

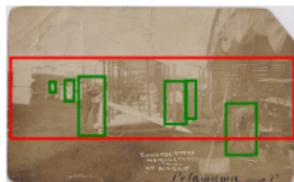
Computational Learning Theory - MT 2018

Introduction and Course Details

Varun Kanade

University of Oxford
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What is Machine Learning?



- ▶ 200-basic level categories
- ▶ Here: Six pictures containing airplanes and people
- ▶ Dataset contains hundreds of thousands of images
- ▶ Imagenet competition (2010-)
- ▶ 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 shows the Google News homepage in a Mozilla Firefox browser. The page is organized into several sections:

- Top Stories:** A vertical list of categories including 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.
- Main Article:** "US election: Donald Trump says he will not quit over video". The article text states: "US presidential candidate Donald Trump has said he will not withdraw from the race in phone interviews with US media. Mr Trump has been under pressure after a tape of him making lewd sexual comments and bragging about groping and kissing women ...". It includes a "VIEWERS' GUIDE" section and a "Live Updating" link for the "Second presidential debate 2016".
- Related Articles:** "German city on lock down as police investigate bomb plot threat" (Police are questioning three people after explosives were found hidden in an apartment officers raided in connection with a Syrian man suspected of planning a bomb attack on a German airport.) and "Trump vows to stay in race after calls for him to quit over lewd remarks" (NEW YORK/WASHINGTON, Oct 8 (Reuters) - U.S. Presidential nominee Donald Trump vowed on Saturday to remain in the race even as his campaign was thrown into crisis as his own running mate criticized him and some prominent Republicans withdrew ...).
- Other Articles:** "A weakening Matthew rakes Atlantic coast; US death toll at 4" (CHARLESTON, S.C. (AP) - A fast-weakening Hurricane Matthew continued its march along the Atlantic coast Saturday, leaving two of the South's most historic cities and some of its most popular resort islands, flattening trees, swamping streets and ...) and "Derby County part company with Nigel Pearson by mutual agreement" (Derby have announced they have parted company with their manager Nigel Pearson with immediate effect. The former Leicester boss had been suspended last month and the club began investigating a number of disciplinary issues).
- Right Sidebar:** Includes a sign-in prompt, "Weather for Oxford, England" (Today 14° F, Sun 14° F, Mon 13° F, Tue 15° F), "Oxford, England" location selector, a video player for "Controlled explosion came out after mortar found in Oxford river", a "Half marathon effort follows friends 'miraculous' recovery" link, a "MICHAEL APPLETON COLUMN: A change in nature but we will be ready for tomorrow" link, and an "Editors' Picks" section featuring "Mirror" magazine.

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

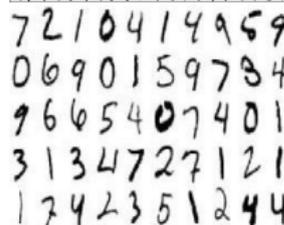
Active Learning

- ▶ 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)

Outline

What is Machine Learning?

What is Learning Theory?

Course Logistics

Course Information

Website

www.cs.ox.ac.uk/people/varun.kanade/teaching/CLT-MT2018/

Lectures

Mon 15h-16h, Thu 16h-18h (about 20 contact hours)

Classes

Weeks 3-7

Instructors: Alexandros Hollender, Philip Lazos, Francisco Marmolejo, David Martínez

Office Hours

After Monday lecture (16-17h)

Course Information

Textbooks

Kearns and Vazirani - An Introduction to Computational Learning Theory

Several additional texts for suggested reading on website

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/cltmt2018

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