

# Mathematics for Machine Learning

Companion webpage to the book "Mathematics for Machine Learning". Copyright 2020 by Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong. Published by Cambridge University Press.

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Please link to this site using <https://mml-book.com>.

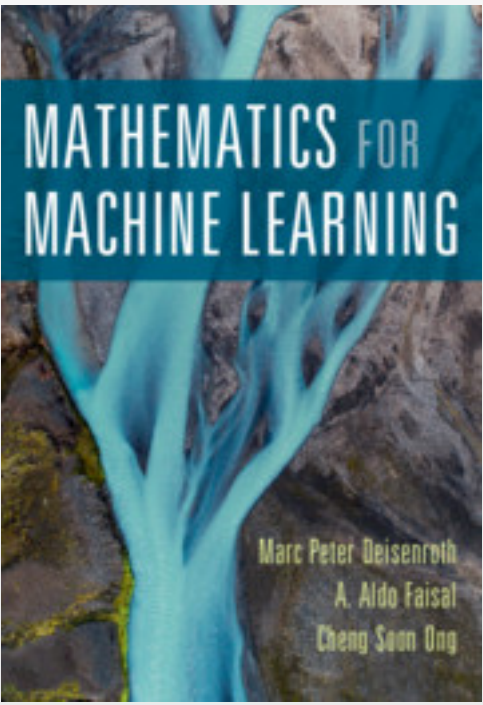
Twitter: [@mpd37](#), [@AnalogAldo](#), [@ChengSoonOng](#).

We wrote a book on Mathematics for Machine Learning that motivates people to learn mathematical concepts. The book is not intended to cover advanced machine learning techniques because there are already plenty of books doing this. Instead, we aim to provide the necessary mathematical skills to read those other books.

The book is available at [published by Cambridge University Press](#) (published April 2020).

We split the book into two parts:

- Mathematical foundations
- Example machine learning algorithms that use the mathematical foundations



We aimed to keep this book fairly short, so we don't cover everything.

We will keep [PDFs of this book freely available](#).

## Table of Contents

### Part I: Mathematical Foundations

1. **Introduction and Motivation**
2. **Linear Algebra**
3. **Analytic Geometry**
4. **Matrix Decompositions**
5. **Vector Calculus**
6. **Probability and Distribution**
7. **Continuous Optimization**

### Part II: Central Machine Learning Problems

8. **When Models Meet Data**
9. **Linear Regression**
10. **Dimensionality Reduction with Principal Component Analysis**
11. **Density Estimation with Gaussian Mixture Models**
12. **Classification with Support Vector Machines**

### Report errata and feedback.

Any issues you raise now may not make it into the printed version, but we will keep an updated PDF around (and the errata).

## Downloads

### PDF of the book

This version is the most up-to-date version of the book, i.e., we continue fixing typos etc.

**Instructor's manual containing solutions to the exercises** (can be requested from [Cambridge University Press](#))

### Errata on overleaf

### PDF of the printed book

This version is equivalent (modulo formatting) with the printed version of the book. GitHub issues starting from 433 are not included in this version.

## Solutions to exercises

- [Instructor's manual containing solutions to the exercises](#) (can be requested from Cambridge University Press)
- [Additional exercises \(with solutions\)](#)

## Tutorials

- Jupyter notebook tutorials (for learning)
  1. [Linear Regression](#)
  2. [PCA](#)
  3. [Gaussian Mixture Models](#)
  4. [SVM](#) (work in progress)
- Jupyter notebook tutorials (solutions)
  1. [Linear Regression](#)
  2. [PCA](#)
  3. [Gaussian Mixture Models](#)
  4. [SVM](#) (work in progress)
- [NeurIPS-2020 tutorial on integration and differentiation](#)

## External resources

Other people have created [resources](#) that support the material in this book.

## Testimonies

'This book provides great coverage of all the basic mathematical concepts for machine learning. I'm looking forward to sharing it with students, colleagues, and anyone interested in building a solid understanding of the fundamentals.' Joelle Pineau, McGill University and Facebook

'The field of machine learning has grown dramatically in recent years, with an increasingly impressive spectrum of successful applications. This comprehensive text covers the key mathematical concepts that underpin modern machine learning, with a focus on linear algebra, calculus, and probability theory. It will prove valuable both as a tutorial for newcomers to the field, and as a reference text for machine learning researchers and engineers.' Christopher Bishop, Microsoft Research Cambridge

'This book provides a beautiful exposition of the mathematics underpinning modern machine learning. Highly recommended for anyone wanting a one-stop shop to acquire a deep understanding of machine learning foundations.' Pieter Abbeel, University of California, Berkeley

'The book hits the right level of detail for me. Too many of the ML books have a "don't worry your pretty head about this detail" mentality, or go the other way and overwhelm me with detail. Your book is comprehensive and has a sense of ease and expanse, but it feels like I can get to the application part quickly enough.' Sriram Srinivasan