EE 468: Selected Topics in Communications and Signal Processing
Neural Networks and Deep Learning

Electrical Engineering Department
College of Engineering

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Pre-requisites: Linear algebra, calculus, and undergraduate-level statistics and probability
Textbooks:

T1: "Pattern Recognition and Machine Learning," by Christopher M. Bishop, 1st Edition (2006).

T2: "Neural Networks and Learning Machines," by Simon Haykin, 3rd Edition (2009).

T3: "Deep Learning," by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, 1st Edition (20016)

References: Lecture notes prepared by the instructor, and a small collection of papers discussing state-of-the-art applications.

1 Course Objectives

An introduction is presented in this course to modern principles and applications of Artificial Neural Networks (ANNs). It is designed to give student a taste of the field of Deep Learning, where ANNs are the driving power, with focus on most recent applications that are relevant to the students' background in electrical engineering. More concretely, the course is aimed to:

1. Introduce the basic principles underlying the construction and design of ANNs. Examples include and not limited to: the perceptron model, the artificial neuron model, the Multi-Layer Perceptron (MLP) network, training of ANNs, and the backpropagation algorithm and its relation to the chain rule of derivatives.

2. Familiarize students with deep learning, and introduce them to modern-day ANN architectures, most importantly of which are the MLP and Convolutional Neural Networks (CNNs).

3. Provide students with a clear idea on how ANNs are generally used to tackle some modern engineering problems relevant to the students' electrical engineering background, CNNs application in image classification and MLP application in wireless channel prediction to name two examples.

4. Help students learn Python coding and implement the aforementioned architectures (point 2). Please Note: focus is on basic Python coding skills that are relevant to ANNs, e.g., learning to use the numpy library, create Python classes and functions, loading and saving MATLAB data files,... etc.

2 Evaluation

Grading in this proposed course will pay close attention to students' understanding of basic principles and their Python-programming skills. The suggested approach to evaluate them is as follows:

1. **Coding assignments:** worth a total of 30%.

2. **Two midterms:** worth a total of 30% (15% each).

3. **Final Exam:** worth 40%.

3 Proposed Course Outline

The course is broken down into four major sections. The outline below details the content of each section and its references from the textbook list[1].

[1] [Chapter X, TY] refers to chapter X from textbook TY

1. **Overview of Basic Machine Learning Principles**

    1.1 What is machine learning? [Chapter 1, T3]

    1.2 What is a learning algorithm? definitions of task, experience, performance measure, and training. [Chapter 5, T3]

    1.3 Curve-fitting and the linear regression model. [Chapter 1, T1]

    1.4 Classification and the Rosenblatt's perceptron. [Chapter 1, T2]

2. **Fundamentals of Artificial Neural Networks**

    2.1 The Multi-Layer Perceptron (MLP) network [Chapter 6, T3]

    2.2 Types of nonlinear functions [Chapter 6, T3]

    2.3 Training of MLP [Chapter 5 and 6, T3]

        i. Algorithm generalization (fitting, overfitting, and underfitting).
        ii. Training as an optimization problem.
        iii. Gradient descent algorithm.
        iv. Training with mini-batches and stochastic gradient descent.

    2.4 The back-propagation algorithm [Chapter 4, T2][Chapter 6, T3]

    2.5 Regularization and modern training practices [Chapter 7, T3]

        i. Weight decay.
        ii. Dropout.

3. **Deep Learning and Modern ANN Architectures**

    3.1 What does deep mean? And why is it important? [Chapter 5, T3]

    3.2 Convolutional Neural Networks (CNN). [Chapter 9, T3]

    3.3 Recurrent Neural Networks (RNN) [Chapter 10, T3]

    3.4 Transformer network or autoencoders.

4. **Modern Applications of Deep Learning**

    4.1 Image classification

    4.2 Object detection

    4.3 Large-scale MIMO

4 Tentative Course Timeline

Table 1 presents a suggested timetable for the course. It estimates the number of weeks needed to cover each section in the outline above (henceforth referred to as the period). It also presents the skills students are expected to develop within each period.

Weeks	Topics	Skills
1-4	Overview of basic machine learning principles	Basic Python programming
5-9	Fundamentals of artificial neural networks	Coding forward pass of an MLP Coding backward pass of an MLP Training and testing different MLP networks
10-12	Deep learning and modern ANN architectures	Building a CNN Training and testing a CNN
13-15	Modern applications of ANNs	Mini-project: Designing a deep ANN for some application of choice

Table 1: Timetable

5 Example Courses

The proposed course is inspired by two courses offered at Stanford University, CA, USA and McMaster University, ON, Canada. The two courses are

1. CS 230: Deep Learning, Computer Science Department, Stanford University (advanced undergraduate). Visit course website for more information.

2. ECE 772: Neural Networks and Learning Machines, Electrical and Computer Engineering Department, McMaster University (graduate level)