Foundations of Machine Learning II : Information Theory & Reinforcement Learning

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Introduction

Machine learning is at the core of many recent technology revolutions and is required to extract information from the large amounts of data that are now produced daily. Its applications are wide, from training robots how to walk, to clinical trials, advertisement suggestions, recognizing handwritten characters, playing Go, detecting spam...

This course is the continuation to the course *Foundations of Machine Learning* by Chloé-Agathe Azencott. It will cover the remaining main domains of machine learning, i.e. *information theory* and *reinforcement learning*.

Information theory is the mathematical foundation of machine learning: it is essential to understand its underlying concepts, and to model machine learning problems properly. We will see how the notions of prediction (what is likely to be the next character in this text?), generation (improvising new sentences) and compression (how to store losslessly large amounts of text as compactly as possible) are closely related, and what are the natural quantities to consider when considering distributions, in order to quantify the efficiency of machine learning algorithms.

Reinforcement learning is the part of machine learning dedicated to exploration strategies. In a given environment (a video game, clinical trials, robot moving in a gravitational field), given a set of possible actions (press this key, test this drug, move this articulation), what is the best sequence of actions to achieve the goal (winning the game, finding out the best drug, walking without falling) ?

A few practical sessions will be planned, to fully grasp the concepts and techniques. A final written exam will also take place.

Contact and information

Email: `guillaume.charpiat@inria.fr`
Slides, exercises, updates and more details (videos...) will be available at
`http://www.lri.fr/~gcharpia/machinelearningcourse/` .

Program

0 - Introduction

We will start with an overview of the course : typical problems addessed, why we need information theory, etc.

Part A - Information Theory

1 - Entropy

Concepts : natural distributions, entropy, mutual information
Examples : tax fraud detection; brain-computer interface: writing characters by thought (or moving a mouse) via EEG (electro-encephalography)

2 - Compression, prediction, generation

Concepts : lossless compression, prediction, generative models, arithmetic/Hoffman encodings
Examples : text compression and generation

3 - Minimum description length and low-rank approximation

Concepts : Kolmogorov complexity, minimum description length (MDL), low-rank approximation, collaborative filtering, ranking
Examples : movie/book suggestions, advertisement

4 - Information geometry

Concepts : importance of the metrics, Kullback-Leibler divergence, Fisher information
Examples : music partition generation with recurrent neural networks

Part B - Reinforcement Learning

5 - Prediction of time series

Concepts : model selection, multi-armed bandits, combining advice from multiple experts
Examples : drug testing, electricity consumption forecast

6 - Exploration strategies

Concepts : Markov decision process, Monte Carlo tree search, upper confidence tree, value iteration, direct policy search, Q-learning
Examples : robotics (virtual robot walking), moGo (Go player), Atari game player

7 - Gaussian processes

Concepts : Gaussian process
Examples : robotic arm playing ping-pong

Final exam (March 22)