Genetic Programming and Machine Learning for Scheduling

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Abstract:

Scheduling is an important optimisation problem that reflects the practical and challenging issues in real-world scheduling applications such as order picking in warehouses, the manufacturing industry and grid/cloud computing. Job shop scheduling (JSS) is a typical scheduling problem, which covers a full range of topics and tasks including static JSS, dynamic JSS, flexible JSS, dynamic flexible JSS, from basic research to a huge number of real-world industrial applications. With recent technological advances in internet-of-things, artificial intelligence, and automation, modern production systems are digitalized and more flexible, and production environments can be monitored and diagnosed in real-time. Scheduling in such dynamic and complex environments is challenging since scheduling needs to be more efficient and reactive, and scheduling decisions have to incorporate dynamic information and uncertainty.

Instead of manually designing scheduling heuristics and algorithms for each problem, we can use machine learning and hyper-heuristics to automatically learn effective scheduling heuristics from low-level heuristics, characteristics of scheduling problems, and dynamic information from production environments. Among the techniques studied and applied within the research field of JSS, genetic programming (GP), a powerful evolutionary machine learning technique, has been successfully used to learn scheduling heuristics for JSS, especially for dynamic JSS. This automated design approach can significantly reduce the time required to develop solution methods by domain experts and increase the chance of discovering novel and effective scheduling heuristics.

Although GP has shown its advantage in learning scheduling heuristics for JSS, GP still has several limitations for handling JSS such as high computational cost and large search space. In addition, most of existing studies focus mainly on single JSS task optimization, the multiple tasks solving ability of GP has not been explored.

This tutorial will provide a comprehensive introduction to evolutionary machine learning techniques for JSS. This tutorial will cover different types of (advanced) evolutionary machine learning approaches for JSS. From this tutorial, you are expected to get familiar with evolutionary machine learning in four aspects. First, you will learn the definition of hyper-heuristic learning with a comparison of heuristic learning. Second, the details of JSS (e.g., static, dynamic, flexible JSS) will be given. Third, how to use GP as hyper-heuristic approaches to learn heuristics for JSS will be introduced with examples. Last, this tutorial will show how to use advanced machine learning techniques such as feature selection, surrogate and multitask learning with GP to JSS. All the techniques mentioned will be introduced with promising results.

Outline of Tutorial Structure:

This tutorial contains seven parts:
(1) Different types of scheduling and their applications
• Scheduling and its applications
• General introduction of job shop scheduling
• Static vs dynamic job shop scheduling
• Flexible vs non-flexible job shop scheduling
• The similarities and differences between different types of job shop scheduling

(2) Evolutionary machine learning and genetic programming
• Hyper-heuristic learning
• Representation of genetic programming
• Evaluation of genetic programming
• Parent selection in genetic programming
• Genetic operators (i.e., crossover, mutation, and reproduction) of genetic programming

(3) Genetic programming for job shop scheduling
• Scheduling heuristics for different types of job shop scheduling
• Genetic programming to learn scheduling heuristics
• Set up genetic programming as a hyper-heuristic approach for job shop scheduling (e.g., representations, terminal set and function set)

(4) Surrogate-Assisted genetic programming for job shop scheduling
• Surrogate basic concepts
• Phenotype VS Genotype of genetic programming individuals
• K-nearest neighbour based surrogate for genetic programming
• Instance rotation based surrogate in genetic programming
• Simplified model based surrogate for genetic programming
• Collaborative multi-fidelity based surrogates for genetic programming

(5) Genetic programming with feature selection for job shop scheduling
• Feature selection basic concepts
• Feature frequency-based feature selection
• Contribution-based feature selection

(6) Multitask genetic programming for job shop scheduling
• Multitask basic concepts
• Multitask genetic programming based generative hyper-heuristics
• Surrogate-Assisted evolutionary multitask genetic programming
• Task related based multitask genetic programming
• Multitask multi-objective genetic programming

(7) Future directions
• Limitations of existing studies in this field
• Potential solutions to handle the limitations

Intended audience

This tutorial targets researchers who are not familiar with GP and/or production scheduling as well as experienced researchers who are interested in special research topics.

Organizer/Presenter

(1) Dr. Fangfang Zhang is a Postdoctoral Research Fellow in the School of Engineering and Computer Science, Victoria University of Wellington, New Zealand. She has over 45 journal and conference papers including one authored book. Her current research interests include evolutionary computation, hyper-heuristics learning/optimisation, job shop scheduling, and multitask learning. She is the speaker of the tutorials of “Evolutionary Machine Learning for Combinatorial Optimisation” at CEC 2022, “Genetic Programming for Job Shop Scheduling” at SSCI 2021, and “Genetic Programming and Machine Learning for Job Shop Scheduling” at SSCI 2022. She is also the chairs of the special sessions on “Evolutionary Machine Learning for Planning and Scheduling” at CEC 2022, “Evolutionary Scheduling and Combinatorial Optimisation” at CEC2022 and BICT 2022, and “Genetic Programming and Machine Learning for Scheduling” at SSCI 2022 and SSCI 2021.

Dr Fangfang is an associate editor of Expert Systems with Applications. She is a member of the IEEE Computational Intelligence Society and Association for Computing Machinery, and has been serving as a reviewer for top international evolutionary computation journals such as the IEEE Transactions on Evolutionary Computation, and the IEEE Transactions on Cybernetics. She is also a committee member of the IEEE New Zealand Central Section. She was the Chair of the IEEE Student Branch at VUW, is currently the chair of Professional Activities Coordinator, the treasurer of Young Professional Affinity Group, and a member of Women-in-Engineering Affinity Group of IEEE NZ Central Section. In addition, she is a member of AI Researchers Association in New Zealand.

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(2) Prof. Mengjie Zhang is a Professor of Computer Science, the Head of the Evolutionary Computation Research Group, and the Associate Dean (Research and Innovation) with the Faculty of Engineering, Victoria University of Wellington, New Zealand. His current research interests include artificial intelligence and machine learning, particularly genetic programming, job shop scheduling, and transfer learning. He has published over 700 research papers in refereed international journals and conferences.
Prof. Zhang is a Fellow of the Royal Society of New Zealand, Fellow of Engineering New Zealand, a Fellow of IEEE and an IEEE Distinguished Lecturer. He was the Chair of the IEEE CIS Intelligent Systems and Applications Technical Committee, the IEEE CIS Emergent Technologies Technical Committee, and the Evolutionary Computation Technical Committee, and a member of the IEEE CIS Award Committee. He is a Fellow of the Royal Society, and a Fellow of Engineering of New Zealand, a Fellow of IEEE and an IEEE Distinguished Lecturer.

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Dr. Mei was a Vice-Chair of the IEEE CIS Emergent Technologies Technical Committee and a member of the Intelligent Systems Applications Technical Committee. He is an Editorial Board Member/Associate Editor of three international journals, and a Guest Editor of a special issue of the Genetic Programming and Evolvable Machines journal. He serves as a reviewer of over 30 international journals.

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(4) Dr. Su Nguyen is a Senior Lecturer (Business Analytics and AI) and Algorithm Lead at the Centre for Data Analytics and Cognition (CDAC), La Trobe University, Australia. He received his Ph.D. degree in Artificial Intelligence and Operations Research from Victoria University of Wellington (VUW), Wellington, New Zealand, in 2013. His expertise includes simulation-optimization, evolutionary computation, automated algorithm design, interfaces of artificial intelligence and operations research, and their applications in logistics, energy, and transportation. Nguyen has a strong track record in developing simulation models, simulation-based decision support tools, and simulation-optimisation algorithms for industry applications. He has 70+ publications in top peer-reviewed journals and conferences in computational intelligence and operations research. His current research focuses on hybrid intelligence systems that combine the power of modern artificial intelligence technologies and operations research methodologies. He was the chair (2014-2018) of IEEE task force on Evolutionary Scheduling and Combinatorial Optimisation and is a member of IEEE CIS Data Mining and Big Data technical committee. He delivered tutorials about evolutionary simulation-optimisation and AI-based visualisation at Parallel Problem Solving from Nature Conference (2018) and IEEE World Congress on Computational Intelligence (2020).

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