Genetic improvement of software: a case study

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Genetic Improvement Programming

- Automatically improving a system's behaviour with respect to some desired criteria using Genetic Programming
- The criteria for improvement can be non-functional properties of the system, such as execution time
- Relies on a set of test cases, obtained from running the original system
- Genetic Programming tries many possible options, leave software designer to choose between best

Bowtie2

Bowtie2 is one of the tools used in processing DNA sequences generated by next-generation DNA sequencing machines.

- 50 000 lines of C++
- over 50 main system modules and 67 header files
- focused GP search on 2744 heavily used lines

Results

- Wanted to trade-off performance v. speed:
  - On "1000 genome" nextgen DNA sequences
  - 70+ faster on average
  - Very small improvement in Bowtie2 results
- Only 7 lines of code changed in 3 C++ files

Motivation

Try another example

- Easy to analyse
- Popular
- (Competition)

Software chosen

Example well-known SAT solver: MiniSAT

Boolean satisfiability problem (SAT)
is the problem of deciding whether there is a variable assignment that satisfies a given propositional formula.

SAT solver Applications

- Bounded Model Checking
- Planning
- Software Verification
- Automatic Test Pattern Generation
- Combinational Equivalence Checking
- Combinatorial Interaction Testing
- and many others..

Representation of the System to be Evolved

- Source code
- Grammar used to constrain changes (syntactically valid)
  - more chance of compiling
  - thus high chance of running
  - timeouts to force termination

Representation: Move operations

- Change code by re-using existing human written code
  - Copy a line
  - Replace a line with another line from the program
  - Delete a line
- Evolve a list of changes
- Grammar rule: a line of code or a part of loop/condition (for, if, while, else)

BNF grammar

```
 <Solver_135>    ::=     "{Log_count64++;/*135*/} if" <IF_Solver_135> "  return false;\n"
<IF_Solver_135> ::=     "(!ok)"
<Solver_138>    ::=     "" <_Solver_138> "{Log_count64++;/*138*/}\n"
<_Solver_138>   ::=     "sort(ps);"
<Solver_139>    ::=     "Lit p; int i, j;\n"
<Solver_140>    ::=     "for(" <for1_Solver_140> ";" <for2_Solver_140> ";" <for3_Solver_140> ") {\n"
<for1_Solver_140>       ::=     "i = j = , p = lit_Undef"
<for2_Solver_140>       ::=     "i < ps.size()"
<for3_Solver_140>       ::=     "i++"
```

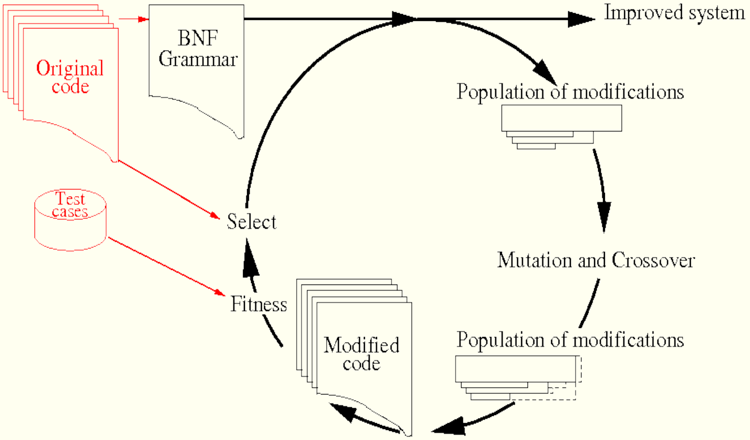
Representation: Combining moves

- Mutation: append another random change to the list
- Crossover: append lists from two parents
- Only creating a new individual shortens the list

Fitness function

- Run program and count lines used
- 2 measures:
  - Quality of answers produced (right/wrong, automatic oracle)
  - Resources used (number of lines used)

GP Improvement



MiniSAT

- SAT solver
- 16 header files, 6 C++ files (core solving algorithm in Solver.cc)
- of the 582 lines of C++ code in Solver.cc file, BNF produces 321 lines that genetic programming can manipulate (delete, replace, insert)

GP evolution parameters

- training data set size: 71
- population size: 20
- generations: 100
- 50% crossover
- 50% mutation (delete,replace,insert)
- selection (top half)
- 5 test examples, reselected every generation

Results

- around 14 hours
- around 73% compiled
- no clear winner so far..
- mainly stats and optimisations removed

SAT example

$$x_1 \vee x_2 \vee \neg x_4$$
$$\neg x_2 \vee \neg x_3$$

- x_i : a Boolean variable
- x_i, $\neg x_i$: a literal
- $\neg x_2 \vee \neg x_3$: a clause

Example

```
bool Solver::satisfied(const Clause& c) const {
   for (int i = 0; i < c.size(); i++){
       if (value(c[i]) == l_True){
           return true;
       }
   }
   return false;
   }
```

Example

```
bool Solver::satisfied(const Clause& c) const {
   for (int i = 0; ; i++){
       if (value(c[i]) == l_True){
           return true;
       }
   }
   return false;
   }
```

Research directions

- specialise test sets for GP
- include pre-processing
- change population and generation size
- try to discover historical changes using an older version of the solver

Summary

- Genetic Improvement Programming automatically improves system behaviour according to some desired critaria using GP
- Bowtie2 : 70+ runtime improvement
- MiniSAT : ?