Mathematics for Machine Learning

Lecture 1
(11.04.2024)

Introduction to MML

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Introduction

What do we do here?

Mathematics

- It is boring: **When you do not understand but memorize**
  - Equations
  - Theorems
  - Axioms

- It is interesting: **When you focus on the true nature**
  - Why do we need math?
  - What do numbers, vectors, equations, ... try to tell us?

- The way to interpret the process, to find a solution to problem, to generalize use cases, identify malfunctions, to prepare antidots for catastrophic issues and tons of things can be handled by mathematics.

Mathematics for Machine Learning

Solve the Problems

- **Problem 1:**

$$3x = 6$$

- **Problem 2:**

$$3x + y = 9$$
$$4x - 2y = 5$$

- **Problem 3:**
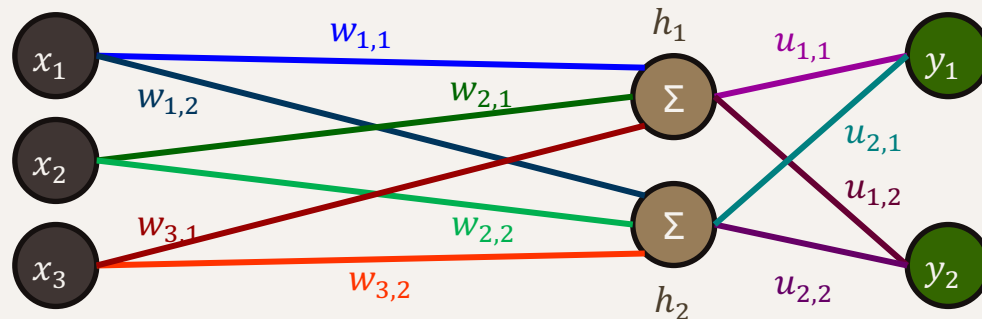
$$2x + 4y - z = 5$$
$$7x - 2y + 3z = 6$$
$$9x + 2y + 2z = 11$$

- **Problem 4:**

$$2x + 4y = 5$$

- **Let's increase dimensionality!**

Simple Multi-Layer Perceptron

- Given 3-dimensional input, we predict 2-dimensional output

- Nothing is given in between!

- Even we do not know, how correct if we map the input to output!

Mathematics, again!

- We need to know:
  - o Linear Algebra
  - o Probability Theory (consequently, Statistics)
  - o Calculus

- **Linear Algebra** will make computations of **Calculus** easier to solve **Statistical** optimization problems.

- Two terminology differences come to play in this course:
  - o Vectors are not arrows (in the most cases), but lists of features;
  - o Matrices are not tables of coefficients (in the most cases), but linear mapping objects;

Goals

What will we have at the end?

Understanding

- **You will see the specific subset of the Mathematics for Machine Learning. That will allow you to:**

  - Gain more focused background in ML;

  - Learn, develop and apply mathematics in two dimensions: Code + Paper;

Analysis

- **Rather than memorizing equations, we will learn algorithmic approaches. That will be helpful in the long-term to:**

  - Develop Machine Learning tools (e.g., Linear Regression, SVM, Perceptron);

  - Understand what is going on in the background of Machine Learning frameworks (e.g., Tensorflow, PyTorch);

  - Gain ability of reading mathematical results to express performance of what you implement (e.g., accuracy metrics, loss functions);

Problem Solving

- **Google or not to Google, that is what matters:**

  ○ You can search a solution in web, but blind search will not direct you to the solution!

  ○ You will have an intuition what to search, which modifications should be made;

To sum up:

- **You will have specific math knowledge for ML;**

- **You will be able to develop a model from scratch (REALLY, SCRATCH)**

- **You will see mathematical tricks to save time;**

- **You will play with math to build a model;**

- **You will take the first step to be ML architect, rather than copy-paste coder in Python;**

Course Contents

How do we reach to our destination?

Linear Algebra

- Vectors

- Vector spaces

- Linear Transformation

- Linear Equation Systems

- Analytic Geometry

- Matrix Decompositions

Vector Calculus

- Partial Differentiation

- Gradient

- Backpropagation

- Automatic Differentiation

Probability Theory (Statistics)

- Discrete and Continuous probabilities

- Summary Statistics and Independence

- Probability Distributions

Machine Learning Applications

- Data, Model and Learning

- Linear Regression

- Dimensionality Reduction

- Multi-layer Perceptron Model

Course Logistics

Book, exercises, exam

Book and References

- "Mathematics for Machine Learning" by Deisenroth, M. P., Faisal, A. A., & Ong, C. S.
  - https://mml-book.github.io/book/mml-book.pdf

- Specific Youtube videos as suggestion (but not included in exam)

- Colab Notebooks for exercises

MATHEMATICS FOR MACHINE LEARNING

Marc Peter Deisenroth
A. Aldo Faisal
Cheng Soon Ong
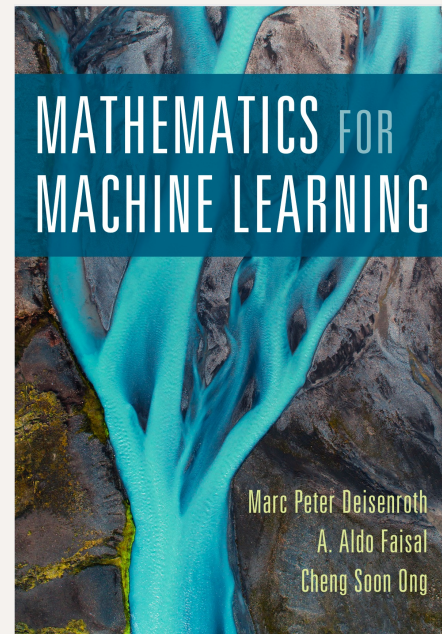
Schedule

- Lectures: Every Thursday at 16:30, F.0.530 (2 hours)

- Exercises: Every Friday at 13:00, F.1.110 (3 hours)

- Each exercise class will cover contents of 2 weeks: One for programming, one for exercises

- Note: No lectures on 9th and 30th of May

Achievement

- You have only one exam

- Expected to be:
  - First session: 15.08.2024 (place and time will be provided)
  - Second session: 05.09.2024 (place and time will be provided)

- Exam contents:
  - Theoretical background;
  - Mathematical questions;
  - Coding snippets

The End

Thanks for your attention!

Mahammad Namazov