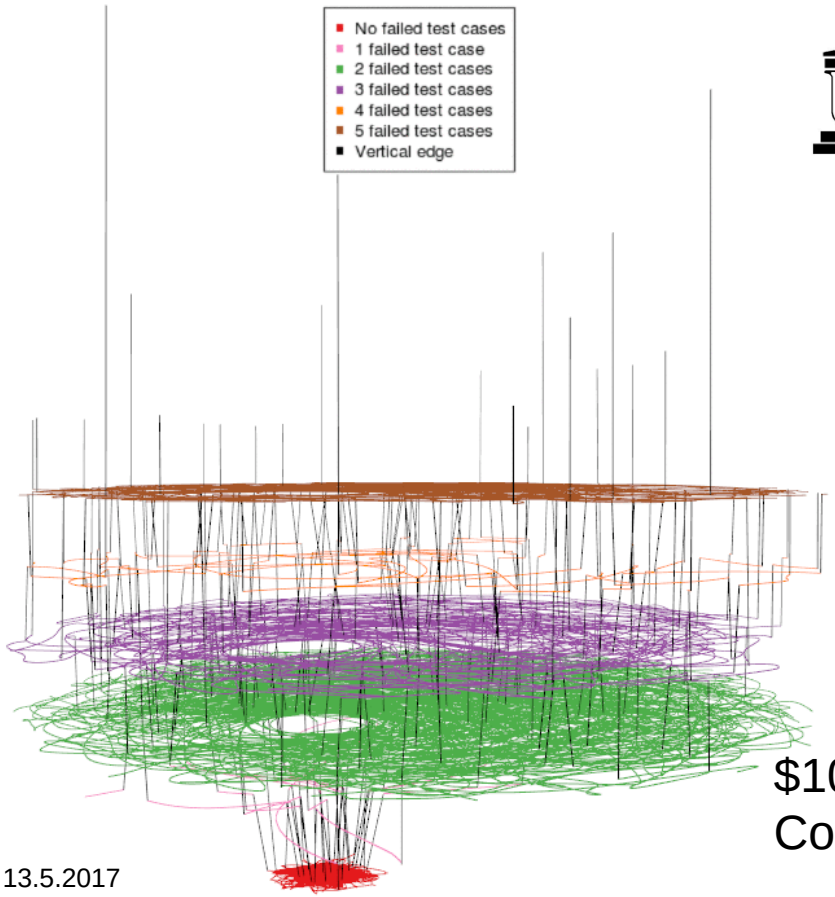
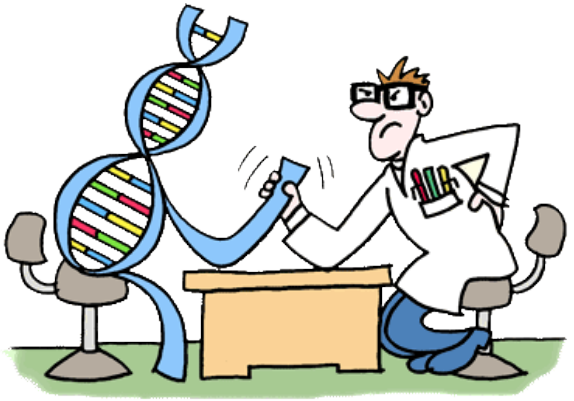


Humies
$10,000 Human-Competitive Results



Fitness Landscape of the Triangle Program

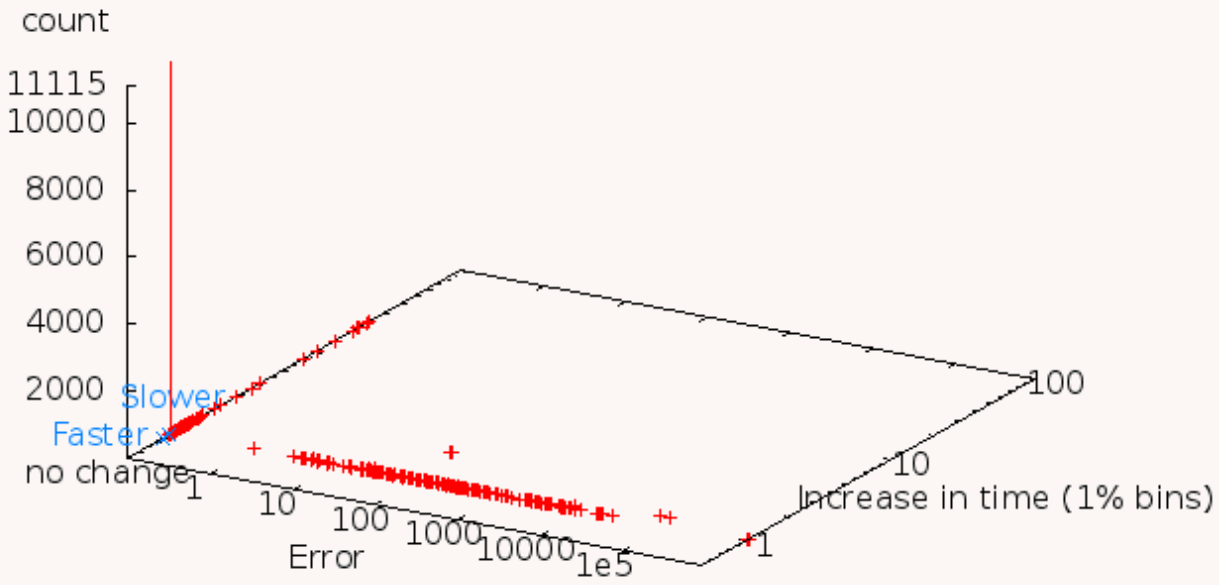
- Software is not fragile
- the Triangle program
  - ~~Two versions: binary and all C code comparisons~~
- ~~Existing analysis~~ ~~EuroGP-2017~~
- Benchmark, with no run time analysis
  - ~~Population based~~
  - ~~Hill climbing~~
  - ~~Empirical~~
- variable interaction graph
- Theory for Genetic Improvement

Software is not fragile

- Automatic bugfixing
  - suggests many repairs are easy
- Equivalent mutants in mutation testing
  - suggests many moves are neutral
- Failure of error propergation
  - suggests many moves are neutral
- Success of genetic improvement
  - software landscape is not so hard to search
- Empirical study suggests software is robust

Genetic Improvement Mutation Fitness Landscapes

14,173 Successful single code mutations to BWA on execution path



89% mutations which compile make no change to test case CS-DC'15

BWA 0.7.12-r1039
10958 lines of code

Triangle Program

- Given length of three sides what type is triangle? (Software Engineering benchmark)
- Test suite (14) covers all paths JSS 83(12) (2010) 2416–2430

  Quantified information flow 3×32 = 96 → 2 bits
- Mutate conditionals
- Fitness is number of tests that fail (minimize)
- Code and datasets online
  http://www.cs.ucl.ac.uk/staff/W.Langdon/egp2017/triangle/
- whole landscape

All 17 comparisons are potential mutation sites. Shown in red

39 lines of C code

```
int gettri(int side1, int side2, int side3)
{

    int triang ;

   if( side1 <= 0 || side2 <= 0 || side3 <= 0){
      return 4;
   }

   triang = 0;

   if(side1 == side2){
      triang = triang + 1;
   }
   if(side1 == side3){
      triang = triang + 2;
   }
   if(side2 == side3){
      triang = triang + 3;
   }

   if(triang == 0){
      if(side1 + side2 <= side3 ||
 side2 + side3 <= side1 || side1 + side3 <= side2){
         return 4;
      }
      else {
         return 1;
      }

   }

   if(triang > 3){
      return 3;
   }
   else if ( triang == 1 && side1 + side2 > side3) {
      return 2;
   }
   else if (triang == 2 && side1 + side3 > side2){
      return 2;
   }
   else if (triang == 3 && side2 + side3 > side1){
      return 2;
   }

   return 4;
}
```

testcases_oracle.txt 14 tests

Inputs are the three sides of the triangle.

Output is correct classification of the triangle.

Test suite covers all paths but is not strong enough to detect all mutations.

Dataset gives whole test equivalent fitness landscape for 2-way comparisons.

Three inputs	expected output
0 0 0	4
1 0 0	4
1 1 0	4
1 1 1	3
2 2 1	2
1 1 2	4
2 1 2	2
1 2 1	4
2 1 1	4
3 2 2	2
3 2 1	4
4 3 2	1
2 3 1	4
2 1 3	4

Variable Interactions Scalene Triangle

```
int gettri(int side1, int side2, int side3)
{

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   if( side1 <= 0 || side2 <= 0 || side3 <= 0){
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   }
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      return 2;
   }

   return 4;
}
```

Vertical control flow.
Mutations only affected by mutations before them

Simplest example
test case 12: 4,3,2
correct answer scalene(1)

Depends on loci {1,2,3,4,5,6,7} only

Variable Interactions Scalene Triangle

```
int triang ;

    if( 4 <= 0 || 3 <= 0 || 2 <= 0){
        return 4;
    }

    triang = 0;

    if(4 == 3){
        triang = triang + 1;
    }
    if(4 == 2){
        triang = triang + 2;
    }
    if(3 == 2){
        triang = triang + 3;
    }

    if(triang == 0) return 1;
```

Vertical control flow.
Mutations only affected by mutations before them

Simpliest example
test case 12: 4,3,2
correct answer scalene(1)

Depends on loci {1,2,3,4,5,6,7} only

Loci {1,2,3} only <, <= or ==
Loci {4,5} only <,<=,==
Locus 6 only <,<=,==
Locus 7 only ==
Loci {8…17} anything
$4.40798\ 10^{10}$ solutions

Problems:
Have only solved one of 14 test cases.
Does a program which passes the test cases actually work.

Variable Interactions graph

```
int triang ;

    if( 4 <= 0 || 3 <= 0 || 2 <= 0){
        return 4;
    }

    triang = 0;

    if(4 == 3){
        triang = triang + 1;
    }
    if(4 == 2){
        triang = triang + 2;
    }
    if(3 == 2){
        triang = triang + 3;
    }

    if(triang == 0) return 1;
                .
                .
```

What are the variables?
C code: side1, side2, side3, triang

But search variable are 17 loci <=, == etc.
Test cases, C code, variables and constants tell us how our search variables interact.

Simple non-deceptive building blocks.
2048 solutions:
== == == * >**==*==*

* two options

How do we use variable interaction graph?
Guide crossover.
For scalene, graph says loci 1-6 interact with 7
Build new graph for each test case?
Union too simple? Weight edges by number of test cases where they apply?

Conclusions

Triangle Program fitness landscape

- available and tractable (up to 16,926,659,444,735)
- Realistic
- Scalable (small 2^{17} and larger versions)
- Unsolved

  Next: Runtime analysis?

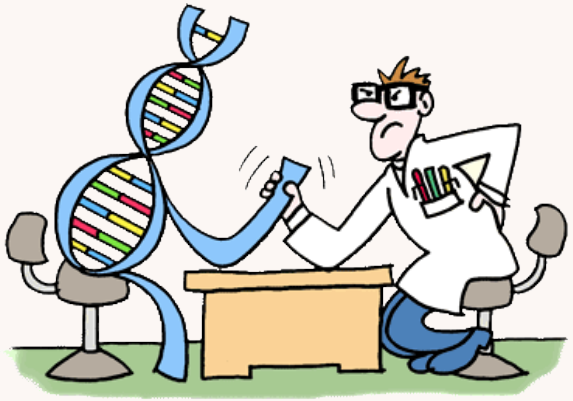
  Variable interaction graph

  Abstract features, generalise to other software?

  Other programs?

  Analyse information flow?

Humies
$10000
Human-Competitive Results



END

http://www.cs.ucl.ac.uk/staff/W.Langdon/

http://www.epsrc.ac.uk/ EPSRC

Genetic Improvement

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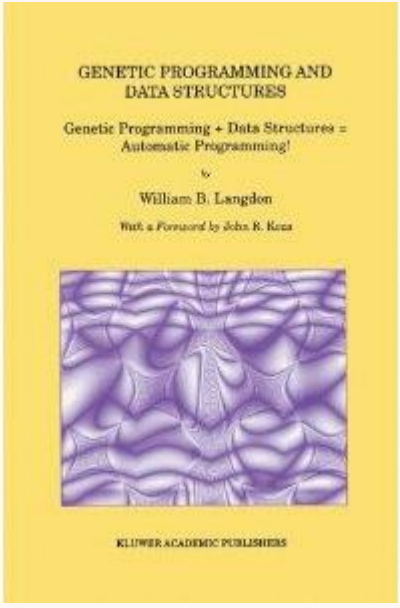
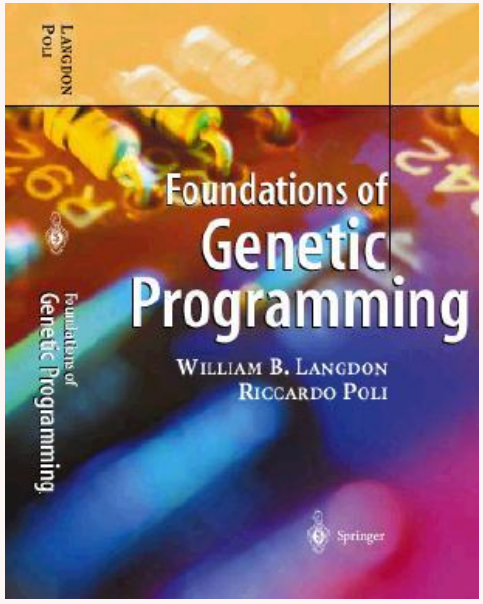
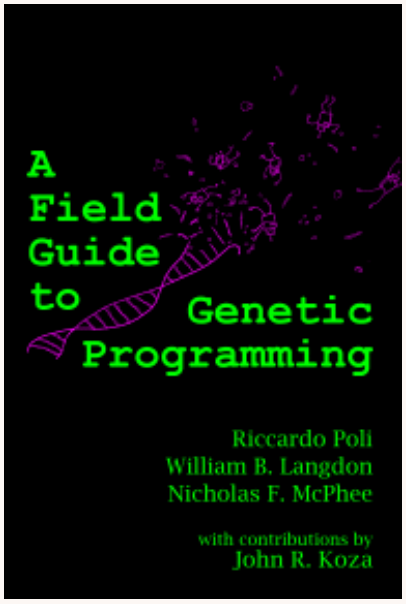
CREST

Department of Computer Science







The Genetic Programming Bibliography

http://www.cs.bham.ac.uk/~wbl/biblio/

11504 references

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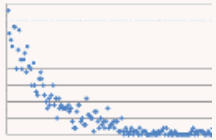

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