# Preface

Machine learning is an integral part of many commercial applications and research projects today, in areas ranging from medical diagnosis and treatment to finding your friends on social networks. Many people think that machine learning can only be applied by large companies with extensive research teams. In this book, we want to show you how easy it can be to build machine learning solutions yourself, and how to best go about it. With the knowledge in this book, you can build your own system for finding out how people feel on Twitter, or making predictions about global warming. The applications of machine learning are endless and, with the amount of data available today, mostly limited by your imagination.

## Who Should Read This Book

This book is for current and aspiring machine learning practitioners looking to implement solutions to real-world machine learning problems. This is an introductory book requiring no previous knowledge of machine learning or artificial intelligence (AI). We focus on using Python and the `scikit-learn` library, and work through all the steps to create a successful machine learning application. The methods we introduce will be helpful for scientists and researchers, as well as data scientists working on commercial applications. You will get the most out of the book if you are somewhat familiar with Python and the NumPy and `matplotlib` libraries.

We made a conscious effort not to focus too much on the math, but rather on the practical aspects of using machine learning algorithms. As mathematics (probability theory, in particular) is the foundation upon which machine learning is built, we won't go into the analysis of the algorithms in great detail. If you are interested in the mathematics of machine learning algorithms, we recommend the book *The Elements of Statistical Learning* (Springer) by Trevor Hastie, Robert Tibshirani, and Jerome Friedman, which is available for free at the authors' website. We will also not describe how to write machine learning algorithms from scratch, and will instead focus on

how to use the large array of models already implemented in `scikit-learn` and other libraries.

## Why We Wrote This Book

There are many books on machine learning and AI. However, all of them are meant for graduate students or PhD students in computer science, and they're full of advanced mathematics. This is in stark contrast with how machine learning is being used, as a commodity tool in research and commercial applications. Today, applying machine learning does not require a PhD. However, there are few resources out there that fully cover all the important aspects of implementing machine learning in practice, without requiring you to take advanced math courses. We hope this book will help people who want to apply machine learning without reading up on years' worth of calculus, linear algebra, and probability theory.

## Navigating This Book

This book is organized roughly as follows:

- Chapter 1 introduces the fundamental concepts of machine learning and its applications, and describes the setup we will be using throughout the book.
- Chapters 2 and 3 describe the actual machine learning algorithms that are most widely used in practice, and discuss their advantages and shortcomings.
- Chapter 4 discusses the importance of how we represent data that is processed by machine learning, and what aspects of the data to pay attention to.
- Chapter 5 covers advanced methods for model evaluation and parameter tuning, with a particular focus on cross-validation and grid search.
- Chapter 6 explains the concept of pipelines for chaining models and encapsulating your workflow.
- Chapter 7 shows how to apply the methods described in earlier chapters to text data, and introduces some text-specific processing techniques.
- Chapter 8 offers a high-level overview, and includes references to more advanced topics.

While Chapters 2 and 3 provide the actual algorithms, understanding all of these algorithms might not be necessary for a beginner. If you need to build a machine learning system ASAP, we suggest starting with Chapter 1 and the opening sections of Chapter 2, which introduce all the core concepts. You can then skip to "Summary and Outlook" on page 127 in Chapter 2, which includes a list of all the supervised models that we cover. Choose the model that best fits your needs and flip back to read the

section devoted to it for details. Then you can use the techniques in Chapter 5 to evaluate and tune your model.

## Online Resources

While studying this book, definitely refer to the `scikit-learn` website for more in-depth documentation of the classes and functions, and many examples. There is also a video course created by Andreas Müller, "Advanced Machine Learning with scikit-learn," that supplements this book. You can find it at *http://bit.ly/advanced_machine_learning_scikit-learn*.

## Conventions Used in This Book

The following typographical conventions are used in this book:

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: Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords. Also used for commands and module and package names.

**`Constant width bold`**
: Shows commands or other text that should be typed literally by the user.

*`Constant width italic`*
: Shows text that should be replaced with user-supplied values or by values determined by context.

This element signifies a tip or suggestion.

This element signifies a general note.

This icon indicates a warning or caution.

## Using Code Examples

Supplemental material (code examples, IPython notebooks, etc.) is available for download at *https://github.com/amueller/introduction_to_ml_with_python*.

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# Acknowledgments

## From Andreas

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CHAPTER 1

# Introduction

Machine learning is about extracting knowledge from data. It is a research field at the intersection of statistics, artificial intelligence, and computer science and is also known as predictive analytics or statistical learning. The application of machine learning methods has in recent years become ubiquitous in everyday life. From automatic recommendations of which movies to watch, to what food to order or which products to buy, to personalized online radio and recognizing your friends in your photos, many modern websites and devices have machine learning algorithms at their core. When you look at a complex website like Facebook, Amazon, or Netflix, it is very likely that every part of the site contains multiple machine learning models.

Outside of commercial applications, machine learning has had a tremendous influence on the way data-driven research is done today. The tools introduced in this book have been applied to diverse scientific problems such as understanding stars, finding distant planets, discovering new particles, analyzing DNA sequences, and providing personalized cancer treatments.

Your application doesn't need to be as large-scale or world-changing as these examples in order to benefit from machine learning, though. In this chapter, we will explain why machine learning has become so popular and discuss what kinds of problems can be solved using machine learning. Then, we will show you how to build your first machine learning model, introducing important concepts along the way.

## Why Machine Learning?

In the early days of "intelligent" applications, many systems used handcoded rules of "if" and "else" decisions to process data or adjust to user input. Think of a spam filter whose job is to move the appropriate incoming email messages to a spam folder. You could make up a blacklist of words that would result in an email being marked as