UNIVERSITY NAME

DOCTORAL THESIS

Thesis Title

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for the degree of Doctor of Philosophy*

in the

Research Group Name
Department or School Name

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Declaration of Authorship

I, John SMITH, declare that this thesis titled, "Thesis Title" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.

- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.

- Where I have consulted the published work of others, this is always clearly attributed.

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- I have acknowledged all main sources of help.

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Signed:

Date:

"Thanks to my solid academic training, today I can write hundreds of words on virtually any topic without possessing a shred of information, which is how I got a good job in journalism."

Dave Barry

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Abstract

Faculty Name
Department or School Name

Doctor of Philosophy

Thesis Title

by John Smith

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Acknowledgements

The acknowledgments and the people to thank go here, don't forget to include your project advisor...

Contents

List of Figures

List of Tables

List of Abbreviations

LAH   List Abbreviations Here
WSF   What (it) Stands For

Physical Constants

Speed of Light $\quad c_0 = 2.997\,924\,58 \times 10^8\,\mathrm{m\,s^{-1}}$ (exact)

List of Symbols

a	distance	m
P	power	W ($\mathrm{J\,s^{-1}}$)
ω	angular frequency	rad

For/Dedicated to/To my...

Chapter 1

Machine Learning

Machine Learning is a subfield of Artificial Intelligence (AI) and is used in a wide range of applications, such as computer vision, speech recognition, drug discovery or medical image analysis. It is a study of computer algorithms that construct statistical models trained to perform some specific task. The models improve their performance automatically by learning from examples instead of relying on static program instructions. Importantly, learning in this context does not mean to memorize examples but to extract patterns or rules from the training data that can also be used to make predictions for data points not present in the training examples.

Broadly speaking, ML algorithms can be divided into two categories: Supervised and Unsupervised learning. The supervised learning approach uses labeled data, where each input is linked to a desired output. Typical examples of supervised learning are regression or classification tasks. The unsupervised approach deals with unlabeled data, where only the inputs are given, and aims to find structure in the data, like clustering the data points.

ML is an umbrella term for many different algorithms, such as Kernel methods, decision trees or Artificial Neural Networks (ANNs). In this work we will focus on the latter.

1.1   Artificial Neural Networks

Nervous systems have the fascinating ability to organize themself and learn from experience. This has motivated researchers over the past century to develop artificial models of its biological counterpart. The history of ANNs began in 1943 with the creation of the first computational model of a neural network by Warren McCulloch and Walter Pitts based on algorithms called threshold logits. The next milestone was taken by F. Rosenblatt in 1958 with the invention of the perceptron: A two-layer neural network able to perform pattern recognition. The publication of the book 'perceptron' by Marvin Minsky and Seymour Papert in 1969 lead to the AI winter and research in the field stagnated as they stated that basic two-layer networks are incapable of solving the exclusive or circuit (non-linearly separable data). Larger networks were needed to solve the problem but could not be realized because of a lack of computational processing power and efficient algorithms at that time. Fortunately, the research field was not completely abandonned and ANNS were revived in the early 1980s due to the increased computational processing power and the introducing of the backpropagation algorithm in 1975 by Werbos that made it possible to train multi-layer networks. Nowadays, ANNs have won several state of the art ML contests and are used in many applications of our everyday life.

1.1.1   A Neuron

Nervous systems are built up from a large number of interconnected cells, called neurons. The human brain, as an example, consists of $\sim 10^{11}$ neurons. The main task of a neuron is to receive, process and transmit signals. To achieve this, a biological neuron is equiped with dendrites (receiver), a cell body (processor) and an axon (transmitter). Dendrites are thin fibers connected via synapses with the axons of thousands of other neurons. Signals captured by the dendrites are weighted by the synapses and can either increase or decrease the electrical cell potential. If a specific threshold potential is reached the axon fires a signal.

An artificial neuron works similarly to this: An input tensor x is weighted by a weight tensor w and the result is accumulated. Afterwards, a threshold value ψ is subtracted and a lon-linear function, called activation function, $a()$ is applied to derive the output y.

$$y = a(\sum_i x_i a_i - \psi)$$

(1.1)

In this example x and w are vectors but higher rank tensors are common as well.

1.1.2   Layer

A single neuron is a very simple processing unit, but a network of neurons becomes a powerful information processing system: Signals from the environment captured by sensory cells are encoded and processed by the network to create an appropriate response.

To explain the mechanism of information processing we can turn to visual object recognition: Our retina encodes visual stimuli into electrical signals that are transmitted to the visual cortex. Here, the incoming signal will cause a subset of neurons to respond, which can be described as a response vector. The response vector for a given object is not constant but varies under identity preserving transformations, such as shifts in position, rotations or changing illumination. Therefor, a given object has to be linked to a set of response vectors that span a manifold in the high dimensional space of all possible response vectors. The object identity manifold for different objects might be highly tangled and introducing an accurate decision boundary for object recognition becomes impossible. This is where the special structure of the visual cortex plays an important role: Neurons are grouped into subsequent layers and the further the signals are processed the more flattened and seperated the manifolds become.

1.2   Generative model

Appendix A

Frequently Asked Questions

A.1 How do I change the colors of links?

The color of links can be changed to your liking using:

    `\hypersetup{urlcolor=red}`, or

    `\hypersetup{citecolor=green}`, or

    `\hypersetup{allcolor=blue}`.

If you want to completely hide the links, you can use:

    `\hypersetup{allcolors=.}`, or even better:

    `\hypersetup{hidelinks}`.

If you want to have obvious links in the PDF but not the printed text, use:

    `\hypersetup{colorlinks=false}`.