CM3015 Machine Learning and Neural Networks syllabus

Course description

Through this course you will study a range of machine learning techniques, including an exploration of neural networks. This course builds upon previous machine learning content in this syllabus, providing you with a deeper understanding and a more powerful toolkit, including coverage of deep neural networks.

Module goals and outcomes

This course provides a broad view of machine learning and neural networks. You will learn how to solve common machine learning problems such as regression, classification, clustering, matrix completion and pattern recognition. You will learn about neural networks and how they can be trained and optimised, including an exploration of deep neural networks. You will learn about machine learning and neural network software libraries that allow you to rapidly develop machine learning systems, and you will learn how to verify and evaluate the results.

Upon successful completion of this module, you will be able to:

1. Explain and compare fundamental machine learning concepts and use a number of machine learning algorithms.
2. Analyse the difference between different machine learning problems (e.g. supervised/unsupervised, classification/regression, clustering/dimensionality reduction).
3. Select and justify appropriate feature representations for different types of data.
4. Describe the basic components of a neural network and how they can be combined to form moderately complex learning architectures
5. Select and apply standard machine learning methods on data

Textbook and Readings

Specific essential readings for each topic from the following list are included in the reading page for each topic.

The main reading for this course is Cholett, F. (2017) *Deep Learning with Python*, first edition, Manning Publications ebook which can be downloaded from Manning Publications website. Please read the instruction on how to access this ebook.

The following books are also recommended for reading in part 1 of this course:

Alpaydin, E. *Introduction to machine learning*. (Cambridge, MA: MIT Press, 2014) 3rd edition [ISBN 9780262028189].

Murphy, K. *Machine learning: a probabilistic perspective*. (Cambridge, MA: MIT Press, 2012) [ISBN 9780262018029]

Mitchell, T. M. *Machine learning*. (London: McGraw-Hill, 1997). Chapter 1, Introduction.

Module outline

The module consists of ten topics that focus on key areas of the fundamentals of computer science.

Topic 1. Introduction to Machine Learning and Neural Networks	**Key concepts:** • applications of machine learning (and deep learning) • supervised and unsupervised learning • classification and regression **Learning outcomes:** 1. Explain fundamental machine learning concepts 2. Describe various types of machine learning problem 3. Describe various applications of machine learning
Topic 2. Classification	**Key concepts:** • K-nearest neighbour • Confusion matrices • Classifier evaluation **Learning outcomes:**

	1. Explain how a simple nearest neighbour algorithm works 2. Evaluate a supervised classification algorithm on a dataset 3. Describe the Decision Tree Classifier
Topic 3. Regression	**Key concepts:** • linear models • gradient descent • data scaling **Learning outcomes:** 1. Explain the concept of linear regression and interpret results. 2. Apply linear regression on a dataset. 3. Explain the idea behind gradient descent
Topic 4. Model improvement	**Key concepts:** • bias-variance (overfitting, underfitting) • cross-validation • regularisation **Learning outcomes:** 1. Explain the effect of overfitting. 2. Explain the concept of cross-validation. 3. Explain how regularisation works.
Topic 5. Probabilistic classifiers	**Key concepts:** • probabilistic modelling • bayes' rules • naïve bayes classification • generative vs. discriminative modeling **Learning outcomes:** 1. Explain Bayes' rule 2. Describe the Naive Bayes classifier

	3. Discuss the difference between generative and discriminative models
Topic 6. Unsupervised Learning	**Key concepts:** • k-means clustering • dimensionality reduction • linear projections **Learning outcomes:** 1. Explain the concepts of clustering and dimensionality reduction 2. Implement the k-means algorithm 3. Explain principal component analysis (PCA) and its properties.
Topic 7. Introduction to Neural networks and Deep Learning - Part 2	**Key concepts:** • deep learning contexts • mathematical fundamentals • deep learning application • deep learning methodology **Learning outcomes:** 1. Describe multi-layer neural networks, backpropagation and deep networks 2. Explain machine learning workflow 3. Talk about the history and assess the future of deep learning
Topic 8. The mathematical building blocks of neural networks	**Key concepts:** • the key mathematical concepts: tensors, transformations and stochastic gradient descent • sequence of data transformations • gradient descent optimisation

	Learning outcomes: 1. Understand the MNIST dataset 2. Understand how a simple neural network is built and trained with Tensorflow 3. Discover how data is packed into tensors and the fundamental of data representation of neural networks 4. Explain how a computer recognises hand written digits - our first neural network.
Topic 9. Getting started with Neural Networks	**Key concepts:** • deep learning programs • training and validation plots • model evaluation • classification of movie reviews • multi-class classification **Learning outcomes:** 1. Understand the anatomy of a neural network 2. Apply neural networks to binary classification tasks 3. Apply neural networks to multi-class classification tasks 4. Apply neural networks to regression tasks
Topic 10. Fundamentals of machine learning	**Key concepts:** • data preprocessing, • spotting and dealing with under- and over-fitting • the universal machine learning workflow. **Learning outcomes:** 1. Know how and when to preprocess data 2. Know when a neural network is under-fitting or overfitting 3. Know how to address overfitting with network capacity reduction, weight regularisation and dropout

Activities of this module

The module is comprised of the following elements *(please explain in detail the activities included in the module, for example:*

- *Lecture videos.*
- *Practice Quizzes.*
- *Activities, e.g. programming exercises in Labs*
- *Graded summative assignments.*
- *Discussion Prompt.*
- *Readings.*

How to pass this module

The module has two major assessments each worth 50% of your grade:

- Coursework 1 will be assessed half way through course (after week 12)
- In the end of the study session there will be Coursework 2 submitted in week 22.

This is a detailed breakdown of all of the marks.

Activity	Required?	Deadline week	Estimated time per module	% of final grade
Written, staff graded coursework 1	Yes	12	Approximately 20 hours	50%
Written, staff graded coursework 2	Yes	22	20 hours	50%