Tutorial Title:

Evolutionary Deep Learning for Image Classification: A Genetic Programming Approach

Tutorial Abstract:

Image classification is an important and fundamental task in machine learning and computer vision with a wide range of important applications, such as recognising faces from photographs, detecting cancers from X-ray images, and classifying fish species from underwater images. Many computational intelligence approaches have been developed for image classification. Deep learning, particularly deep convolutional neural networks (CNNs), is a dominant approach to image classification. Evolutionary deep learning is an emerging topic that studies the combinations of evolutionary computation (EC) and deep learning. This topic becomes more and more popular in recent years and EC has shown great potential in this field by achieving better performance than many manually designed CNNs. Genetic programming (GP) is a promising approach to automatic programming using a variable-length representation. Its ability in learning different types of models has been verified in successfully solving many tasks, including symbolic regression, classification, feature construction, scheduling, and image analysis. However, the potential of GP in learning deep models has seldom been recognised and systematically summarised. Therefore, we will deliver a tutorial on GP for evolving deep models with a special focus on solving image classification tasks.

In this tutorial, we will introduce the task of image classification and traditional algorithms. An overview of deep learning and evolutionary deep learning, including concepts, representative deep models and summaries of limitations, will be provided. We will introduce the definition of evolutionary computation and the GP algorithm, and justify why and how GP can be used to evolve deep models. Existing works on using GP to evolve deep models for image classification will be summarised and categorized. The main tutorial will focus on discussing existing work on using GP to evolve neural network-based models and non-neural network-based models. Particularly, it will introduce a series of GP algorithms for evolving deep models for binary classification, feature extraction, selection and construction, and ensemble classification. Recent advanced topics such as improving computational efficiency, multitask learning and transfer learning, and evolving deep models for other tasks will be also included in this tutorial. We will show the potential of GP in the above aspects by providing methods with promising classification results. We hope this tutorial will flourish the field of evolutionary deep learning and attract more researchers and students over the world to conduct research on this topic and further explore the potential of different types of evolutionary deep learning techniques.

Topic Overview:

This tutorial contains the following eight parts:
(1) Introduction of image classification
- Image classification task definition, applications, and main challenges
- General procedure to deal with image classification

(2) Introduction of deep learning and evolutionary deep learning
- Concepts of deep learning and typical models
- Limitations of deep learning methods
- The definition/description of evolutionary computation
- Concepts of evolutionary deep learning and categories of existing methods

(3) Introduction of genetic programming
- Basic concepts of genetic programming
- Why genetic programming is an evolutionary deep learning method?
- Advantages of genetic programming

(4) Evolving deep neural-network-based models
- Evolving CNNs

(5) Evolving deep models of classifiers from images
- Genetic programming for image classification
- Two-tier genetic programming
- Three-tier genetic programming
- HOG+GP
- Multi-layer genetic programming

(6) Genetic programming with deep structures for image feature extraction, selection and construction
- Feature extraction, feature selection, feature construction, and feature learning
- Genetic programming with convolutional and pooling filters
- Genetic programming for global and/local feature learning
- Genetic programming for feature learning from low-quality images
- Genetic programming with flexible model structures
- Genetic programming with feature reuse

(7) Recent advances in genetic programming for evolving deep models
- Evolving deep models of ensembles
- Improving computational efficiency
- Transfer learning and multitask learning
- Learning from a small number of training images
- Examples of evolving deep models for other tasks

(8) Conclusions and future directions
- Summary of existing studies in this field
- Potential research directions for future study

Learning outcomes:

This tutorial targets junior researchers who are interested in evolutionary deep learning, genetic programming and machine learning classification as well as experienced/senior researchers who are interested in special research topics. The learning outcomes will be

1. Researchers with a background in genetic programming will deeply understand how genetic programming is used to evolve deep models using different representations, function sets, terminal sets, operators, and search mechanisms, which are good for further developments of effective and efficient GP methods for solving various tasks.
2. Researchers with a background in deep learning and machine learning will form a broad perspective of deep learning by learning the concepts and algorithms of evolutionary deep learning and the potential of evolutionary computation in this recent popular field.
3. Researchers with a background in evolutionary computation will familiarise themselves with image classification tasks from this tutorial and understand promising methods for solving image classification tasks using different evolutionary deep learning methods based on genetic programming. They will also learn how genetic programming algorithms are developed for solving the image classification tasks, which hopefully provide inspiration for their own research.
4. Researchers who are specialised in this field will deeply understand state-of-the-art evolutionary deep learning algorithms based on genetic programming, recent advances on this topic, limitations, and future research directions, which are very important and useful for their future research.

Expected length of the tutorial: 1.5h

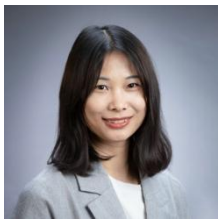
Justification: This is a hot research topic involving different fields, i.e., evolutionary computation, deep learning and computer vision. Many works have been conducted in recent years. Therefore, we plan the content of this tutorial for 3 hours to cover a full range of important concepts and typical works to make the tutorial more comprehensive and useful.

The level of the tutorial (introductory or advanced): advanced/specialised

Speakers and affiliations:

- Dr Ying Bi, Victoria University of Wellington, New Zealand
- Prof. Bing Xue, Victoria University of Wellington, New Zealand
- Prof. Mengjie Zhang, Victoria University of Wellington, New Zealand

Speaker biographies:



Ying Bi is a postdoctoral research fellow with the School of Engineering and Computer Science at Victoria University of Wellington (VUW), New Zealand. Her research focuses mainly on computer vision, image analysis, machine learning, deep learning, evolutionary computation, genetic programming, classification, feature learning, and transfer learning. She has published an authored book on genetic programming for image classification and over 50 papers in fully refereed journals and conferences in computer vision and evolutionary computation. She has been serving as a workshop chair of IEEE CEC 2024, student affair co-chair of GECCO 2023, an organizing committee member of ECOLE 2022, IEEE CEC 2019 and Australasian AI 2018, an organizer of a workshop in ICDM 2022, ICDM 2021, the symposium in SSCI 2022, a special session in SSCI 2021 and a special session in IDEAL 2021, and a program committee member of over twenty international conferences including IJCAI, GECCO, IEEE CEC, IEEE SSCI, and Australasian AI. She was co-chair Poster session in IEEE CEC 2019. She is serving as a reviewer of over twenty international journals. She is a member of IEEE, IEEE Computational Intelligence Society (CIS) and ACM SIGEVO.

Bing Xue is currently a Professor of Artificial Intelligence and Deputy Head of School in the School of Engineering and Computer Science at VUW. She has over 300 papers published in fully refereed international journals and conferences and her research focuses mainly on evolutionary computation, data mining, machine learning, classification, symbolic regression, feature selection, evolving deep neural networks, image analysis, transfer learning, multi-objective machine learning. Dr Xue is currently the Chair of IEEE CIS Task Force on Transfer Learning & Transfer Optimization, and Vice-Chair of IEEE Task Force on Evolutionary Feature Selection and Construction and of IEEE CIS Task Force on Evolutionary Deep Learning and Applications. She was the Chair of IEEE CIS Data Mining and Big Data Analytics Technical Committee.

Prof Xue is the organizer of the special session on Evolutionary Feature Selection and Construction in IEEE CEC 2015, 2016, 2017, 2018, 2019, 2020, 2021 and 2022. Prof Xue has been a chair for a number of international conferences including the Chair of Women@GECCO 2018, a co-Chair of the Evolutionary Machine Learning Track for GECCO 2019 and 2020, a co-Chair of the Neuroevolution Track for GECCO 2021 and 2022. She is the Lead Chair of IEEE Symposium on Computational Intelligence in Feature Analysis, Selection, and Learning in Image and Pattern Recognition (FASLIP) at SSCI 2016, 2017, 2018, 2019 and 2020, a Program Chair of Australasian AI 2018, Finance Chair of IEEE CEC 2019, a Workshop Chair of 2021 IEEE ICDM, a Conference Activities Chair of IEEE SSCI 2021, a General Co-Chair of IVCNZ 2020, a Tutorial Co-Chair of IEEE WCCI 2022, a Publication Co-Chair of EuroGP 2022, a conference Chairo f IEEE CEC 2024.

She is an Editor of the IEEE CIS Newsletter. She is an Associate Editor or Member of the Editorial Board for over ten international journals, including IEEE TEVC, IEEE CIM, IEEE TAI, IEEE TETCI, and ACM TELO.

Mengjie Zhang is a Fellow of the Royal Society of New Zealand, a Fellow of New Zealand Engineering, a Fellow of IEEE, an IEEE CIS Distinguished Lecturer, and currently a Professor of Computer Science at VUW, where he heads the interdisciplinary Evolutionary Computation Research Group. He is a member of the University Academic Board, a member of the University Postgraduate Scholarships Committee, Associate Dean (Research and Innovation) in the Faculty of Engineering, and Chair of the Research Committee of the Faculty of Engineering and School of Engineering and Computer Science.

His research is mainly focused on evolutionary computation with the application areas of feature selection/construction and dimensionality reduction, computer vision and image processing, evolutionary deep learning and transfer learning, job shop scheduling, multi-objective optimization, and clustering and classification with unbalanced and missing data. Prof Zhang has published over 700 research papers in refereed international journals and conferences in these areas.

He has been serving as an associated editor or editorial board member for over 10 international journals including IEEE TEVC, IEEE TCYB, ECJ (MIT Press), ACM TELO, GPEM(Springer), IEEE TETC, AOSO, and EAAI, and as a reviewer of over 30 international journals. He has been a major chair for eight international conferences. He has also been serving as a steering committee member and a program committee member for over 80 international conferences including all major conferences in evolutionary computation. Since 2007, he has been listed as one of the top ten world genetic programming researchers by the GP bibliography (http://www.cs.bham.ac.uk/~wbl/biblio/gp-html/index.html).

He was the Tutorial Chair for GECCO 2014, an AIS-BIO Track Chair for GECCO 2016, an EML Track Chair for GECCO 2017, and a GP Track Chair for GECCO 2020 and GECCO 2021. Since 2012, he has been co-chairing several parts of IEEE CEC, SSCI, and EvoIASP/EvoApplications conference (he has been involving major EC conferences such as GECCO, CEC, EvoStar, SEAL). Since 2014, he has been co-organizing and co-chairing the special session on evolutionary feature selection and construction at IEEE CEC and SEAL, and also delivered a keynote/plenary talk for IEEE CEC 2018, IEEE ICAVSS 2018, DOCSA 2019, IES 2017 and Chinese National Conference on AI in Law 2017. Prof. Zhang is the Chair of IEEE CIS PhD Dissertation Award Committee and IEEE CIS Publication Strategic Planning Committee. He was the Chair of the IEEE CIS Intelligent Systems Applications, the IEEE CIS Emergent Technologies Technical Committee, and the IEEE CIS Evolutionary Computation Technical Committee; a Vice-Chair of the IEEE CIS Task Force on Evolutionary Feature Selection and Construction, the IEEE CIS Task Force on Evolutionary Computer Vision and Image Processing, and the IEEE CIS Task Force on Evolutionary Deep Learning and Applications; and also the founding chair of the IEEE Computational Intelligence Chapter in New Zealand.