An Unsystematic Review of Genetic Improvement

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A Systematic Study of GI

…is currently under preparation.


Justyna Petke


Mark Harman


Bill Langdon


John Woodward


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This presentation is based on a “snapshot” of this work.

Review Unmethod

1. Working list of ~ 300 papers.

2. Reduced to 150 by eliminating those I didn't *think* would be relevant to my view of GI.

3. Cherry-picked meta-papers, significant papers for my definition of significant, controversial papers.

4. Read. A lot.

5. Summary stats and observations.

Outline

1. Trends.

2. Progress in the field.

3. Challenges.

4. New Directions.

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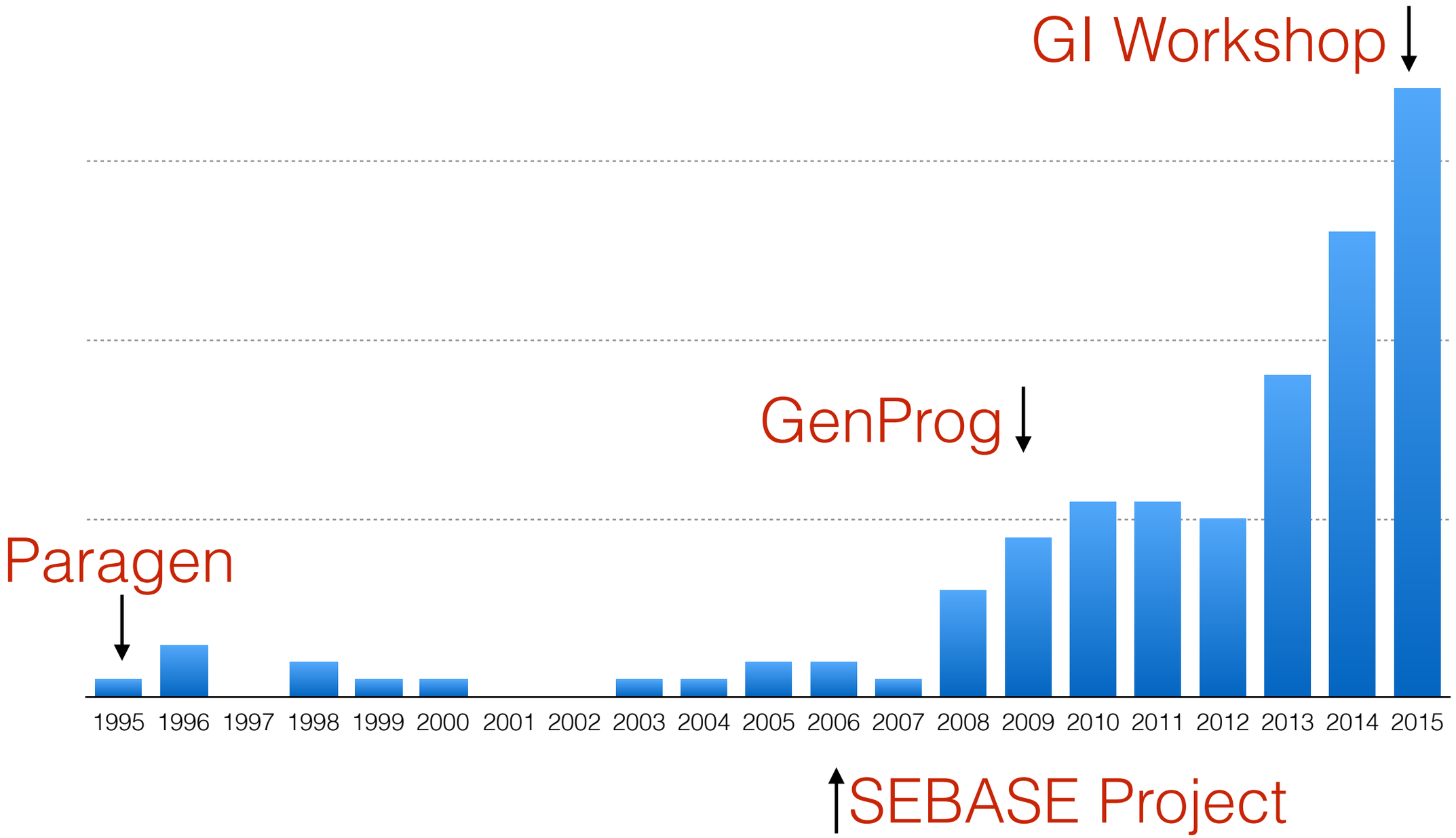
GI Papers by Year

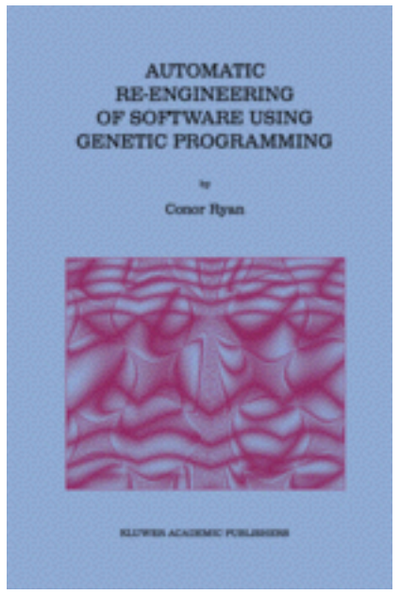


Earliest GI

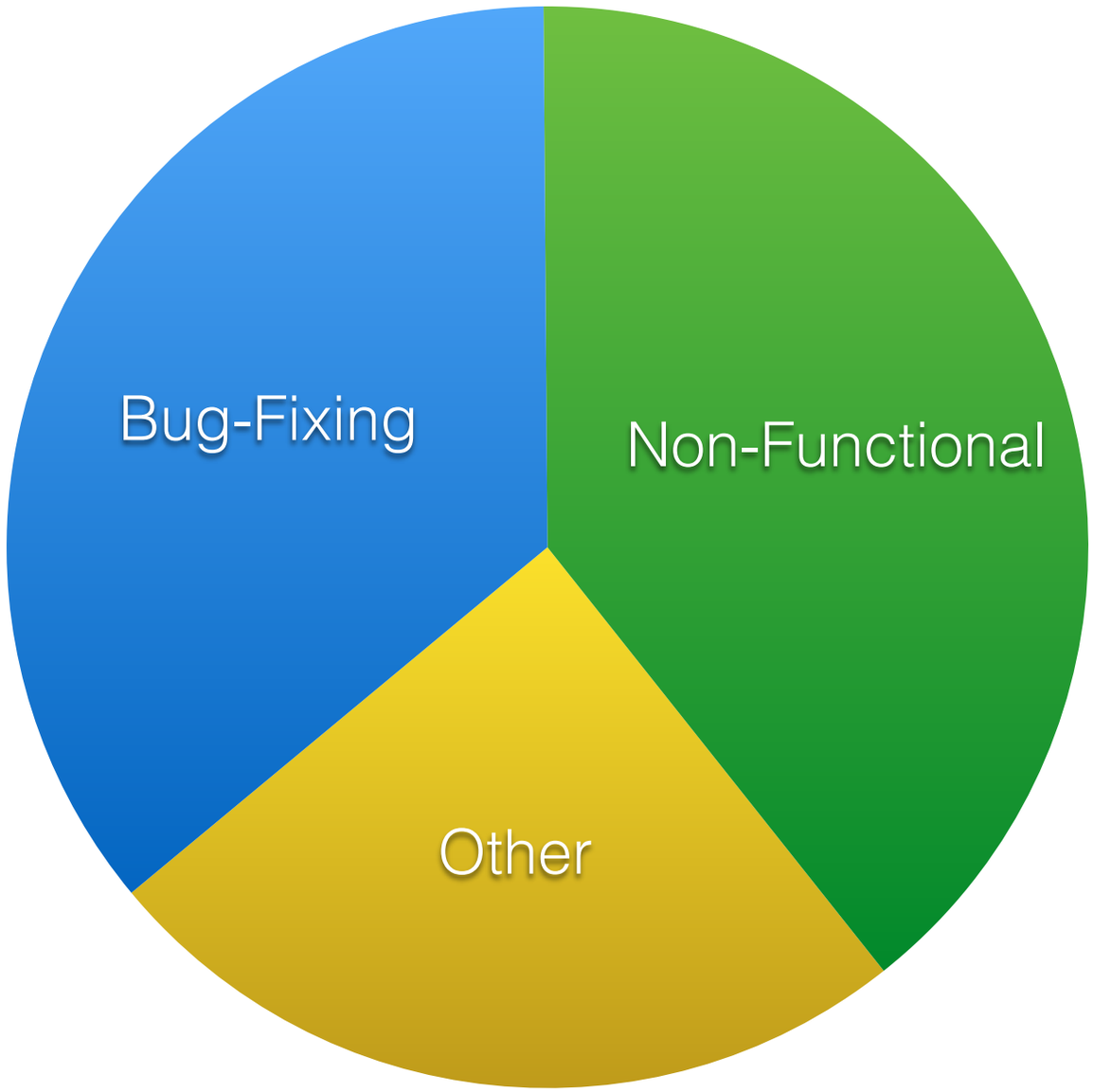
ParaGen System

Paul Walsh, Conor Ryan, ParGen1995.

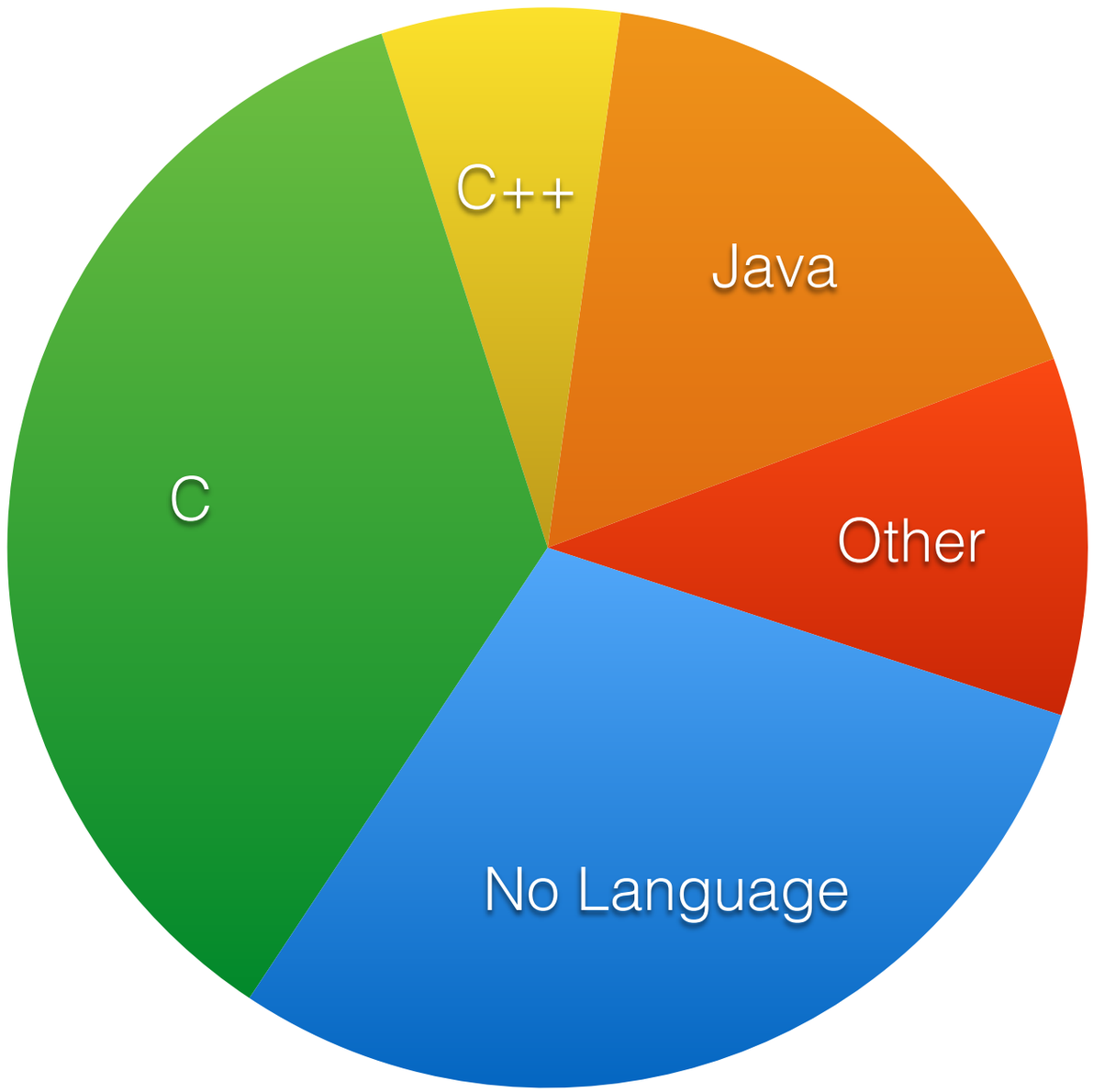
Formally verifiable results.



Bug-Fixing vs Non-Functional



Target Language



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Toy Problems

```
void sort(int* a, int length) {
 for (; 0 < (length - 1); length--) {
  for (int j = 0; j < (length - 1); j++) {
   if (a[j] > a[1 + j]) {
    k = a[j];
    a[j] = a[j + 1];
    a[1 + j] = k;
   }
  }
 }
```

Evolutionary Improvement of Programs. White et al. IEEE TEC. vol.15, no.4, pp.515-538, 2011

2009: The Zune Bug

```
void year_from_days_since_1980(int days) {
  int year = 1980;
  while (days > 365)  {
    if (isLeapYear(year)){
      if (days > 366)  {
        days -= 366;
        year += 1;
      } else {
      }
    } else {
      days -= 365;
      year += 1;
    }
   }
  printf("current year is %d\n", year);
}
```

Try input days = 366.

Drops into empty else.

A Genetic Programming Approach to Automated Software Repair. Forrest et al. GECCO 2009.

2009: The Zune Bug

```
void year_from_days_since_1980(int days) {
  int year = 1980;
  while (days > 365)  {
    if (isLeapYear(year)){
      if (days > 366)  {
        //days -= 366;          repair deletes
        year += 1;
        } else {
        }
        days -= 366;            repair inserts
    } else {
      days -= 365;
      year += 1;
    }
   }
  printf("current year is %d\n", year);
}
```

A Genetic Programming Approach to Automated Software Repair. Forrest et al. GECCO 2009.

Awards

GECCO Human-Competitive Awards

A Genetic Programming Approach to Automated Software Repair. Forrest et al. GECCO 2009. Gold award.

Using Genetic Improvement and Code Transplants to Specialize a C++ Program to a Problem Class. Petke et al. EuroGP 2014. Silver award.

A Systematic Study of Automated Program Repair: Fixing 55 out of 105 bugs for $8.00 each. Dewey-Vogt et al. ICSE 2012. Bronze award.

ICSE Distinguished Paper Award

Automatically Finding Patches Using Genetic Programming. Weimar et al. Distinguished Paper Award. ICSE 2009.

Code 'transplant' could revolutionise programming

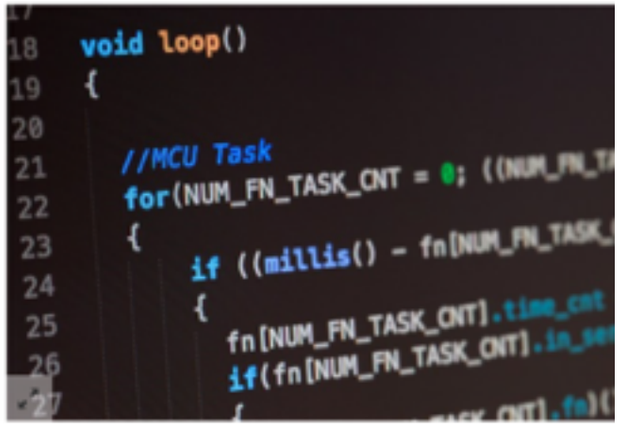
PROGRAMMING / 30 JULY 15 / by JAMES TEMPERTON

Code has been automatically "transplanted" from one piece of software to another for the first time, with researchers claiming the breakthrough could radically change how computer programs are created.

The process, demonstrated by researchers at University College London, has been likened to organ transplantation in humans. Known as MuScalpel, it works by isolating the code of a useful feature in a 'donor' program and transplanting this "organ" to the right "vein" in software lacking the feature. Almost all of the transplant is automated, with minimal human involvement.

Automated transplants of features between apps could free human programmers from tedious, manual work and make developing software faster and cheaper.

"As any programmer will attest, a large amount of programming work consists of this kind of manual transplantation work; redesigning, implementing and reinventing functionality that already exists in some form on some other system." Mark Harman, head of software systems engineering at UCL tells WIRED.co.uk. "By automating it, we make it much faster and cheaper."



Shutterstock

The research team behind MuScalpel, from left to right, Bill Langdon, Mark Harman, Alex Marginean, Justyna Petke, Earl Barr, Yue Jia *Mark Harman/UCL*

Progress: Representation

Originally, GI directly manipulated the AST as with traditional GP.

Most work uses a patch-based representation. [1, 2]

Empirical evidence that patches are more effective [3].

[1] Evolving Patches for Software Repair. Ackling et al. GECCO 2011.

[2] Automatically Finding Patches using Genetic Programming. Weimar et al. ICSE 2009.

[3] Representations and Operators for Improving Evolutionary Software Repair. Le Goues et al. GECCO 2012.

Traditional GP Search Space

$$c(d) = \begin{cases} n_0 & \text{if } d=1 \\ \max\limits_{a=0} \sum n_a \cdot c(d-1)^a & \text{if } d>1 \end{cases}$$

$c(d)$ is the number of possible trees of depth d.
d is the maximum tree depth.
n_0 the number of terminals in the function set.
n_a is the number of functions of arity a.

Patch Search Space

$$O(m^{k^2})$$

m is the number of operators.

k is the number of program nodes.

Progress: Fault Localisation

GenProg: simple statistical approach.

Reduce the value of *k* by focusing on instructions executed by the failing test cases.

Other work has used program counter sampling with Gaussian Convolution! [1]

[1] Automated Repair of Binary and Assembly Programs for Cooperating Embedded Devices. Schulte et al. SIGARCH Comput. Archit. News 41:1 pp317-328.

Applications

Targeting GPGPU.

[1] Genetically Improved CUDA C++ Software. Langdon and Harman. EuroGP 2014.

[2] Improving 3D Medical Image Registration CUDA Software with Genetic Programming. Langdon et al. GECCO 2014.

Objectives

Bug-fixing

Automatic Repair of Concurrency Bugs. Bradbury and Jalbert. SSBSE 2010.

Execution time

Evolutionary Improvement of Programs. White et al. TEC. 15:4. 2011.

Power consumption

Reducing Energy Consumption Using Genetic Improvement. Bruce et al. GECCO 2015.

Memory

A Methodology to Automatically Optimize Dynamic Memory Managers Applying Grammatical evolution. Risco-Martína et al. JSS 91, 109-123.

Diversity.

Generating Diverse Software Versions with Genetic Programming: an Experimental Study. Feldt. IEE Software 145:6. 1998.

Objectives Cont.

Parallelisation

Automatic conversion of programs from serial to parallel using Genetic Programming - The Paragen System. Walsh and Ryan. ParCo ’95.

Translation

Evolving a CUDA kernel from an nVidia template. Langdon. CEC 2010.

Simplification

Genetic programming for shader simplification. Sitthi-amorn et al. SA ’11.

Extending Functionality

Automated Software Transplantation. Barr et al. ISSTA 2015.

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Empirical Method

There has been criticism of existing work, including GenProg [1].

Biggest issue is overfitting.

Observation: Many papers focus on statistics rather than code. We need more qualitative examination of results. There is not much code in the papers!

Avoid “horse-race” [2] papers that add little of scientific value.

[1] An Analysis of Patch Plausibility and Correctness for Generate-and-Validate Patch Generation Systems. Qi et al. ISSTA 2015.

[2] A Theoretician’s Guide to the Experimental Analysis of Programs Johnson. DIMACS Implementation Challenges.2002.

Correctness

Generate and Validate Approaches have problems with overfitting.

They may also break more functionality than they fix.

Is the Cure Worse Than the Disease? Overfitting in Automated Program Repair. Smith et al. ESEC/FSE 2015.

Credibility

Also a wider issue for GP and EC.

Evolution is self-evidently a powerful general learning method.

Are programs a suitable subject? Evidence they are surprisingly robust [1], and neutral networks exist [2].

[1] Software is Not Fragile. Langdon and Petke. CS-DC 2015.

[2] Neutral Networks of Real-World Programs and their Application to Automated Software Evolution. Schultz. PhD Thesis. Uni. New Mexico, 2014.

Theory

Limited work on the theoretical side.

Some work on “mutational robustness”.

Where is the landscape analysis?

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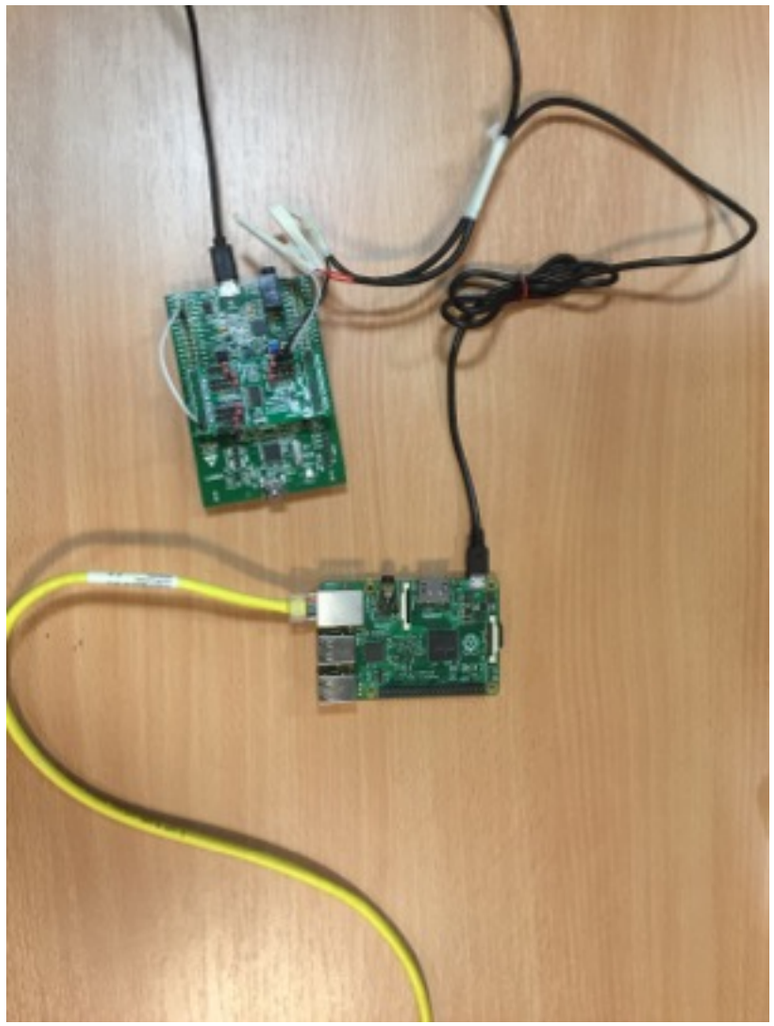
Hardware Measurement

Simulators are out, physical measurements are in.



[1] Energy Optimisation via Genetic Improvement. Bruce. GECCO 2015.

Binaries

Bug-fixing and program thinning without source code.

Interesting problem: harder to intuit whether a patch is “correct”.

Removing the Kitchen Sink from Software. Lanesborough et al. GECCO 2015.

Repairing COTS Router Firmware without Access to Source Code or Test Suites: A Case Study in Evolutionary Software Repair. Schulte et al. GECCO 2015.

Automatic Error Elimination by Horizontal Code Transfer Across Multiple Applications. Sadironglou-Douskos et al. PLDI 2015.

Deep Parameter Optimisation

Optimise parameters within code rather than code itself: thus possess an oracle.

Use mutation testing to determine impact of parameters.

Transform non-functional properties. Target key components, e.g. malloc [1].

Also a suitable target for Amortised Optimisation. [2]

[1] Deep Parameter Optimisation. Wu et al. GECCO 2015.

[2] Amortised Optimisation of Non-functional Properties in Production Environments. Yoo. SSBSE 2015.

Code Transplantation

Extend functionality of existing code by importing features from other codebases.

Process of locating a transplantation point; extracting relevant code; finding correct bindings; minimisation; passing regression tests.

Automated Software Transplantation. Barr et al. ISSTA 2015.

Semantic Search

Index and search large code repositories: it's about existing code.

Find patches with similar semantics expressed in SMT.

Much higher success rate in producing repairs that generalise.

Repairing Programs with Semantic Code Search. Ke et al. ASE 2015.

Summary

We’re at a crucial juncture for GI Research.

We must address empirical method problems.

Solid theory or systematic empirical methods required. Qualitative, explanatory, evidence is key.

Wide range of possible avenues for work: many circumvent objections and address challenging problems.

Call For Papers

The Second International Genetic Improvement Workshop (GI-2016) will be held in **Denver, Colorado**, during the Genetic and Evolutionary Computation Conference (GECCO-2016).

Key Dates

Paper submission deadline:	**April 2, 2016**
Authors notification:	**April 19, 2106**
GECCO Conference, Denver, Colorado:	**July 20-24, 2016**

Website:
http://geneticimprovementofsoftware.com

We invite submissions that discuss recent developments in all areas of research on, and applications of, Genetic Improvement. The workshop also provides an opportunity for researchers interested in GI to exchange ideas and find out about current research directions in the field and receive guidance on the application of GI to their problem domain. Topics of interest include, but are not limited to, using genetic improvement to automatically:

- fix bugs
- improve efficiency
- decrease memory consumption
- decrease power consumption
- transplant new functionality
- specialise software