Applied Machine Learning

Introduction
Practicalities

Slides and exercises will be posted on the website of the class the day before class:

http://lasa.epfl.ch/teaching/lectures/ML_Msc/index.php
http://lasa.epfl.ch/ ➔ Teaching ➔ Lectures ➔ Applied Machine Learning

Solutions to the exercises will be posted a week after the exercise session.
Practicalities

Contact Information of the Instructors

**Instructors**

**Prof. Aude Billard**

LASA Laboratory  
Swiss Federal Institute of Technology - EPFL  
CH-1015 Lausanne, Switzerland  
email: aude.billard@epfl.ch  
Office Hours: Monday, 14:00 to 16:00, by appointment. (room ME.A3.393)  
Tel: +41 (21) 693.54.64  
fax: +41 (21) 693.78.50

**Assistants**

Laura Cohen  
email: laura.cohen@epfl.ch  
Room: ME.A3.454  
Tel: 021 693 29 19

Murali Karnam  
email: murali.karnam@epfl.ch  
Room: ME.A3.395  
Tel: 021 693 38 55

Denys Lamotte  
email: denys.lamotte@epfl.ch  
Room: ME.A3.474  
Tel: 021 693 34 63

**Time and Location**

09:15-13:00  
Class takes place in room ELA1 and CO4-C05-C06 for the whole semester. Class alternates between Lectures and Exercises. Lectures + exercises take place in the same room ELA1, and practical sessions on computer in CO4-C05-C06.  
Grade is divided as follows: 25% In-class assessment + 75% Written Exam

**MachineLearningDemos Software**
Class Format

• Lectures with interactive exercises: 9h15-12h00
• Exercises (In class): 12h15-13h00
• Lectures alternates with Practical session held in C06-C04, see class schedule!

! Practical sessions run from 8h00 to 13h00 with one hour break 10h00-11h00.

• Attendance to practical and exercise sessions is highly recommended….
Grading Scheme

Practicals (25% of the grade) – done in team of 2
  1 report – due 16/12/2016
or
  1 oral presentation – December 16/12/2016
Register on doodle links on class website!

Written Exam (75% of the grade)
  3 hours long
  Closed book
  Allowed 1 A4 pages with handwritten notes
Welcome to the official website of the Learning Algorithms and Systems Laboratory, or (in French) the Laboratoire d'Algorithmes et Systemes d'Apprentissage (LASA).

Research at LASA develops means by which humans can teach robots to perform skills with the level of dexterity displayed by humans in similar tasks. Our robots move seamlessly with smooth motions. They adapt adequately and on-the-fly to the presence of obstacles and to sudden perturbations, hence mimicking humans' immediate response when facing unexpected and dangerous situations.

Fields covered at LASA include: Learning and Dynamical Systems, Neural Computation and Modeling, Human-Machine Interaction, Humanoids Robotics, Mechatronics, Design of Therapeutic and Educational Devices.
## Pre-requisites

### Linear Algebra
- Vector / Matrix notation
- Eigenvalue decomposition
- Linear dependency

### Probability / Statistics
- Probability Distribution Function
- Covariance, Expectation
- Joint, conditional probability
- Correlation / Statistical Independence

### Optimization
- Global versus local optima
- Gradient descent
- Method of Lagrange Multipliers

**Brief recap of main algorithms in class**
Class Objectives

- To understand the basics of some key algorithms of Machine Learning

- To apply some of these algorithms with real data and, by so doing, to understand the limitations of the algorithm for real-time systems

- To raise in you enough interest for the field, so that you will later try to learn more about it (advanced class at the doctoral school, search on-line, …)

- To have more engineers apply these techniques for robust control, signal processing, prediction, learning, etc.
Learning Outcomes

Main learning outcomes:
By the end of the course, the student must be able to:
• Choose an appropriate ML method
• Assess / Evaluate an appropriate ML method
• Apply an appropriate ML method

Transversal skills
• Write a scientific or technical report.
• Make an oral presentation.
Today’s class format

• Taxonomy and basic concepts in ML + examples of ML applications

• Introduction to Principal Component Analysis
Data Mining

Pattern recognition with very large amount of high-dimensional data

(Tens of thousands to billions)  (Several hundreds and more)
Data Mining: examples

Mining webpages

- Cluster groups of webpage by topics
- Cluster links across webpages

Other algorithms required:
- Fast methods for crawling the web
- Text processing (Natural Language Processing)
- Understanding semantics

Issues:
- Domain-specific language / terminology
- Foreign languages
- Dynamics of web (pages disappear / get created)
Machine Learning: definitions

*Machine Learning is the field of scientific study that concentrates on induction algorithms and on other algorithms that can be said to ``learn.''
* Machine Learning Journal, Kluwer Academic

*Machine Learning is an area of artificial intelligence involving developing techniques to allow computers to “learn”. More specifically, machine learning is a method for creating computer programs by the analysis of data sets, rather than the intuition of engineers. Machine learning overlaps heavily with statistics, since both fields study the analysis of data.* Webster Dictionary

*Machine learning is a branch of statistics and computer science, which studies algorithms and architectures that learn from data sets.* WordIQ
What is Machine Learning?

Machine Learning encompasses a large set of algorithms that aim at inferring information from what is hidden.

Independent Component Analysis (ICA) can decompose mixture of signals

What is Machine Learning?

Helps compute automatically information that would take days to do by hand.

The mapping can be done through support vector regression → An algorithm we will see in class

What is Machine Learning?

The strength of ML algorithms is that they can apply to arbitrary set of data. It can recognizing patterns from what from various source of data.

Recognizing human speech.
Here this the wave produced when uttering the word “allright”.

Modeling time series: *Hidden Markov Models* be used to recognize complex sounds, including human speech.
What is Machine Learning?

Classification: Two patterns that are different should still be grouped in the same class.
Why and when do we need learning in Robotics?
A typical problem of Robotics

Peg and Hole Problem
A typical problem of Robotics

Peg and Hole Problem
A typical problem of Robotics

A: Engineer the environment
A typical problem of Robotics

A: Engineer the environment

B: Engineer the body
A typical problem of Robotics

A: Engineer the environment

B: Engineer the body

C: Engineer the controller

Systematic search

→ Adaptive control

→ Learning Machine!
To engineer the environment is not always desirable. Rather, it is desirable to have a system that is adaptable to different environments that can generalize across tasks.

Kronander, Burdet and Billard, Learning Peg in Hole Insertion from Human Demonstrations, 2013.
Problem

ROWS 1-3
Make an autonomous robot that distributes graded assignments to a class of students

ROWS 4-6
Make an autonomous robot that cleans dirty dishes in the cafeteria

A: Engineer the environment
B: Engineer the body
C: Engineer the controller
Machines that learn

To engineer the environment is not always desirable

Rather, it is desirable to have a system that is

*adaptable* to different environments

can generalize across tasks
Taxonomy in ML

• **Supervised learning** — where the algorithm learns a function or model that maps a set of inputs to a set of desired outputs.

• **Unsupervised learning** — where the algorithm learns a model that represents a set of inputs without any feedback (no desired output, no external reinforcement).

• **Reinforcement learning** — where the algorithm learns a mechanism that generates a set of outputs from one input in order to maximize a reward value (external and delayed feedback).
Supervised learning

• Supervised learning relates to a vast group of methods by which one estimates a model from a set of examples,

→ The system is given the desired output.

• When these examples are provided by a human expert, this is referred to robot learning from demonstration; robot programming by demonstration.
Supervised learning

Where do the eyes look?

→ Map image of the eyes to point in the camera image

Supervised learning

What is sometimes impossible to see for humans is easy for ML to pick.

Exploit information not only on the pupil, cornea, but also on wrinkles, eyelids and eyelashed pattern to infer gaze direction.

Support Vector Regression can be used to learn this mapping.

Supervised learning

Learn a function $f$: $y = f(x)$

**Input:** 50 images of the eyes, In grey color 20x20 pixels

$$x^i \in \mathbb{R}^{20 \times 20}, \ i = 1...50$$

**Output:** 50 images of the scene, In grey color 240x320 pixels

$$y^i \in \mathbb{R}^{240 \times 320}, \ i = 1...50$$

Support Vector Regression can be used to learn this mapping

Unsupervised Learning

Unsupervised learning refers to a variety of methods by which a pair of signals $y$ and $x$ are associated but there is no explicit labeling as to which $y$ should be associated to which $x$.

This is often done through association, i.e. through associative learning.
Associative Learning for Learning Word-Objects Relations

Reinforcement Learning (RL)

RL tries to infer the optimal path to the goal, through a process of Trial-and-error, so as to maximize the reward.

Reinforcement learning is a tedious learning method.

It is slow and is functional only in well-defined problems with small search space.
Reinforcement Learning
Robotics Applications

The robot tracks the position of the two colored ball. Using a model of the inverse pendulum dynamics, it learns which joint angle displacement to produce to ensure that the ball remains in equilibrium.

Summary

Machine Learning encompasses a large area of works which cannot all be covered here.

We will focus on a subset of algorithms that form the foundation of most current advances in machine learning.

We however omit topics. Some of these are covered in other courses on machine learning at EPFL.
Some Machine Learning Resources

On-line resources:
• http://www.machinelearning.org/index.html
• http://www.pascal-network.org/ Network of excellence on Pattern Recognition, Statistical Modelling and Computational Learning (summer schools and workshops)

Journals:
• Machine Learning Journal, Kluwer Publisher
• IEEE Transactions on Signal processing
• IEEE Transactions on Pattern Analysis
• IEEE Transactions on Pattern Recognition
• The Journal of Machine Learning Research

Conferences:
• ICML: int. conf. on machine learning
• Neural Information Processing Conference – on-line repository of all research papers, www.nips.org