The 14th International Workshop on Genetic Improvement (GI @ ICSE 2025)

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ABSTRACT

The GI @ ICSE 2025 workshop, held 27 April, in addition to presentations, contained a keynote on the latest results on automated program generation for testing static program analyzers, which could have huge impact on GI for improving programs for APG, and a tutorial on Magpie, a widely used language independent GI tool. We summarise these, the papers, people, prizes, acknowledgements, discussions and hopes for the future.

1. INTRODUCTION

The fourteenth International Workshop on Genetic Improvement (GI 2025) was held in Ottawa, Ontario, Canada, co-located with the 47th International Conference on Software Engineering (ICSE 2025). The workshop offered both in-person and virtual participation through Zoom. Genetic Improvement (GI) is a research area focused on improving existing software using automated search techniques [51]. GI has been successfully applied to many software engineering tasks, as demonstrated by the wide range of work presented in the recent editions of the GI workshop. These include for example work on automated bug fixing [31, 32, 50, 59]; on optimisation of non-functional properties such as execution time [14, 24, 38, 58, 71], energy consumption [17], or network usage [21]; and on domain-specific context such as deep neural networks security [8], generative art [29], shoreline evolution forecasting models [1], or procedural story generation [27]. We have also observed a growing interest in work at the intersection of software improvements and large language models [70], investigating, for example, how LLMs can guide or accelerate automated software improvement or how GI techniques can be used to refine or adapt LLM-generated code [15, 33, 63]. GI research has won five "Humies" [6, 7, 34, 52, 65], prestigious cash prizes awarded for demonstrating human-competitive results at difficult-to-automate tasks. As of the workshop, the community website's GPbib-based living survey covers almost 600 GI-related work (Figure 1). As in previous editions, the workshop brought together GI researchers and enthusiasts, offering a productive space for exchanging ideas, fostering collaboration, and identifying new challenges and directions for the GI community.

2. WORKSHOP FORMAT

As per previous editions, this year's Genetic Improvement workshop was once again held as a full-day event. It took place on Sunday, April 27th, before the main ICSE 2025 conference. The complete program is available on the workshop website `http://geneticimprovementofsoftware.com/events/icse2025` as well as in the ICSE 2025 workshop proceedings [10]. GI @ ICSE 2025 featured one keynote, one tutorial, five research paper presentations, one position paper talk, and an open discussion session.

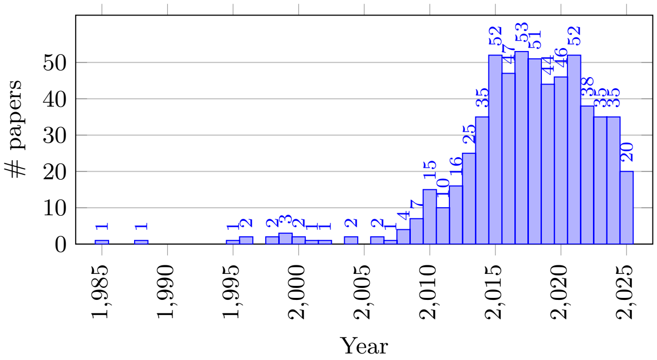
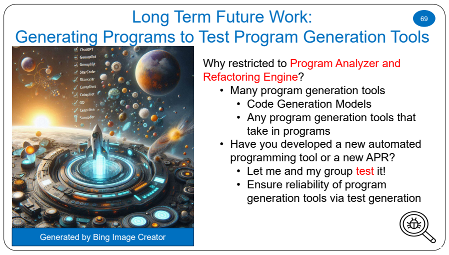


Figure 1: Publication year distribution of the 592 GI-related papers currently identified in the community website's living survey (`https://geneticimprovementofsoftware.com/learn/survey`)

Figure 2: Keynote speaker Dr. Shin Hwei Tan

Keynote Dr. Shin Hwei Tan:
Put on Your Tester Hat: Improving programs for Automated Program Generation.

This year we were treated to an invited keynote presentation by Dr. Shin Hwei Tan of Concordia University [59], Figure 2. Dr. Tan obtained her PhD degree from National University of Singapore with Abhik Roychoudhury, having previously studied for both undergraduate and masters degrees at the University of Illinois at Urbana-Champaign (USA). During her Masters degree she was co-advised by Darko Marinov and Lin Tan. Prior to joining Concordia two years ago, Dr. Tan was a lecturer in SUSTech (China). She organised the GI workshop, in 2019, when ICSE was also held in Canada (Montreal) [46], before founding the international series



Long Term Future Work:
Generating Programs to Test Program Generation Tools

Why restricted to Program Analyzer and Refactoring Engine?

- Many program generation tools
  - Code Generation Models
  - Any program generation tools that take in programs
- Have you developed a new automated programming tool or a new APR?
  - Let me and my group test it!
  - Ensure reliability of program generation tools via test generation

Figure 3: Put on Your Tester Hat, Dr. Shin Hwei Tan keynote. Genetic Improvement testing program generation tools [59].

of workshops on Automated Program Repair (APR) at ICSE in 2020. Next year she will be the general chair of the ACM's International Conference on the Foundations of Software Engineering (FSE 2026), when it will be hosted by Concordia University in Montreal.

Shin Hwei took as her title "Put on Your Tester Hat: Improving programs for Automated Program Generation", Figure 3 (see also tester's red hat in Figure 4). After a whistle stop tour through early work [53, 60–62, 64, 69], she concentrated upon automated ways to create tests to test static analysers. Like computer compilers, static analysers process computer programs. Today Artificial Intelligence (AI) is quite capable of generating small programs. However Dr. Tan proposed the clever bit was not just generating source code but also having ways to check that the source analyser was giving the right answer. I.e. having a test oracle [47]. Ways forward included metamorphic testing and comparing answers given by different static analysers. Although she noted that of the five static analysers she had tested, there were cases when they contained similar bugs. Nonetheless mutation operators which produced non-trivial semantically equivalent source code, should cause a static analyser to give the same answer as before the mutation. That is, if the outputs differ, the test has found a bug. Also production of nearly equivalent mutations may induce interesting corner-cases. These tests may cause the analyser to fail completely or it may fail to give "similar" answers.

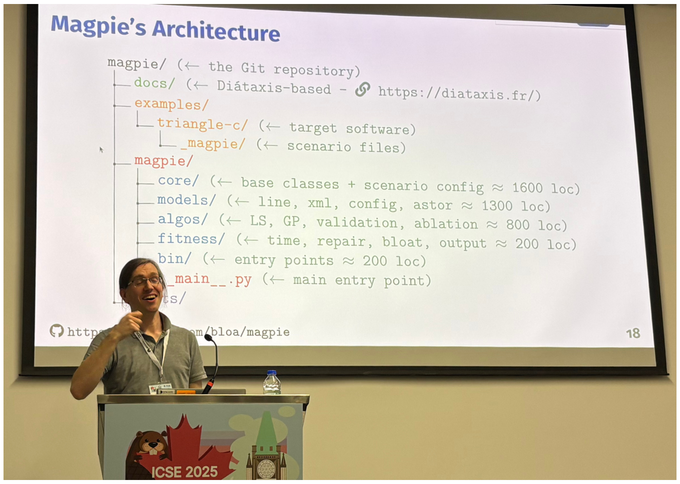
Also these ways of automatically generating source code might be good at finding bugs in source code refactoring tools.

The Q&A was joined by Prof. Roychoudhury. The discussion included possible ways to increase the tradeoff between performance and functionality. Also to what extent software engineers feel able to understand and interact with automatically generated program source code, as well as ways to ameliorate developer induced errors.

The keynote slides are available via `http://gpbib.cs.ucl.ac.uk/gi2025/gi_2025_slides/GIworkshop-keynote.pdf`

Tutorial.
Dr. Aymeric Blot (Figure 5) gave an extensive review of his Magpie system [11], tracing its development from the earlier PyGGI [3, 4] GI framework. Magpie builds upon the capabilities of PyGGI, showcasing compatibility with any programming language and support for improving both functional and non-functional aspects of software. However, Magpie also introduces novel features such as an improved user interface, the addition of parameter configuration to complement program source code manipulation, and the support for a much broader range of local search, genetic programming, and validation algorithms. During the tutorial, participants gained insights into the framework's structure, philosophy,

Figure 4: Shin Hwei Tan Keynote "Put on Your Tester Hat"



Magpie's Architecture

```
magpie/ (← the Git repository)
├─docs/ (← Diátaxis-based - 🔗 https://diataxis.fr/)
├─examples/
│ └─triangle-c/ (← target software)
│   └─_magpie/ (← scenario files)
├─magpie/
│ ├─core/ (← base classes + scenario config ≈ 1600 loc)
│ ├─models/ (← line, xml, config, astor ≈ 1300 loc)
│ ├─algos/ (← LS, GP, validation, ablation ≈ 800 loc)
│ ├─fitness/ (← time, repair, bloat, output ≈ 200 loc)
│ ├─bin/ (← entry points ≈ 200 loc)
│ └─_main__.py (← main entry point)
└─ts/
```

Figure 5: Dr. Aymeric Blot's Magpie Tutorial [9]

key components, and newest developments, whilst also engaging with practical examples. Dr. Blot concluding by outlining future directions and challenges.

Magpie is free and open source, accessible on GitHub at `https://github.com/bloa/magpie`. The tutorial slides are available via `http://www0.cs.ucl.ac.uk/staff/a.blot/files/slides/blot_gi@icse_2025.pdf`

Paper presentations. This year, the GI workshop accepted five research papers [14, 15, 40, 58, 63] and one position paper [24]. Each having received three independent reviews from the workshop's programme committee (Section 6). The authors of the accepted research papers had 20 minutes for the presentation and 10 for questions (Figures 10–14), whilst the accepted position paper had 10 minutes for the presentation and 5 minutes for questions (Figure 15).

Figure 7 shows some of the workshop participants.

VOTING AND DISCUSSIONS
VOTE
Link on Zoom: h...cs.google.com/forms/d/1H0krragGR1e4tY1mhMhGMXSU-HjdAcUs00TjW_80dyw

Figure 6: Aymeric Blot leading online and in person discussion.

Awards. Following the GI workshop tradition, the best paper award is given to researchers for their outstanding contributions to the Genetic Improvement field, and is decided based on reviews provided by the programme committee (Section 6). Similarly the best presentation award followed tradition and was decided by a vote amongst the participants of the workshop (Figure 6).

Best research paper award: "Large Language Model based Code Completion is an Effective Genetic Improvement Mutation" by Jingyuan Wang and Carol Hanna and Justyna Petke [63] (Figure 8).

Best presentation award: Dimitrios Bouras for "LLM-Assisted Crossover in Genetic Improvement of Software" [15] (Figure 9), which was delivered via the Internet from Peking University in China.

The workshop was followed by a social event along with the other ICSE 2025 workshops. Daniel Amyot persuaded the Cafe Nostalgica (Figure 16) to open especially and exclusively for ICSE on Sunday evening.

GI and LLMs:

The GI @ ICSE 2025 workshop featured two research papers that leveraged large language models (LLMs) to enhance the genetic improvement process.

LLM-Assisted Crossover [15]: This work proposed a novel LLM-based approach to the crossover operation in genetic programming. Implemented within the MAGPIE framework, the LLM-assisted crossover uses contextual information to intelligently select and combine edits from parent variants. Across seven benchmarks, it outperformed five traditional crossover methods in producing high-quality, performant, and viable program variants. Key results included an 8.5% improvement in fitness and 4.8% more viable variants on average, demonstrating the potential of LLMs to guide search more effectively.

LLM-based Masking Mutation [63]: This paper introduced a new mutation operator for GI, based on LLM code completion. Rather than replacing entire functions, this masking mutation replaces only selected statements using LLM-generated completions. Evaluated across five Java projects, the approach produced more valid, compiling, and test-passing patches than both traditional mutations and a previous LLM-based replacement operator. It also reduced response time by up to 60.7%. However, combining it with traditional mutations yielded mixed results, pointing to future work on integration strategies.

Together, these papers exemplify how LLMs can be embedded into core GI operations—mutation and crossover—demonstrating tangible benefits in patch quality, performance, and efficiency. They signal a growing research direction at the intersection of software improvement and modern AI capabilities.

3. DISCUSSION/FUTURE TOPICS

Genetic Improvement [35, 51, 67] has been successfully applied across a wide range of software engineering tasks, including automated bug fixing [48, 65], optimising non-functional properties—such as execution time [5, 25, 42], memory usage [22, 41, 56, 68], energy consumption [2, 13, 19, 20, 26], among others [1, 12, 21]—and functionality transplantation from one system to another [6, 52]. Beyond general-purpose applications, GI has also been used in domain-specific contexts, such as bioinformatics [44, 49] and generative art [28]. This is demonstrated by the wide range of work presented in the recent editions of the GI workshop.

3.1 Future: AI for program improvement

We are already seeing great interest in using the latest artificial intelligence tools in GI. We have already mentioned that two papers presented at the workshop used large language models (LLMs) [15, 63]. Indeed LLMs for GI were first presented at an earlier workshop [33]. Other early works include [18, 54, 57]. Indeed our Keynote speaker Dr. Shin Hwei Tan, thinks AI will play and increasing role in automatic testing, Figure 3. We expect researchers to continue to explore the intersection of GI and large language models. Future directions may include: enhancing explainability of GI transformations, integrating with developer tools, and improving performance predictability.

3.2 Extension of Recent Work

Following the success of GI @ ICSE 2025, the community anticipates continued collaboration and a potential workshop at ICSE 2026. We also encourage submission of extended versions of accepted papers to a future GI special issue of Springer-Nature's Automated Software Engineering journal.

4. WORKSHOP OUTCOMES

Following the success of the earlier Genetic Improvement special issues of the ASE journal, we anticipate that in future some authors of accepted papers will be invited to submit their extended work to future ASE special issues. (Special Issue editors: Oliver Krauss and Vesna Nowack) [23, 30, 36].

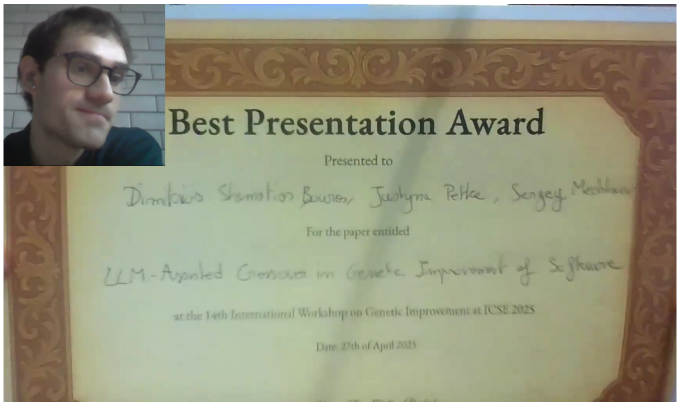
As with earlier workshops [16, 39, 43, 45, 46], there will be a short write up in the ACM SIGSOFT SEN newsletter (this document).

72
Tester Perspective: Coverage
Genetic Improvement Engine
Software Quality Standard
Maintainability
Portability
Security
Functional Suitability
ISO/IEC 25010
Reliability
Performance Efficiency
Usability
Compatibility
What are the criteria to cover?
Tester
✓ My talk m cover "Maintainability" and "Reliability"
✓ Most GI ocus on "Perfor ce Efficiency"
✓ How abo vement of oth ty aspects?
ICSE 2025
ttawa

Figure 7: Some of GI @ ICSE 2025 workshop participants: Xi Zhang, Aymeric Blot, Bill Langdon, Shin Hwei Tan, Zoe Aghababaeyan, Carol Hanna, Thanatad Songpetchmongkol, Haibo Wang.

Best Paper Award
Presented to
n Wang, Carol Hanna, and Justyna Petke
For the paper entitled
e Language Model based Code Completion
n Effective Genetic Improvement Mutation
ternational Workshop on Genetic Improvement at ICSE 2025
Date: 27th of April 2025
Me to Everyone
Link for voting for the best presentation: https://docs.google.com/forms/d/1H0krragGR1e4tY1mhMhGMXSU-HjdAcUs00TjW_80dyw
justyna to Hosts and panelists
From my experience people are not as excited about faster code than bug fixing for instance. We have issued lots of pull requests that are just left there as they don't have high priority. Even with LLMs, although people know they are expensive, people use then anyway to get the results they want (just my two cents)
I agree that GI in a way is noe more environmentally friendly and it does not require vast amounts of data, totally agree with current speaker
Who can see your messages? Recording on
To: Everyone
Type message here...
Talking: Encore Show43

Figure 8: Shin Hwei Tan presenting the Best Paper award to Carol Hanna for "Large Language Model based Code Completion is an Effective Genetic Improvement Mutation" by Jingyuan Wang and Carol Hanna and Justyna Petke [63]. Workshop organiser Aymeric Blot to left.



Best Presentation Award

Presented to

Dimitrios Stamatios Bouras, Justyna Petke, Sergey Mechtaev

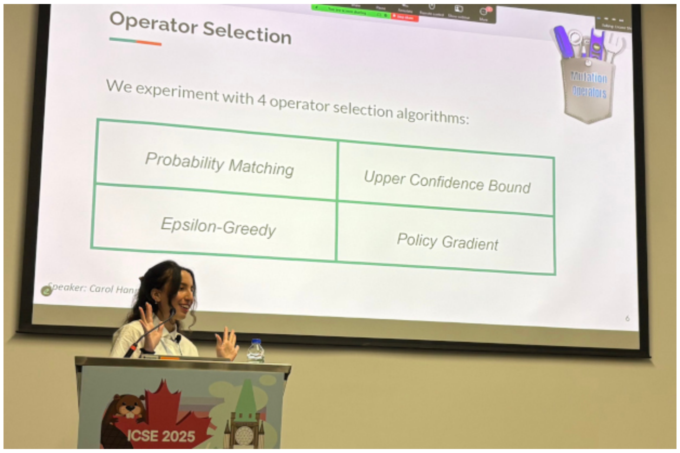
For the paper entitled

LLM-Assisted Crossover in Genetic Improvement of Software

at the 14th International Workshop on Genetic Improvement at ICSE 2025

Date: 27th of April 2025

Figure 9: Shin Hwei Tan presented the Best Presentation award via zoom to Dimitrios Stamatios Bouras for "LLM-Assisted Crossover in Genetic Improvement of Software" by Dimitrios Stamatios Bouras, Justyna Petke, and Sergey Mechtaev [15].

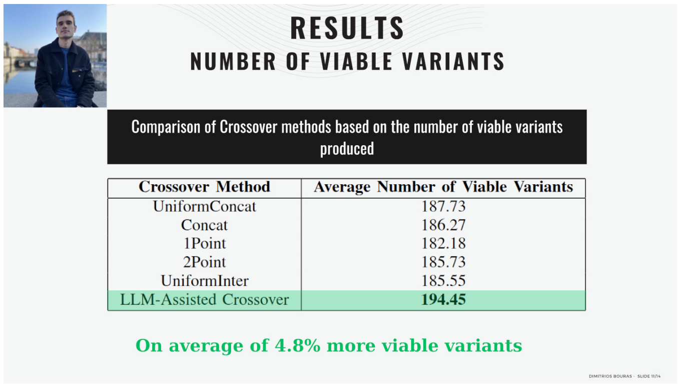


Operator Selection

We experiment with 4 operator selection algorithms:

Probability Matching	Upper Confidence Bound
Epsilon-Greedy	Policy Gradient

Figure 10: Carol Hanna presenting the Best Paper "Large Language Model based Code Completion is an Effective Genetic Improvement Mutation" by Jingyuan Wang and Carol Hanna and Justyna Petke [63].



RESULTS

NUMBER OF VIABLE VARIANTS

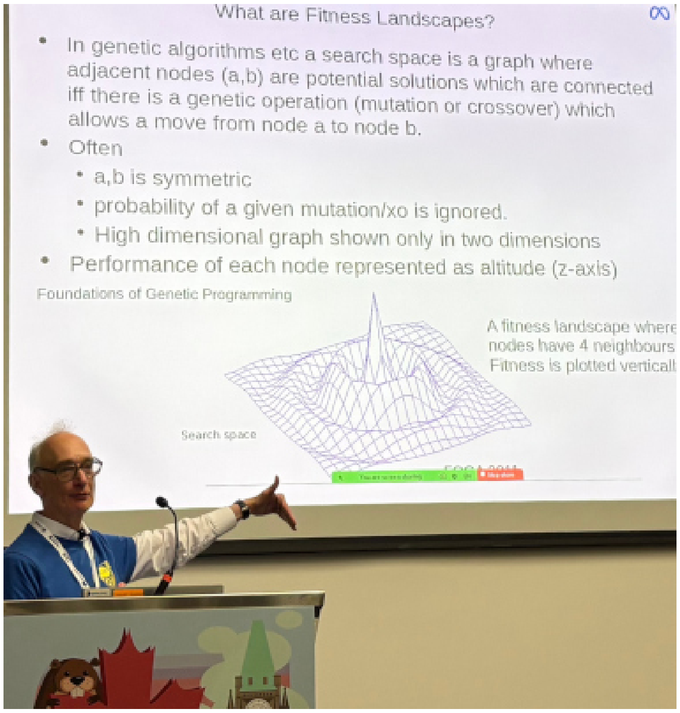
Comparison of Crossover methods based on the number of viable variants produced

Crossover Method	Average Number of Viable Variants
UniformConcat	187.73
Concat	186.27
1Point	182.18
2Point	185.73
UniformInter	185.55
LLM-Assisted Crossover	**194.45**

On average of 4.8% more viable variants

DIMITRIOS BOURAS · SLIDE 11/14

Figure 11: Dimitrios Bouras won the best presentation award: "LLM-Assisted Crossover in Genetic Improvement of Software" by Dimitrios Stamatios Bouras and Justyna Petke and Sergey Mechtaev [15].



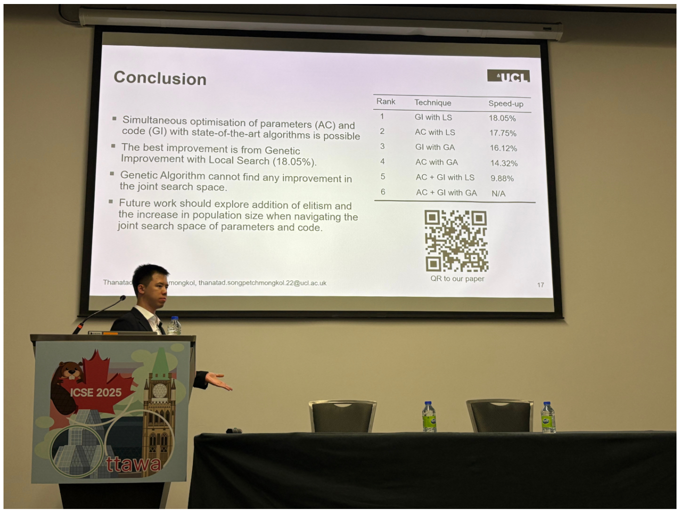
What are Fitness Landscapes?

- In genetic algorithms etc a search space is a graph where adjacent nodes (a,b) are potential solutions which are connected iff there is a genetic operation (mutation or crossover) which allows a move from node a to node b.
- Often
  - a,b is symmetric
  - probability of a given mutation/xo is ignored.
  - High dimensional graph shown only in two dimensions
- Performance of each node represented as altitude (z-axis)

Foundations of Genetic Programming

A fitness landscape where nodes have 4 neighbours Fitness is plotted verticall

Figure 12: Bill Langdon [40]



Conclusion

- Simultaneous optimisation of parameters (AC) and code (GI) with state-of-the-art algorithms is possible
- The best improvement is from Genetic Improvement with Local Search (18.05%).
- Genetic Algorithm cannot find any improvement in the joint search space.
- Future work should explore addition of elitism and the increase in population size when navigating the joint search space of parameters and code.

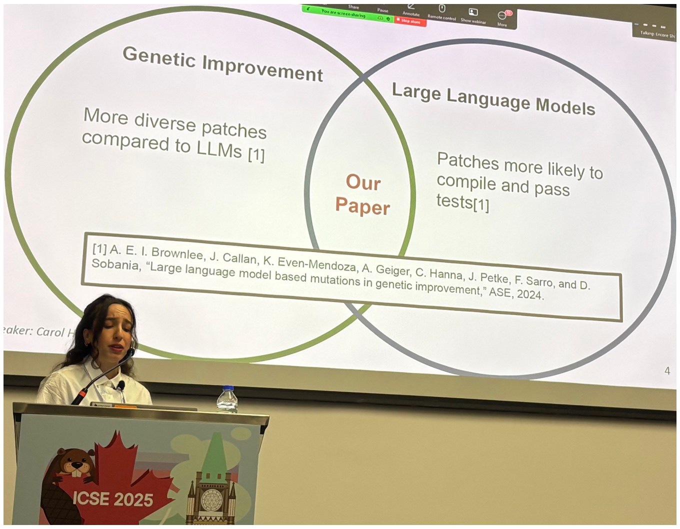
Rank	Technique	Speed-up
1	GI with LS	18.05%
2	AC with LS	17.75%
3	GI with GA	16.12%
4	AC with GA	14.32%
5	AC + GI with LS	9.88%
6	AC + GI with GA	N/A

QR to our paper

Thanatad mongkol, thanatad.songpetchmongkol.22@ucl.ac.uk

17

Figure 13: Thanatad Songpetchmongkol [58]



Genetic Improvement

More diverse patches compared to LLMs [1]

Large Language Models

Patches more likely to compile and pass tests[1]

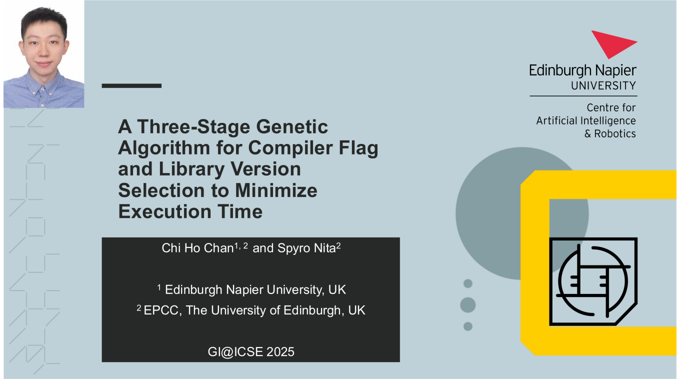
Our Paper

[1] A. E. I. Brownlee, J. Callan, K. Even-Mendoza, A. Geiger, C. Hanna, J. Petke, F. Sarro, and D. Sobania, "Large language model based mutations in genetic improvement," ASE, 2024.

eaker: Carol H

4

Figure 14: Carol Hanna presenting "Enhancing Software Runtime with Reinforcement Learning-Driven Mutation Operator Selection in Genetic Improvement" by Damien Bose, Carol Hanna and Justyna Petke [14].



Edinburgh Napier UNIVERSITY

Centre for Artificial Intelligence & Robotics

A Three-Stage Genetic Algorithm for Compiler Flag and Library Version Selection to Minimize Execution Time

Chi Ho Chan[1, 2] and Spyro Nita[2]

[1] Edinburgh Napier University, UK

[2] EPCC, The University of Edinburgh, UK

GI@ICSE 2025

Figure 15: Chi Ho Chan presented "A Three-Stage Genetic Algorithm for Compiler Flag and Library Version Selection to Minimize Execution Time" by Chi Ho Chan and Spyro Nita [24] via the Internet.

Figure 16: Social event: Cafe Nostalgica, University of Ottawa. Right: Korean Canadian dish kimchi poutine.

5. GI 2024 WORKSHOP ORGANISERS

Aymeric Blot

Vesna Nowack

Penn Faulkner Rainford

Oliver Krauss

6. GI 2025 PROGRAMME COMMITTEE

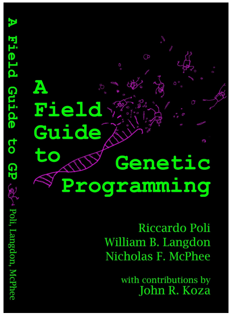
Each submission received three independent reviews from the workshop's programme committee (see Figure 17).

In addition to providing feedback to the authors and deciding which submissions to accept, the best paper award (Figure 8) was decided by the organisers using the reviewers' comments.

Acknowledgement

We would like to thank: our ICSE 2025 student volunteer, photographer "Dif" Thanatad Songpetchmongkol, and session chairs: Justyna Petke, Carol Hanna and Thanatad Songpetchmongkol. Also our thanks to Carol Hanna for additional photographs and to Daniel Amyot for organising the very enjoyable ICSE 2025 workshops' social event at Cafe Nostalgica on Sunday evening (Figure 16).

Sponsored by A Field Guide to Genetic Programming [55].



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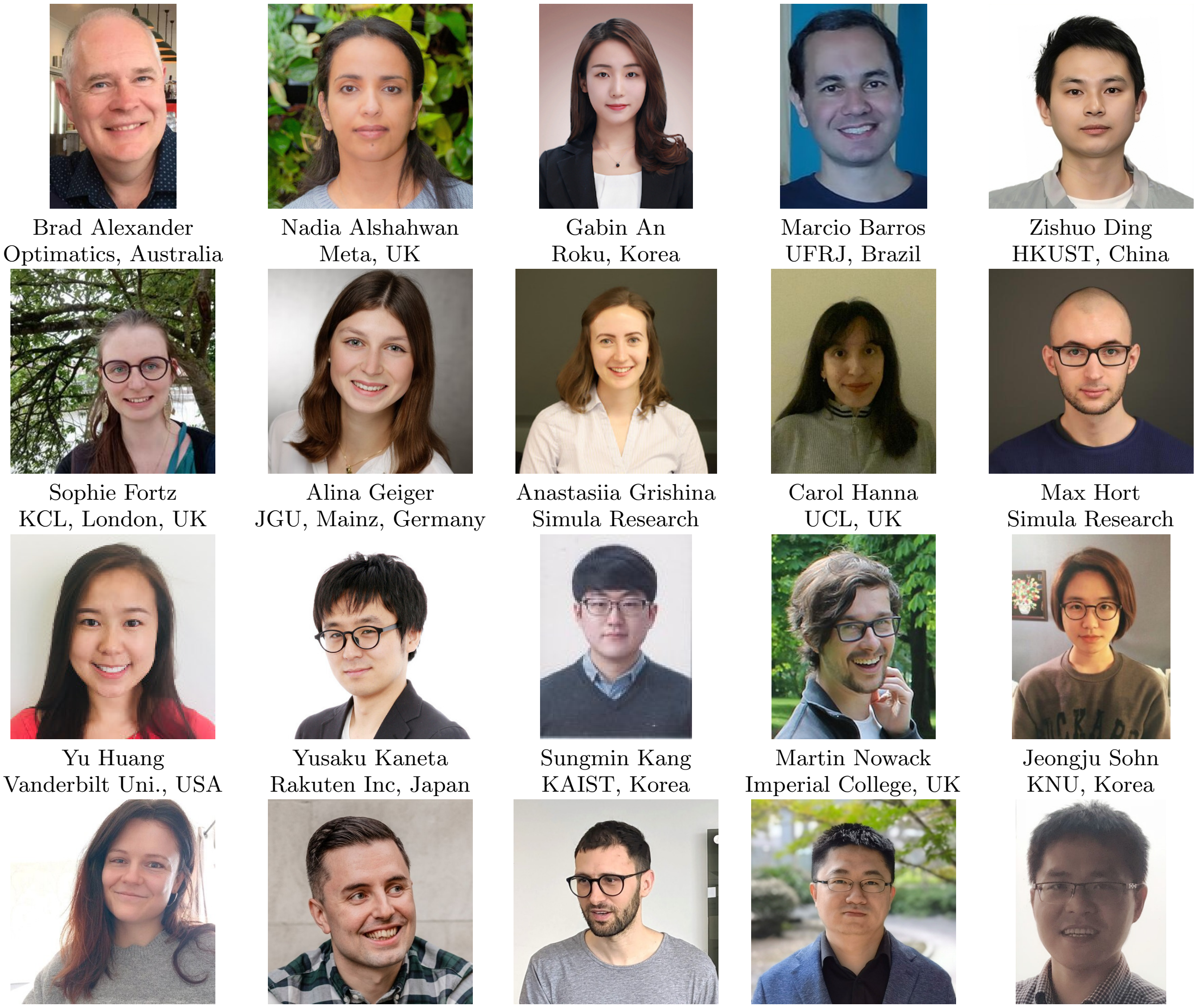

Brad Alexander
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Sophie Fortz
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Jifeng Xuan
Wuhan Uni., China

Yuan Yuan
MSU, USA

Figure 17: GI @ ICSE 2025 Reviewers

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