Title: Large Language Model Driven Evolutionary Optimization

Organizer: Hua Xu

(Department of Computer Science, Tsinghua University, <u>xuhua@tsinghua.edu.cn</u>) **Speaker:** Hua Xu (Department of Computer Science, Tsinghua University),

Xiaodong Li (School of Computing Technologies, RMIT University), Yuan Yuan (School of Computer Science and Engineering, Beihang University), Yuan Sun (Research Center for Data Analytics and Cognition, La Trobe University), HuigenYe (Department of Computer Science, Tsinghua University)

Short Introduction

Evolutionary optimization has been widely used to solve complex problems, but traditional evolutionary algorithms often face challenges such as cold starts and inefficiency in find ing solutions. With the advancement of machine learning, learning-based evolutionary optim ization has become a hot research topic at the intersection of machine learning and evolut ionary computation. These approaches can extract useful feature representations from optim ization problems, enabling the prediction of near-optimal solutions, reducing problem dime nsionality, and leveraging knowledge gained from training data to guide the search proces s, ultimately improving the efficiency and effectiveness of the optimization. However, the se methods typically require large amounts of training data and are often limited to solvi ng specific types of problems and lacking generalizability. The emergence of large languag e models (LLMs) has provided new opportunities in this space. Pre-trained on vast amounts of data, LLMs contain a wealth of knowledge and can be fine-tuned with minimal examples to explore and generate effective heuristic algorithms for evolutionary optimization in a tar geted manner.

In recent years, evolutionary optimization guided by large language models has become a ma jor trend in the development of intelligent, learning-based optimization algorithms. This tutorial will present the latest research development in five key areas of this evolving f ield:

- 1. An overview of intelligent evolutionary optimization, focusing on the transition fr om deep learning to large language models.
- **2**. Evolutionary optimization enhanced by machine learning, highlighting the integration n of classical machine learning techniques to improve optimization algorithms.
- **3**. Business optimization and problem formulation using large language models, focusing on how LLMs reduce human intervention in business optimization problems.
- Evolutionary optimization guided by large language models, emphasizing the use of L LMs in generating effective heuristic operators for large-scale combinatorial optim ization problems.
- **5**. Optimization data generators and benchmark datasets, illustrated with examples from mixed integer linear programming (MILP) problems.

Outline of the Tutorial

The tutorial will cover the following key topics over two hours:

Overview: Intelligent Evolutionary Optimization - Guided by Deep Learning and Larg e Language Models (15 minutes)

Speaker: Hua Xu, Tsinghua University

This section will provide a comprehensive introduction to the field of intelligent evolutionary optimization, highlighting the transition from deep learning to large language models in guiding optimization processes. The focus will be on how LLMs in fluence the creation of heuristic algorithms and their application in various optim ization domains.

Evolutionary Optimization Enhanced by Machine Learning (25 minutes) Speaker: Xiaodong Li, RMIT University

This section will explore how classical machine learning techniques, such as decisi on trees, support vector machines, and deep learning, have been integrated into evo lutionary optimization. Xiaodong Li will discuss the key challenges and opportuniti es in using machine learning to enhance traditional evolutionary algorithms, and ho w these approaches can be applied to real-world large-scale optimization problems.

3. Business Optimization and Problem Formulation Using Large Language Models (25 minu tes)

Speaker: Yuan Sun, La Trobe University

Business optimization often requires complex problem formulations, traditionally re liant on human expertise. This section will discuss how large language models (LLM s) can minimize human intervention in business optimization problem formulation. It will cover techniques for fine-tuning LLMs for specific tasks, modularization to ha ndle token limitations, and metrics for assessing problem formulations. Examples fr om production scheduling and other business optimization problems will be presente d.

Evolutionary Optimization Guided by Large Models (25 minutes) Speaker: Huigen Ye, Tsinghua University

This section will discuss the latest advancements in using large language models (L LMs) to guide the development of heuristic algorithms for solving large-scale combinatorial optimization problems. The focus will be on how LLMs can be leveraged to g enerate effective heuristic operators, enhancing both the efficiency and quality of solutions. Additionally, we will provide a live demo with visualizations and share the code for an intelligent agent that combines Evolutionary Computation (EC) with LLMs.

5. Test Case Generation for Heuristic Algorithms Using Large Language Models (20 minu tes)

Speaker: Yuan Yuan, Beihang University

This section will focus on how LLMs can be used to generate test cases to evaluate the performance of heuristic algorithms. Yuan Yuan will introduce the "TestChain" f ramework, which uses a multi-agent approach to decouple the generation of test inpu ts and outputs, significantly improving the accuracy of test case generation. This part will showcase the experimental results from business optimization problems and discuss how this framework can improve algorithm testing.

6. Interactive Session and Discussion (15 minutes)

An open discussion where participants can ask questions, share insights, and discus s challenges and future directions in the field of LLM-driven evolutionary optimiza tion. The speakers will engage with the audience, offering guidance and addressing specific topics of interest.

Level of the Tutorial

Advanced

Expected Length of the Tutorial

Two hours

Bios of Presenters

1. Hua Xu

Affiliation: Department of Computer Science, Tsinghua University Email: [xuhua@tsinghua.edu.cn]

Short Bio:

Hua Xu is a tenured associate professor in the Department of Computer Science at Ts inghua University. His research focuses on intelligent optimization and human-machi ne interaction in AI. He has published over 80 papers in top international conferen ces and high-impact journals, accumulating more than 8000 Google Scholar citations and 2000 SCI citations. Dr. Xu has authored several influential books, including *In telligent Evolutionary Optimization* (Elsevier, 2024), and holds 36 granted patents and 26 software copyrights. His contributions have earned him prestigious awards, s uch as the National Science and Technology Progress Award (Second Class) and the Be ijing Science and Technology Award (First Class). He serves as the editor-in-chief of *Intelligent Systems with Applications* and associate editor-in-chief of *Expert Sy stems with Applications*, and is actively involved in several national AI research i nitiatives.

2. Xiaodong Li

Affiliation: School of Computing Technologies, RMIT University Email: [xiaodong.li@rmit.edu.au]

Short Bio:

Xiaodong Li received PhD in Artificial Intelligence from University of Otago, Duned in, New Zealand. He is a Professor in Artificial Intelligence currently with the Sc hool of Computing Technologies, RMIT University, Melbourne, Australia. His research interests include machine learning, evolutionary computation, data mining/analytic s, multiobjective optimization, multimodal optimization, large-scale optimization, deep learning, math-heuristic methods, and swarm intelligence. He served as an Asso ciate Editor of journals including IEEE Transactions on Evolutionary Computation, S warm Intelligence (Springer), and International Journal of Swarm Intelligence Resea rch. He is a founding member of IEEE CIS Task Force on Swarm Intelligence, a former vice-chair of IEEE Task Force on Multi-modal Optimization, and a former chair of IE EE CIS Task Force on Large Scale Global Optimization. He is the recipient of 2013 A CM SIGEVO Impact Award and 2017 IEEE CIS "IEEE Transactions on Evolutionary Computa tion Outstanding Paper Award". His h-index is 62, with a total number of citations 17000+ (according to Google Scholar). He is an IEEE Fellow. He is the general chair for GECC02024.

3. Yuan Yuan

Affiliation: School of Computer Science and Engineering, Beihang University Email: [yuan21@buaa.edu.cn]

Short Bio:

Yuan Yuan is a Professor and PhD Supervisor who received his Ph.D. from Tsinghua Un iversity in 2015. He has held postdoctoral research positions at Nanyang Technologi cal University and Michigan State University and was selected for China's National Young Top Talent Program in 2020. His research focuses on computational intelligenc e, machine learning, intelligent software engineering, and multi-objective optimiza tion. He has published over 10 first-author papers in leading journals and conferen ces, including *IEEE TSE, IEEE TEVC*, and *AIJ*, with more than 3200 citations on Googl e Scholar. Dr. Yuan has received several awards, including the First Prize of the C hina Federation of Logistics & Purchasing Technological Invention Award. He serves as an Associate Editor for *IEEE TETCI* and has been a guest editor for several top i nternational journals. Additionally, he has chaired and served on the program committees of major conferences such as ACM GECCO, IEEE CEC, and IJCAI.

4. Yuan Sun

Affiliation: Research Center for Data Analytics and Cognition, La Trobe University Email: [yuan.sun@latrobe.edu.au]

Short Bio:

Yuan Sun is a Lecturer in Business Analytics and Artificial Intelligence at La Trob e University, Melbourne. His research focuses on artificial intelligence, machine l earning, and optimization, with a particular emphasis on using machine learning to solve large-scale combinatorial optimization problems. Yuan was among the first to develop machine learning-based methods for problem reduction and to propose novel t echniques for integrating machine learning with traditional optimization algorithm s. His work has been published in top-tier journals such as *IEEE Transactions on Pa ttern Analysis and Machine Intelligence*, and presented at leading AI conferences li ke ICML. He has served as the Hybridization Chair for GECCO 2024 and is a regular p rogram committee member for conferences including AAAI, NeurIPS, ICLR, and ICML, as well as a reviewer for prestigious journals like the *European Journal of Operationa 1 Research* and *IEEE Transactions on Evolutionary Computation*.

5. Huigen Ye

Affiliation: Department of Computer Science, Tsinghua University Email: [yhg23@mails.tsinghua.edu.cn] Short Bio:

Huigen Ye is a Ph.D. student at Tsinghua University, focusing on applying machine 1 earning to accelerate large-scale optimization, particularly in mixed-integer progr amming. He has published papers in top conferences such as ICML, ICLR and AAAI. He is actively involved in academic service, serving as a reviewer for conferences lik e AISTATS, NeurIPS and ICLR.