

# Computational Learning Theory - HT 2018

*formerly* Advanced Machine Learning (HT 2017)

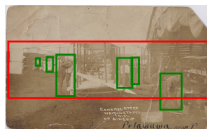
## Introduction and Course Details

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# What is Machine Learning?



- ▶ 200-basic level categories
- ▶ Here: Six pictures containing airplanes and people
- ▶ Dataset contains over 400,000 images
- ▶ Imagenet competition (2010-17)
- ▶ All recent successes through very deep neural networks!

## What is Machine Learning?

| Movie / User             | Alice | Bob | Charlie | Dean | Eve |
|--------------------------|-------|-----|---------|------|-----|
| The Shawshank Redemption | 7     | 9   | 9       | 5    | 2   |
| The Godfather            | 3     | ?   | 10      | 4    | 3   |
| The Dark Knight          | 5     | 9   | ?       | 6    | ?   |
| Pulp Fiction             | ?     | 5   | ?       | ?    | 10  |
| Schindler's List         | ?     | 6   | ?       | 9    | ?   |

Netflix competition to predict user-ratings (2008-09)

Any individual user will not have used most products

Most products will have been used by some individual



# Supervised Learning

Training data has inputs  $x$  (numerical, categorical) as well as outputs  $y$  (target)

**Regression:** When the output is real-valued, *e.g.*, housing price

**Classification:** Output is a category

- ▶ Binary classification: only two classes *e.g.*, spam
- ▶ Multi-class classification: several classes *e.g.*, object detection

# Unsupervised Learning : Group Similar News Articles

The screenshot displays the Google News homepage. On the left, a 'Top Stories' sidebar lists categories like Donald Trump, Google, Florida, Nobel Prize, Brexit, Formula One, Samsung Electronics Limited, Wayne Rooney, Oculus Rift, PlayStation VR, Oxford, England, World, U.K., Business, Technology, Entertainment, Sports, Science, Health, and Spotlight. The main content area features several news articles. The top article is 'US election: Donald Trump says he will not quit over video' from BBC News, dated 1 hour ago. Below it is a 'VIEWERS' GUIDE' for the US presidential debate. Other articles include 'German city on lock down as police investigate bomb plot threat' from the Daily Mail, 'Trump vows to stay in race after calls for him to quit over lewd remarks' from the New York/National, and 'A weakening Matthew rakes Atlantic coast; US death toll at 4' from the Charleston, S.C. (AP). A 'Derby County part company with Nigel Pearson by mutual agreement' article is also visible. On the right, there's a 'Sign in to get news on topics you care about' prompt, a 'Weather for Oxford, England' section showing a 14°C forecast, and an 'Editors' Picks' section featuring the 'Mirror' newspaper.

Group similar articles into categories such as politics, music, sport, etc.

In the dataset, there are no labels for the articles

# Active and Semi-Supervised Learning

## Active Learning

- ▶ Initially all data is unlabelled
- ▶ Learning algorithm can ask a human to label some data



## Semi-supervised Learning

- ▶ Limited labelled data, lots of unlabelled data
- ▶ How to use the two together to improve learning?



# Outline

What is Machine Learning?

What is Learning Theory?

Course Logistics

# What is Learning Theory?

The goal of (computational) learning theory is to develop formal models to analyse questions arising in machine learning

- ▶ How much data do we **need** to learn?
- ▶ What amount of computational resources are necessary for learning?
- ▶ Are there hard learning problems?

# What is Learning Theory?

In this course we'll cover several models that aim to capture questions that are of interest in modern machine learning

- ▶ (How) can we learn in the presence of noisy data?
- ▶ What can we learn when data is obtained in an online manner?
- ▶ (How) can we do useful machine learning while preserving privacy?
- ▶ Can we learn when data and computational power is distributed?

# What is Learning Theory?

Towards the end of the course we'll cover some of the latest topics in the area

- ▶ Can we develop a theoretical understanding of neural networks?
- ▶ Connections to information theory, game theory, etc.
- ▶ Conference on Learning Theory (COLT)

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What is Machine Learning?

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# Course Information

## Website

[www.cs.ox.ac.uk/people/varun.kanade/teaching/CLT-HT2018/](http://www.cs.ox.ac.uk/people/varun.kanade/teaching/CLT-HT2018/)

## Lectures

Mon, Thu 16h-18h (between 20-24 contact hours)

## Classes

Weeks 3-8 (possibly skip one)

**Instructors:** Francisco Marmolejo, David Martínez, Ninad Rajgopal

## Office Hours

After lectures or by appointment

# Course Information

## Textbooks

Kearns and Vazirani - An Introduction to Computational Learning Theory

Mohri, Rostamizadeh, Talwalkar - Foundations of Machine Learning

Shalev-Shwartz and Ben-David - Understanding Machine Learning

Papers and (rough) lecture notes will be posted

## Assessment

Take Home Exam

## Piazza

Use for course-related queries

Sign-up at [piazza.com/ox.ac.uk/other/cltht2018](https://piazza.com/ox.ac.uk/other/cltht2018)

# Who should take this course?

In this course, we will cover

- ▶ Mathematical formulations for different learning paradigms
- ▶ Definitions, theorems, proofs
- ▶ Design and analysis of learning algorithms
- ▶ Provable guarantees on run-time and sample complexity

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In this course, we will not cover

- ▶ Practical applications of learning algorithms - although understanding the theory will likely make you a better practitioner

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It is expected that you will be familiar with most of the following

- ▶ The notion polynomial time, space, etc.
- ▶ Big O notation
- ▶ Basic probability theory - expectation, independence, etc.

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It'd be helpful if (though not necessary that) you've seen at least some of the following

- ▶ Basic complexity theory such as NP-completeness
- ▶ Applied Machine Learning
- ▶ Optimisation algorithms - Linear Programming

## Who should take this course?

This is an advanced theoretical course. If you are taking this course, you should

- ▶ Be keen to understand the theory behind machine learning algorithms
- ▶ Be able to fill in details of algorithms and proofs omitted in the lectures
- ▶ Develop an ability to read research papers