# **Evolutionary Machine Learning for Combinatorial Optimisation**

## **GECCO 2024 Tutorial**

Yi Mei, Associate Professor, Victoria University of Wellington, [yi.mei@ecs.vuw.ac.nz](mailto:yi.mei@ecs.vuw.ac.nz)

Guenther Raidl, Professor, TU Wien, [raidl@ac.tuwien.ac.at](mailto:raidl@ac.tuwien.ac.at)

### **Description**

*(Description of the tutorial scope and content; this field will also be displayed on the website as the default description for your tutorial if it is accepted.)*

Combinatorial optimisation is a very important research area with many real-world applications such as scheduling, vehicle routing, cloud resource allocation, supply chain management, logistics and transport. Most combinatorial optimisation problems are NP-hard, making it challenging to design effective algorithms to solve them to optimality. There have been a variety of traditional solution-optimisation methods proposed for combinatorial optimisation, including exact methods (e.g., mathematical programming), heuristics and meta-heuristics. However, they mainly obtain solutions to a specific problem instance. It requires a lot of trial and error and extensive domain expertise to design an effective and efficient method for each different problem instance encountered in the real world.

In recent years, machine learning has emerged to be a promising paradigm for solving combinatorial optimisation problems. First, machine learning can design combinatorial optimisation algorithms *automatically* by searching for algorithms/heuristics rather than solutions, and the learned algorithms/heuristics can be generalised to future unseen problem instances to obtain high-quality solutions. This can great reduce the reliance on human expertise and time to manually design effective algorithms. Second, machine learning can learn decision-making policies for dynamic combinatorial optimisation problems (e.g., dispatching rules for dynamic scheduling), which can achieve both effectiveness and efficiency simultaneously. Third, machine learning may discover new design patterns and knowledge that can further improve the algorithm design for solving complex combinatorial optimisation problems.

Evolutionary machine learning approaches have been wide used for automatically designing combinatorial optimisation algorithms. It has several advantages over other machine learning techniques, including gradient-free and population-based search that facilitates multi-objective learning. In this tutorial, we will introduce how evolutionary machine learning can be used for solving combinatorial optimisation, including basic design issues and some case studies.

The outline of this 110-minute tutorial will be organised as follows.

1. Introduction and Background [10 mins]
   1. Combinatorial Optimisation: Problems and Methods
   2. Machine Learning
   3. Evolutionary Computation
2. Machine Learning for Combinatorial Optimisation [20 mins] (borrow from tutorials about ML4CO)
   1. Learning to Construct Solutions
   2. Learning to Optimise
3. Evolutionary Machine Learning for Combinatorial Optimisation [70 mins]
   1. Overall Framework
   2. Basic Design Issues
      1. Individual Encoding (Search Space Definition)
      2. Fitness Function (Training Dataset, Performance Metrics, …)
      3. Search Process (Genetic Operators, Speedup by Surrogate, …)
      4. Generalisation
      5. Knowledge Transfer and Multitask Optimisation
      6. Interpretability
   3. Case Studies
      1. GP to learn variable ordering heuristics in constraint programming
      2. GP to learn dispatching rules for dynamic scheduling
      3. GP to learn ambulance dispatching policies (with demo)
      4. GA to learn operators in local search-based framework (selection hyper-heuristics) for VRP
      5. …
   4. Another Perspective: ML-assisted EC algorithms for Combinatorial Optimisation
      1. Automatic Algorithm Configuration/Parameter Tuning (IRACE)
      2. Adaptive Operator Selection
      3. Grammar-guided GP to design EAs
4. Challenges and Future Directions [10 mins]

### **Expected Number of Participants**

100

### **Potential Audience**

*(A description of who might be interested in the tutorial.)*

The following groups of audience might be interested in the tutorial.

* **Researchers in combinatorial optimisation**: they will find a new emerging pathway that can design effective combinatorial optimisation algorithms more easily.
* **Researchers in evolutionary computation**: they will find a different research direction to apply evolutionary computation to complex real-world (combinatorial) optimisation problems.
* **Researchers in machine learning**: they will find a non-mainstream population-based gradient-free machine learning paradigm that can effectively applied to solve complex real-world problems.
* **Real-world practitioners**: they will find a new type of techniques to help solve their practical problems (e.g., scheduling, management, decision-making under uncertainty) more easily.

### **Activities**

*([Highly encouraged] A description of any interactive activity or demo planned within the tutorial presentation.)*

We will have the following activities:

* We will show an interactive demo in some case studies, e.g., GP to learn the ambulance dispatching policies.
* We will show a demo to explain how a policy works during the vehicle dispatch process of a vehicle routing problem.

### **Previous History**

*(If this tutorial was held in a different venue or is a modification of another tutorial, please indicate the venue and/or the changes.)*

This is the first time that we propose this tutorial.

### **Other Info**

*(Any other relevant information.)*