Specialization Structure

Applied AI for Engineers and Scientists: Foundations

Forewords for the Specialization

Many scientists and engineers assume AI is machine learning and are studying machine learning courses for computer science students. However, there are two drawbacks: (1) although machine learning is an important branch of AI, other AI skills that are widely used in science and engineering are less educated; (2) the requirements of AI learning for science and engineering students and computer science students have much overlap but also much difference. Hence, the challenge for scientists and engineers is how to handle the really useful AI knowledge and skills efficiently.

To address this challenge, this specialization is designed for engineering and general science students to learn and apply AI techniques most effectively and efficiently. Different from specializations for computer science students, the most popular and effective AI algorithms that are essential for engineers and scientists are carefully selected and explained understandably. A particular emphasis is the use of these algorithms for real-world engineering and science problems. Through MATLAB toolboxes, students can bypass complex programming to use these techniques and achieve superior results. After taking this specialization, the students can understand the concepts and working principles of key techniques in evolutionary computation and machine learning, and use them fluently in optimization and data analysis tasks in engineering and science practice.

Course 1: Fundamental MATLAB Programming for AI

Week 1: The fundamentals of MATLAB

This module introduces the fundamentals of the programming platform of this course, MATLAB. Through MATLAB's toolboxes for engineering and scientific modeling and AI techniques, students can bypass intricate programming and achieve superior results. After learning this module, students will be able to:

- Apply defining variables, performing calculations, using built-in functions, and saving/loading workspace in MATLAB.
- Understand and apply entering and manipulating data in matrices in MATLAB.
- Understand and apply popular MATLAB built-in functions to assist programming.
- Create and analyze simple MATLAB scripts.
- Understand and apply graphics in MATLAB.

Week 2: Produce effective MATLAB programs for science and engineering problems

This module introduces conditionals and program control, loops, and MATLAB custom functions, followed by two case studies. After learning this module, students will be able to:

- Create customized MATLAB functions.
- Understand conditionals and program control in MATLAB programming and apply them.
- Understand loops in MATLAB programming and apply them.
- Create and analyze effective programs for science and engineering tasks.

Week 3: Get ready to learn AI using MATLAB

This module introduces MATLAB data types and widely used functions in AI programs. Two case studies that are important for AI algorithms for optimization and machine learning in science and engineering are employed to practice students' MATLAB programming skills and get ready for learning AI. After learning this module, students will be able to:

- Understand and apply MATLAB table arrays and cell arrays to manipulate data.
- Understand and apply categorical data and one-hot encoding of them.
- Create objective functions for optimization and machine learning.
- Create programs for data cleaning for machine learning.
- Remember essential widely used functions in data analysis and machine learning.

Course 2: Evolutionary Computation and its Applications

Week 1: Fundamental concepts in optimization

One of the most important applications of AI in science and engineering is optimization. This module introduces fundamental concepts in optimization. After learning this module, students will be able to:

- Understand the essential concepts in optimization.
- Understand different types of optimization problems.
- Analyze an engineering problem and formulate it into an optimization problem.

Week 2: Genetic algorithm

This module introduces genetic algorithm (GA), which is a famous optimization method inspired by the intelligence of the evolution process. After learning this module, students will be able to:

- Understand the working flow and working principles of GA.
- Understand and analyze the main GA operators, including data representation, crossover, mutation, selection, etc.
- Apply MATLAB's built-in GA function to solve real-world optimization problems in science and engineering and evaluate the result.

Week 3: Particle swarm optimization

This module introduces particle swarm optimization (PSO). Swarm intelligence has attracted much attention in the AI field and PSO is a renowned global optimization algorithm based on swarm intelligence. After learning this module, students will be able to:

- Understand the working flow of PSO.
- Understand and analyze the main PSO operators, including velocity, position updates, etc.
- Apply MATLAB's built-in PSO function to solve real-world optimization problems in science and engineering and evaluate the result.

Course 3: Machine Learning and its Applications

Week 1: Machine learning fundamentals I: basic concepts

One of the most important applications of AI in science and engineering is classification and regression using machine learning. This module introduces essential concepts and principles in machine learning using two simple but useful machine learning techniques. After learning this module, students will be able to:

- Understand the essential concepts in machine learning, including those in terms of data, model, training, and prediction.
- Understand the working flow of machine learning and in particular, supervised learning, as well as the basic techniques in each step.
- Understand and apply simple linear regression and K-nearest neighbor machine learning methods.
- Apply MATLAB's built-in functions to solve machine learning problems in science and engineering and evaluate the result.

Week 2: Machine learning fundamentals II: model training and evaluation

Continuing the last module, this module still introduces essential concepts and principles in machine learning with a focus on model training and evaluation. After learning this module, students will be able to:

- Understand the essential concepts in machine learning model training, including training and test data, model and hyperparameters, loss function, etc.
- Understand the process of machine learning model training and the optimization techniques involved.
- Understand and apply key concepts in evaluating the machine learning model, including under and overfitting, generalization, bias, variance, their trade-off, etc, and carry out basic evaluations of machine learning outcomes.
- Understand the machine learning process in a global picture, laying a solid foundation for further study.

Week 3: Data preparation

This module introduces fundamental data preparation concepts and techniques to improve data quality in order to promote machine learning models providing good outcomes in real-world science and engineering practice. After learning this module, students will be able to:

- Understand Gaussian distribution.
- Understand and apply methods to remove outliers.
- Understand and apply data transform methods to generate Gaussian-like data sets.
- Understand and apply training and test set division and cross-validation.

Week 4: Support vector machines

This module introduces support vector machines (SVMs), which is one of the most effective and popular methods for classification. After learning this module, students will be able to:

- Understand the fundamental concepts of SVMs.
- Understand the working principles of SVMs, including linear SVMs with hard and soft margins, nonlinear SVMs, and multi-class SVMs.
- Apply SVMs to solve science and engineering problems using MATLAB's built-in function and evaluate the result.

Week 5: Artificial neural networks

This module introduces artificial neural networks (ANNs), which is one of the most effective and popular methods for regression and classification. After learning this module, students will be able to:

- Understand the fundamental concepts of ANNs.
- Understand the working principles of ANNs, particularly the ANN training.
- Create ANNs, analyze and improve their performance.
- Apply ANNs to solve science and engineering problems using MATLAB's toolbox and evaluate the result.