

Description of the work to be carried out by the student

Large language models (LLMs) have been found useful to guide evolutionary search methods by using LLM-augmented variation operators for recombination and mutation, an approach that has also been already used to leverage genetic programming (GP) [1]. Moreover, LLMs also led to the emergence of evolutionary coding agents such as AlphaEvolve [2]. Despite promising results being reported, to the best of our knowledge, a comprehensive study that compares LLM-driven to traditional GP genetic variation is still missing in the field that considers a cross-domain benchmark testing how generalizable LLM-driven approaches are, which opens new ground for research. The study also intends to consider properties that can hinder the use of LLM-driven methods such as inference time, prompting barriers, or financial costs. With the intention to perform a fair comparison of the considered modern, generative, and traditional methods, we plan to use tools for automated algorithm configuration to obtain fine-tuned methods and models. As a first step, the work will focus on testing public and free-of-charge models against the common GP search operators for tree-based and graph-based GP. A diverse benchmark that considers major problem domains of GP such as symbolic regression, logic synthesis, and program synthesis will be curated from traditional and modern benchmarks. Beyond GP benchmarks, the study will also include contemporary problems that are commonly used to evaluate LLM reasoning models in the domains of symbolic reasoning and code generation (i.e. SudokuBench, ALEBench and SWEBench). Beyond open-source and free-of-cost models, the work will also entail considering frontier models with state-of-the-art reasoning capabilities.

[1] Una-May O'Reilly, and Erik Hemberg 2024. Using Large Language Models for Evolutionary Search. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion, GECCO 2024, Melbourne, VIC, Australia, July 14-18, 2024* (pp. 973–983). ACM.

[2] Alexander Novikov, Ngan Vũ, Marvin Eisenberger, Emilien Dupont, Po-Sen Huang, Adam Zsolt Wagner, Sergey Shirobokov, Borislav Kozlovskii, Francisco J. R. Ruiz, Abbas Mehrabian, M. Pawan Kumar, Abigail See, Swarat Chaudhuri, George Holland, Alex Davies, Sebastian Nowozin, Pushmeet Kohli, and Matej Balog. (2025). AlphaEvolve: A coding agent for scientific and algorithmic discovery.

Short CV of the advisor(s)

Roman Kalkreuth

Roman Kalkreuth is an assistant professor (Akademischer Rat) at the Chair for Artificial Intelligence Methodologies (AIM) which is affiliated with RWTH Aachen University (Germany). His supervisor is Holger H. Hoos. Roman's research is located in the field of evolutionary computation and primarily focused on the analysis and development of algorithms for graph-based genetic programming.

After receiving a Master of Science in Computer Vision and Computational Intelligence with distinction (2012) from South Westphalia University of Applied Sciences, Roman started his Ph.D. study at the Department of Computer Science of the Technical University Dortmund. From 2015 until 2022, he was a research associate of the Computational Intelligence Research Group of Prof. Dr. Günter Rudolph. Roman defended his dissertation in July 2021 and then took up a postdoctoral position within Professor Rudolph's research group. From October 2022 to June 2023, he worked in the Natural Computing Research Group (NaCo) of Professor Thomas Bäck at the Leiden Institute of Advanced Computer Science (LIACS), which is a part of Leiden University. He joined Laboratoire d'Informatique de Paris 6 (LIP6) of Sorbonne University in Paris as a postdoctoral researcher from June 2023 until March of 2024. He then took up an assistant professor position at RWTH Aachen University. Roman has published work at the three evolutionary computation conferences that have the highest CORE Ranking (A): Genetic and Evolutionary Computation Conference (GECCO), Parallel Problem Solving From Nature (PPSN) and Foundations of Genetic Algorithms (FOGA). Roman is a co-founder of the GPBench initiative that aims to improve benchmarking standards in the field of genetic programming. He is the principal investigator of GPBench and TinyverseGP.

Roman's work was nominated for best paper awards at the International Conference on Evolutionary Computation Theory and Applications (ECTA) in 2019 and 2022. Roman was the social media chair for PPSN 2022 and the workshop chair for PPSN 2024. He currently supports GECCO in the framework of a two-year tenure as one of the track chairs of the real-world applications track (RWA).

Holger H. Hoos

Holger H. Hoos is an Alexander von Humboldt Professor of AI at RWTH Aachen University (Germany), Professor of Machine Learning at Universiteit Leiden (the Netherlands) and Adjunct Professor of Computer Science at the University of British Columbia (Canada), where he also holds an appointment as Faculty Associate at the Peter Wall Institute for Advanced Studies. He is a Fellow of the Association for Computing Machinery (ACM), Fellow of the Association for the Advancement of Artificial Intelligence (AAAI), Fellow of the European Association for Artificial Intelligence (EurAI), chairman of the board of the Confederation of Laboratories of Artificial Intelligence Research in Europe (CAIRNE, formerly CLAIRE), president of EurAI, past president of the Canadian Association for Artificial Intelligence (CAIAC), member of the Advisory Board and former Editor-in-Chief of the Journal of Artificial Intelligence Research (JAIR) and former leader of the VISION coordination mandate for the four European networks of centres of excellence in AI established in 2020.

Holger's research is aimed at methodological and technological advances in human-centred AI, AI for Good and AI for All. Specifically, he seeks to improve the efficiency and robustness of AI methods, to automatically increase performance and reduce resource needs, and to broaden access to and use of cutting-edge AI techniques. Overall, Holger and his group develop and study AI methods that augment rather than replace human intelligence, and that help human experts to overcome their biases and limitations. Known for his work on machine learning and optimisation methods for the automated design of high-performance algorithms and on stochastic local search, Holger has developed - and vigorously pursues - the paradigm of programming by optimisation (PbO); he is also one of the originators of the concept of automated machine learning (AutoML). Holger has a penchant for work at the boundaries between computing science and other disciplines; much of his work is inspired by and has broad impact on real-world applications.

In November 2021, Holger has been selected for an Alexander von Humboldt Professorship in AI, Germany's most highly-endowed research award, which honours its recipients for their outstanding research record and aims to facilitate long-term and groundbreaking research contributions. Supported by this award and substantial additional resources made available by the university, he

started building a new research group at RWTH Aachen University (Germany), dedicated to methodological and technological advances in human-centred AI, AI for Good and AI for All, in January 2022. He also co-chairs the board of directors of the RWTH AI Center.

Description of the research group

Chair for Artificial Intelligence Methodology (AIM) at RWTH Aachen University (Germany)

The research of AIM is dedicated to methodological and technological advances in human-centred AI. This includes research across different areas of AI, including machine learning, automated reasoning and optimisation. An important focus of our work is on the area of automated AI (including automated machine learning). AIM belongs to the RWTH Centre for Artificial Intelligence.

As part of the international ADA research group, we collaborate closely with the Leiden Institute of Advanced Computer Science (LIACS) in the Netherlands and the University of British Columbia (UBC) in Canada.

The ADA Research Group advances Artificial Intelligence (AI) methods designed to complement rather than replace human intelligence. Our research focuses on the automated design and analysis of algorithms for computationally challenging problems, combining human creativity, advanced machine learning and optimisation techniques, and high-performance computing.

ADA places particular emphasis on developing reliable, robust and efficient AI systems, with research spanning the following themes: automated machine learning (AutoML), automated data science, neural network verification and data-centric machine learning, particularly for time-series and spatio-temporal data. Our research also extends to high-impact societal, environmental and industrial applications, pursued through strong collaborative partnerships.

RWTH Chair for Artificial Intelligence Methodology: <https://www.aim.rwth-aachen.de/>

RWTH AI Centre: <https://www.ai.rwth-aachen.de/go/id/fhykx/?lidx=1>

ADA Research Group: <https://ada.liacs.nl/>

Other relevant information

RWTH – University of Excellence: Recognized as a University of Excellence, RWTH Aachen University excels in interdisciplinary approaches to science and technology. Through Germany's Excellence Strategy, the University is pioneering innovative formats in education and research that set new national and international benchmarks. This strategy is central to RWTH's vision for shaping the future of research, teaching and learning, and knowledge transfer at the university.

<https://www.rwth-aachen.de/cms/root/wir/exzellenzinitiative/~cqnwy/exzellenzuniversitaet-rwth-aachen/?lidx=1>

International Office: The International Office coordinates RWTH Aachen's international relationships, develops programs with partner universities abroad, and advises and supports international students, and students wishing to spend time abroad. The department also creates the programs for visits by international delegations.

<https://www.rwth-aachen.de/cms/root/wir/einrichtungen/verwaltung/dezernate/~pvd/internationale-hochschulbeziehungen/?lidx=1>

International Student Center: The International Student Center is dedicated to guiding both prospective and current international students toward academic success. Serving as the main point of contact within the International Office, our team assists with academic planning, visa and immigration matters, and provides support for social or academic concerns—including navigating doubts about your program of study.

<https://www.rwth-aachen.de/cms/root/studium/im-studium/internationales/~rdc/international-student-center-internati/?lidx=1>

Accommodation in Aachen

<https://www.rwth-aachen.de/cms/root/studium/vor-dem-studium/~egp/wohnen-in-aachen/?lidx=1>