Evolutionary Computation Success in Medical Diagnosis

Qurrat Ul Ain

1 Short Introduction of the Topic

From early disease detection through enhanced medical decision-making to better patient outcomes, the healthcare industry has transformed with the right technology in place. Medical imaging data is one of the richest sources of information to help diagnose a disease. However, without proper computer-aided diagnosis methods, doctors are forced to spend hours manually analyzing patient data. Fortunately, with the passage of time and the advancements in technology, the healthcare industry has been successful in utilizing new automation solutions, including computer vision. From the early-stage detection of unique tissue formations, including tumors to the computer-aided inspection of X-ray, CT, and MRI scans of internal organs, detection of microscopic bone fractures, and long-term monitoring of treatment results and change detection, computer vision success spans a large range of medical applications.

Detecting the disease from vast amounts of data or identifying an underlying pattern from the data archived over years seems tiresome for medical practitioners and sometimes impossible to reach/identify conclusions. With the use of feature selection and feature construction, computer scientists and medical practitioners transform vast amounts of data into reduced data representations. In addition, evolutionary computation (EC) algorithms help automatically select and construct new features to improve diagnostic ability. Unlike black-box architectures, EC algorithms particularly Genetic Programming (GP) can evolve interpretable models which can provide explanations to the medical practitioner about the cause of a disease.

This tutorial first describes a general framework of computer vision algorithms for medical imaging techniques including image segmentation, feature extraction, and classification followed by an example application of feature selection and feature construction in skin cancer detection. Then, we will address the challenges and major limitations in medical diagnosis. We will provide how EC techniques, particularly genetic algorithm, particle swarm optimization, and genetic programming can be applied to address the challenges. The effectiveness of EC-based feature reduction is illustrated through several applications including lung nodule segmentation, brain tumor feature extraction, breast mass density classification, and melanoma detection. We will describe in detail how EC techniques have successfully contributed to skin cancer and breast cancer detection. The tutorial concludes with existing challenges for future research. This tutorial is supported by the IEEE CIS Evolutionary Computation Technical Committee, and IEEE CIS Task Force on Evolutionary Computer Vision and Image Processing.

Potential audiences: The tutorial is designed as an introductory tutorial that provides the main concepts and how evolutionary computation has proven useful in several medical applications. At the same time, the attendees will also learn the pros/cons of applying different evolutionary algorithms to achieve feature selection and construction, highlighting the state-of-the-art evolutionary algorithms in medical diagnosis. Some potential future research directions are also explained in the tutorial.

2 Outline of the Tutorial

This tutorial consists of four parts:

1. Computer Aided Diagnosis: an interdisciplinary technology
    - Medical Imaging Techniques such as X-ray, MRI, Endoscopy, dermoscopy, and ultrasound.
    - Artificial Intelligence and Computer Vision linked to Radiology and Pathology Images.

- Example: Skin cancer detection using dermoscopy images.

2. Medical Diagnosis Challenges
    - Massive or (sometimes limited) availability of data.
    - Data collection, pre-processing, processing and system assessments.
    - Various algorithmic limitations such as input data configurations, computational time and resource complexity.
    - Healthcare providers to adopt new CAD systems; interpretation of the system outcomes.
3. Evolutionary Computation Approaches for Medical Diagnosis
    - Lung Nodule Detection in CT images
    - Brain Tumor Segmentation in MRI images
    - Parkinson's Disease Classification in brain MRI images
    - Classification of multiple medical image modalities
4. Evolutionary Computation Approaches for Breast cancer and Skin Cancer Detection
    - Breast tumor classification using Particle Swarm Optimization
    - Breast Mass Density Classification in Mammogram images using genetic programming
    - Melanoma Detection in dermoscopy images using genetic programming
    - Feature selection and construction using Genetic Programming for Skin Cancer Image Classification
    - Interpretability of evolved GP models
5. Existing Challenges and Future Directions

3 Expected Length of the Tutorial

We expect the length of the tutorial will be two hours.

4 Level of the tutorial

The level of the tutorial will be introductory.

5 Names, Affiliations, Websites, and Bios of Presenters

Qurrat Ul Ain (M'16) received her B.Sc. degree in computer engineering from the University of Engineering and Technology, Taxila Pakistan, and her MS degree in computer science from International Islamic University, Islamabad Pakistan. She joined the Victoria University of Wellington New Zealand in 2016, receiving her PhD degree in Computer Science in 2020, and is currently working as a Postdoc Research Fellow in Artificial Intelligence. Her current research interests include cancer detection, evolutionary computation, genetic programming, computer vision, medical image analysis, pattern recognition, machine learning, feature selection, extraction and construction, and transfer learning.

Dr. Qurrat Ul Ain is a member of IEEE New Zealand Central Section, IEEE CIS Task Force on Evolutionary Computation for Feature Selection and Construction, and IEEE Task Force on Evolutionary Computer Vision and Image Processing. She is also a member of the IEEE Computational Intelligence Society and Artificial Intelligence Researchers Associations (AIRA). She has been serving as a reviewer for more than ten international journals and conferences. She is an advisory board member of the Women in AI Awards New Zealand Pacific 2023. She is also a member of the Evolutionary Computation Research Group (ECRG) and Feature Analysis, Selection, and Learning in Image and Pattern Recognition (FASLIP) at Victoria University of Wellington.

Harith Al-Sahaf (M'13) received the B.Sc. degree in computer science from Baghdad University (Iraq), in 2005. He joined the Victoria University of Wellington (VUW), (New Zealand) in July 2007 where he received his MCompSc and PhD degrees in Computer Science in 2010 and 2017, respectively. In October 2016, he has joined the School of Engineering and Computer Science, VUW as a Post-doctoral Research Fellow and as a full-time lecturer since September 2018. His current research interests include evolutionary computation, particularly genetic programming, computer vision, pattern recognition, evolutionary cybersecurity, machine learning, feature manipulation including feature detection, selection, extraction and construction, transfer learning, domain adaptation, one-shot learning, and image understanding.

Dr. Al-Sahaf is a member of the IEEE CIS ETTC Task Force on Evolutionary Computer Vision and Image Processing, the IEEE CIS ETTC Task Force on Evolutionary Computation for Feature Selection and Construction, the IEEE CIS ISATC Task Force on Evolutionary Deep Learning and Applications, and the IEEE CIS ISATC Intelligent Systems for Cybersecurity.

Bing Xue (M'10-SM'21) received the B.Sc. degree from the Henan University of Economics and Law, Zhengzhou, China, in 2007, the M.Sc. degree in management from Shenzhen University, Shenzhen, China, in 2010, and the Ph.D. degree in computer science in 2014 at Victoria University of Wellington (VUW), New Zealand.

She 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, machine learning, classification, symbolic regression, feature selection, evolving deep NNs, image analysis, transfer learning, multi-objective machine learning. Dr Xue is currently the Chair of IEEE CIS Evolutionary Computation Technical Committee, Chair of IEEE CIS Task Force on Evolutionary Deep Learning and Applications, and Editor of IEEE CIS Newsletter. She has also served as associate editor of several international journals, such as IEEE Computational Intelligence Magazine, IEEE Transactions on Evolutionary Computation and ACM Transactions on Evolutionary Learning and Optimization.

Mengjie Zhang (M'04-SM'10-F'19) received the B.E. and M.E. degrees from Artificial Intelligence Research Center, Agricultural University of Hebei, China, and the Ph.D. degree in computer science from RMIT University, Melbourne, Australia, in 1989, 1992, and 2000, respectively. He is currently Professor of Computer Science, Head of the Evolutionary Computation Research Group, and the Associate Dean (Research and Innovation) in the Faculty of Engineering. His current research interests include machine learning, evolutionary computation, genetic programming, image analysis, multi-objective decision making, feature selection and reduction, scheduling and combinatorial optimisation, and evolutionary deep learning and transfer learning. He has published over 700 research papers in refereed international journals and conferences.

Prof. Zhang is a Fellow of Royal Society of New Zealand, a 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 IEEE CIS Evolutionary Computation Technical Committee. He is currently the Chair of the IEEE CIS PubsCom Strategic Planning Committee, the Chair of the IEEE CIS Outstanding PhD Dissertation Award Committee, and the founding chair of the IEEE Computational Intelligence Chapter in New Zealand.