about this book

This book dives into the design of ML algorithms from scratch. Throughout the book, you will develop mathematical intuition for classic and modern ML algorithms and learn the fundamentals of Bayesian inference and deep learning as well as data structures and algorithmic paradigms in ML.

Understanding ML algorithms from scratch will help you choose the right algorithm for the task, explain the results, troubleshoot advanced problems, extend algorithms to new applications, and improve the performance of existing algorithms.

What makes this book stand out from the crowd is its from-scratch analysis that discusses how and why ML algorithms work in significant depth, a carefully selected set of algorithms that I found most useful and impactful in my experience as a PhD student in machine learning, fully worked out derivations and implementations of ML algorithms explained in the text, as well as some other topics less commonly found in other ML texts.

After reading this book, you'll have a solid mathematical intuition for classic and modern ML algorithms in the areas of supervised and unsupervised learning, and will have gained experience in the domains of core ML, natural language processing, computer vision, optimization, computational biology, and finance.

Who should read this book

This book was written for anyone interested in exploring machine learning algorithms in depth. It may prove invaluable to many different types of readers, including the following:

- Aspiring data scientists
- Entry- to principal-level data scientists
- Software developers seeking to transition to data science
- Data engineers seeking to deepen their knowledge of ML models
- Graduate students with research interests in ML
- Undergraduate students interested in ML

The prerequisites for reading this book include a basic level of programming skills in Python, and an intermediate level of understanding of linear algebra, applied probability, and multivariable calculus.

How this book is organized

This book is structured in four parts. It is recommended that you read the chapters in sequence if the topic is new to you. However, feel free to reference a particular algorithm if you are more familiar with the subject. Each chapter is followed by a few exercises to help you practice some of the tools taught in the chapter, and you are welcome to reference appendix B for solutions to these exercises. Also, included at the end of each part is a machine learning research section with the purpose of reviewing state-of-the-art work and encouraging the reader to stay on top of a rapidly changing field.

Part 1 reviews different types of ML algorithms, motivates implementation from first principles, and introduces two main camps of Bayesian inference—Markov chain Monte Carlo and variational inference:

- Chapter 1 introduces the subject of Bayesian inference and deep learning as well as algorithmic paradigms and data structures used in the software implementation of machine learning algorithms.
- Chapter 2 introduces key Bayesian concepts and motivates Markov chain Monte Carlo via a series of examples, ranging from stock price estimation to Metropolis-Hastings sampling of a multivariate Gaussian mixture.
- Chapter 3 focuses on variational inference and, in particular, mean-field approximation in application to image denoising in the Ising model.
- Chapter 4 discusses linear, nonlinear, and probabilistic data structures as well as four algorithmic paradigms: complete search, greedy, divide and conquer, and dynamic programming.

Part 2 reviews supervised learning algorithms. Supervised learning algorithms contain labeled examples as part of the training dataset and consist of two main classes—classification and regression:

- Chapter 5 focuses on classification algorithms. We'll derive several classic algorithms, including the perceptron, SVM, logistic regression, naive Bayes, and decision trees.

- Chapter 6 highlights four intriguing regression algorithms: Bayesian linear regression, hierarchical Bayesian regression, KNN regression, and Gaussian process regression.
- Chapter 7 presents a selected set of supervised learning algorithms, including Markov models, such as page rank algorithms and hidden Markov models; imbalanced learning strategies; active learning; Bayesian optimization for hyperparameter selection; and ensemble methods.

Part 3 reviews unsupervised learning algorithms. Unsupervised learning takes place when no training labels are available. In the case of unsupervised learning, we are often interested in discovering patterns in data and learning data representations.

- Chapter 8 starts by looking at the Bayesian nonparametric extension of the K-means algorithm followed by the EM algorithm for Gaussian mixture models. We will then proceed with two different dimensionality reduction techniques—namely, PCA and t-SNE—in application to learning an image manifold.
- Chapter 9 continues the discussion of selected unsupervised learning algorithms. We'll start by looking at latent Dirichlet allocation for learning topic models, followed by density estimators and structure learning algorithms, and concluding with simulated annealing and genetic algorithms.

Part 4 reviews deep learning algorithms. Deep learning algorithms revolutionized the field of machine learning and enabled many research and business applications that were previously thought to be out of reach of classic ML algorithms.

- Chapter 10 begins with deep learning algorithm fundamentals, such as multilayer perceptron and the LeNet convolutional model for MNIST digit classification, followed by more advanced applications, such as image search based on the ResNet50 convolutional neural network. We will dive into recurrent neural networks applied to sequence classification using LSTMs and implement a multi-input model from scratch for sequence similarity. Finally, we'll conduct a comparative study of different optimization algorithms used for training deep neural networks.
- Chapter 11 presents more advanced deep learning algorithms. We will investigate generative models based on variational autoencoders and implement an anomaly detector from scratch for time-series data. We'll study an intriguing combination of neural networks and probabilistic graphical models, and implement a mixture density network from scratch. Next, we'll describe the powerful transformer architecture and apply it to text classification. Finally, we'll examine graph neural networks and use one to classify nodes in a citation graph.

About the code

This book contains many examples of source code both in numbered listings and in line with normal text. In both cases, source code is formatted in a `fixed-width font like this` to separate it from ordinary text.

In many cases, the original source code has been reformatted; we've added line breaks and reworked indentation to accommodate the available page space in the book. In rare cases, even this was not enough, and listings include line-continuation markers (➥). Additionally, comments in the source code have often been removed from the listings when the code is described in the text. Code annotations accompany many of the listings, highlighting important concepts.

You can get executable snippets of code from the liveBook (online) version of this book at https://livebook.manning.com/book/machine-learning-algorithms-in-depth. All code examples are available for download from the book's website: https://www.manning.com/books/machine-learning-algorithms-in-depth and on GitHub: https://github.com/vsmolyakov/ml_algo_in_depth.

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