

Community Experience Distilled

# Machine Learning with Spark

Create scalable machine learning applications to power a modern data-driven business using Spark

Nick Pentreath

[PACKT] open source\*  
PUBLISHING community experience distilled

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BIRMINGHAM - MUMBAI

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Nick is a member of the Apache Spark Project Management Committee.

---

# Acknowledgments

Writing this book has been quite a rollercoaster ride over the past year, with many ups and downs, late nights, and working weekends. It has also been extremely rewarding to combine my passion for machine learning with my love of the Apache Spark project, and I hope to bring some of this out in this book.

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Finally, thanks to all of you reading this; I hope you find it useful!

---

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# Table of Contents

<b>Preface</b>	<b>1</b>
<b>Chapter 1: Getting Up and Running with Spark</b>	<b>7</b>
<b>Installing and setting up Spark locally</b>	<b>8</b>
<b>Spark clusters</b>	<b>10</b>
<b>The Spark programming model</b>	<b>11</b>
SparkContext and SparkConf	11
The Spark shell	12
Resilient Distributed Datasets	14
Creating RDDs	15
Spark operations	15
Caching RDDs	18
Broadcast variables and accumulators	19
<b>The first step to a Spark program in Scala</b>	<b>21</b>
<b>The first step to a Spark program in Java</b>	<b>24</b>
<b>The first step to a Spark program in Python</b>	<b>28</b>
<b>Getting Spark running on Amazon EC2</b>	<b>30</b>
Launching an EC2 Spark cluster	31
<b>Summary</b>	<b>35</b>
<b>Chapter 2: Designing a Machine Learning System</b>	<b>37</b>
<b>Introducing MovieStream</b>	<b>38</b>
<b>Business use cases for a machine learning system</b>	<b>39</b>
Personalization	40
Targeted marketing and customer segmentation	40
Predictive modeling and analytics	41
<b>Types of machine learning models</b>	<b>41</b>
<b>The components of a data-driven machine learning system</b>	<b>42</b>
Data ingestion and storage	42
Data cleansing and transformation	43

---

*Table of Contents*

---

Model training and testing loop	45
Model deployment and integration	45
Model monitoring and feedback	45
Batch versus real time	47
<b>An architecture for a machine learning system</b>	<b>48</b>
Practical exercise	49
<b>Summary</b>	<b>50</b>
<b>Chapter 3: Obtaining, Processing, and Preparing Data with Spark</b>	<b>51</b>
<b>Accessing publicly available datasets</b>	<b>52</b>
The MovieLens 100k dataset	54
<b>Exploring and visualizing your data</b>	<b>55</b>
Exploring the user dataset	57
Exploring the movie dataset	62
Exploring the rating dataset	64
<b>Processing and transforming your data</b>	<b>68</b>
Filling in bad or missing data	69
<b>Extracting useful features from your data</b>	<b>70</b>
Numerical features	71
Categorical features	71
Derived features	73
Transforming timestamps into categorical features	73
Text features	75
Simple text feature extraction	76
Normalizing features	80
Using MLlib for feature normalization	81
Using packages for feature extraction	82
<b>Summary</b>	<b>82</b>
<b>Chapter 4: Building a Recommendation Engine with Spark</b>	<b>83</b>
<b>Types of recommendation models</b>	<b>84</b>
Content-based filtering	85
Collaborative filtering	85
Matrix factorization	86
<b>Extracting the right features from your data</b>	<b>92</b>
Extracting features from the MovieLens 100k dataset	92
<b>Training the recommendation model</b>	<b>96</b>
Training a model on the MovieLens 100k dataset	96
Training a model using implicit feedback data	98
<b>Using the recommendation model</b>	<b>99</b>
User recommendations	99
Generating movie recommendations from the MovieLens 100k dataset	99

---

Item recommendations	102
Generating similar movies for the MovieLens 100k dataset	103
<b>Evaluating the performance of recommendation models</b>	<b>106</b>
Mean Squared Error	107
Mean average precision at K	109
Using MLib's built-in evaluation functions	113
RMSE and MSE	113
MAP	113
<b>Summary</b>	<b>115</b>
<b>Chapter 5: Building a Classification Model with Spark</b>	<b>117</b>
<hr/>	
<b>Types of classification models</b>	<b>120</b>
Linear models	120
Logistic regression	122
Linear support vector machines	123
The naïve Bayes model	124
Decision trees	126
<b>Extracting the right features from your data</b>	<b>128</b>
Extracting features from the Kaggle/StumbleUpon evergreen classification dataset	128
<b>Training classification models</b>	<b>130</b>
Training a classification model on the Kaggle/StumbleUpon evergreen classification dataset	131
<b>Using classification models</b>	<b>133</b>
Generating predictions for the Kaggle/StumbleUpon evergreen classification dataset	133
<b>Evaluating the performance of classification models</b>	<b>134</b>
Accuracy and prediction error	134
Precision and recall	136
ROC curve and AUC	138
<b>Improving model performance and tuning parameters</b>	<b>140</b>
Feature standardization	141
Additional features	144
Using the correct form of data	147
Tuning model parameters	148
Linear models	149
Decision trees	154
The naïve Bayes model	155
Cross-validation	156
<b>Summary</b>	<b>159</b>

---

<b>Chapter 6: Building a Regression Model with Spark</b>	<b>161</b>
<b>Types of regression models</b>	<b>162</b>
Least squares regression	162
Decision trees for regression	163
<b>Extracting the right features from your data</b>	<b>164</b>
Extracting features from the bike sharing dataset	164
Creating feature vectors for the linear model	168
Creating feature vectors for the decision tree	169
<b>Training and using regression models</b>	<b>170</b>
Training a regression model on the bike sharing dataset	171
<b>Evaluating the performance of regression models</b>	<b>173</b>
Mean Squared Error and Root Mean Squared Error	173
Mean Absolute Error	174
Root Mean Squared Log Error	174
The R-squared coefficient	175
Computing performance metrics on the bike sharing dataset	175
Linear model	175
Decision tree	176
<b>Improving model performance and tuning parameters</b>	<b>177</b>
Transforming the target variable	177
Impact of training on log-transformed targets	180
Tuning model parameters	183
Creating training and testing sets to evaluate parameters	183
The impact of parameter settings for linear models	184
The impact of parameter settings for the decision tree	192
<b>Summary</b>	<b>195</b>
<b>Chapter 7: Building a Clustering Model with Spark</b>	<b>197</b>
<b>Types of clustering models</b>	<b>198</b>
K-means clustering	198
Initialization methods	202
Variants	203
Mixture models	203
Hierarchical clustering	203
<b>Extracting the right features from your data</b>	<b>204</b>
Extracting features from the MovieLens dataset	204
Extracting movie genre labels	205
Training the recommendation model	207
Normalization	207
<b>Training a clustering model</b>	<b>208</b>
Training a clustering model on the MovieLens dataset	208
<b>Making predictions using a clustering model</b>	<b>210</b>
Interpreting cluster predictions on the MovieLens dataset	211
Interpreting the movie clusters	212

---

<b>Evaluating the performance of clustering models</b>	<b>216</b>
Internal evaluation metrics	216
External evaluation metrics	216
Computing performance metrics on the MovieLens dataset	217
<b>Tuning parameters for clustering models</b>	<b>217</b>
Selecting K through cross-validation	217
<b>Summary</b>	<b>219</b>
<b>Chapter 8: Dimensionality Reduction with Spark</b>	<b>221</b>
<b>Types of dimensionality reduction</b>	<b>222</b>
Principal Components Analysis	222
Singular Value Decomposition	223
Relationship with matrix factorization	224
Clustering as dimensionality reduction	224
<b>Extracting the right features from your data</b>	<b>225</b>
Extracting features from the LFW dataset	225
Exploring the face data	226
Visualizing the face data	228
Extracting facial images as vectors	229
Normalization	233
<b>Training a dimensionality reduction model</b>	<b>234</b>
Running PCA on the LFW dataset	235
Visualizing the Eigenfaces	236
Interpreting the Eigenfaces	238
<b>Using a dimensionality reduction model</b>	<b>238</b>
Projecting data using PCA on the LFW dataset	239
The relationship between PCA and SVD	240
<b>Evaluating dimensionality reduction models</b>	<b>242</b>
Evaluating k for SVD on the LFW dataset	242
<b>Summary</b>	<b>245</b>
<b>Chapter 9: Advanced Text Processing with Spark</b>	<b>247</b>
<b>What's so special about text data?</b>	<b>247</b>
<b>Extracting the right features from your data</b>	<b>248</b>
Term weighting schemes	248
Feature hashing	249
Extracting the TF-IDF features from the 20 Newsgroups dataset	251
Exploring the 20 Newsgroups data	253
Applying basic tokenization	255
Improving our tokenization	256
Removing stop words	258
Excluding terms based on frequency	261
A note about stemming	264
Training a TF-IDF model	264
Analyzing the TF-IDF weightings	266

<b>Using a TF-IDF model</b>	<b>268</b>
Document similarity with the 20 Newsgroups dataset and TF-IDF features	268
Training a text classifier on the 20 Newsgroups dataset using TF-IDF	271
<b>Evaluating the impact of text processing</b>	<b>273</b>
Comparing raw features with processed TF-IDF features on the 20 Newsgroups dataset	273
<b>Word2Vec models</b>	<b>274</b>
Word2Vec on the 20 Newsgroups dataset	275
<b>Summary</b>	<b>278</b>
<b>Chapter 10: Real-time Machine Learning with Spark Streaming</b>	<b>279</b>
<b>Online learning</b>	<b>279</b>
<b>Stream processing</b>	<b>281</b>
An introduction to Spark Streaming	281
Input sources	282
Transformations	282
Actions	284
Window operators	284
Caching and fault tolerance with Spark Streaming	285
<b>Creating a Spark Streaming application</b>	<b>286</b>
The producer application	287
Creating a basic streaming application	290
Streaming analytics	293
Stateful streaming	296
<b>Online learning with Spark Streaming</b>	<b>298</b>
Streaming regression	298
A simple streaming regression program	299
Creating a streaming data producer	299
Creating a streaming regression model	302
Streaming K-means	305
<b>Online model evaluation</b>	<b>306</b>
Comparing model performance with Spark Streaming	306
<b>Summary</b>	<b>310</b>
<b>Index</b>	<b>311</b>

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# Preface

In recent years, the volume of data being collected, stored, and analyzed has exploded, in particular in relation to the activity on the Web and mobile devices, as well as data from the physical world collected via sensor networks. While previously large-scale data storage, processing, analysis, and modeling was the domain of the largest institutions such as Google, Yahoo!, Facebook, and Twitter, increasingly, many organizations are being faced with the challenge of how to handle a massive amount of data.

When faced with this quantity of data and the common requirement to utilize it in real time, human-powered systems quickly become infeasible. This has led to a rise in the so-called big data and machine learning systems that learn from this data to make automated decisions.

In answer to the challenge of dealing with ever larger-scale data without any prohibitive cost, new open source technologies emerged at companies such as Google, Yahoo!, Amazon, and Facebook, which aimed at making it easier to handle massive data volumes by distributing data storage and computation across a cluster of computers.

The most widespread of these is Apache Hadoop, which made it significantly easier and cheaper to both store large amounts of data (via the Hadoop Distributed File System, or HDFS) and run computations on this data (via Hadoop MapReduce, a framework to perform computation tasks in parallel across many nodes in a computer cluster).



However, MapReduce has some important shortcomings, including high overheads to launch each job and reliance on storing intermediate data and results of the computation to disk, both of which make Hadoop relatively ill-suited for use cases of an iterative or low-latency nature. Apache Spark is a new framework for distributed computing that is designed from the ground up to be optimized for low-latency tasks and to store intermediate data and results in memory, thus addressing some of the major drawbacks of the Hadoop framework. Spark provides a clean, functional, and easy-to-understand API to write applications and is fully compatible with the Hadoop ecosystem.

Furthermore, Spark provides native APIs in Scala, Java, and Python. The Scala and Python APIs allow all the benefits of the Scala or Python language, respectively, to be used directly in Spark applications, including using the relevant interpreter for real-time, interactive exploration. Spark itself now provides a toolkit (called MLlib) of distributed machine learning and data mining models that is under heavy development and already contains high-quality, scalable, and efficient algorithms for many common machine learning tasks, some of which we will delve into in this book.

Applying machine learning techniques to massive datasets is challenging, primarily because most well-known machine learning algorithms are not designed for parallel architectures. In many cases, designing such algorithms is not an easy task. The nature of machine learning models is generally iterative, hence the strong appeal of Spark for this use case. While there are many competing frameworks for parallel computing, Spark is one of the few that combines speed, scalability, in-memory processing, and fault tolerance with ease of programming and a flexible, expressive, and powerful API design.

Throughout this book, we will focus on real-world applications of machine learning technology. While we may briefly delve into some theoretical aspects of machine learning algorithms, the book will generally take a practical, applied approach with a focus on using examples and code to illustrate how to effectively use the features of Spark and MLlib, as well as other well-known and freely available packages for machine learning and data analysis, to create a useful machine learning system.

## What this book covers

*Chapter 1, Getting Up and Running with Spark*, shows how to install and set up a local development environment for the Spark framework as well as how to create a Spark cluster in the cloud using Amazon EC2. The Spark programming model and API will be introduced, and a simple Spark application will be created using each of Scala, Java, and Python.

*Chapter 2, Designing a Machine Learning System*, presents an example of a real-world use case for a machine learning system. We will design a high-level architecture for an intelligent system in Spark based on this illustrative use case.

*Chapter 3, Obtaining, Processing, and Preparing Data with Spark*, details how to go about obtaining data for use in a machine learning system, in particular from various freely and publicly available sources. We will learn how to process, clean, and transform the raw data into features that may be used in machine learning models, using available tools, libraries, and Spark's functionality.

*Chapter 4, Building a Recommendation Engine with Spark*, deals with creating a recommendation model based on the collaborative filtering approach. This model will be used to recommend items to a given user as well as create lists of items that are similar to a given item. Standard metrics to evaluate the performance of a recommendation model will be covered here.

*Chapter 5, Building a Classification Model with Spark*, details how to create a model for binary classification as well as how to utilize standard performance-evaluation metrics for classification tasks.

*Chapter 6, Building a Regression Model with Spark*, shows how to create a model for regression, extending the classification model created in *Chapter 5, Building a Classification Model with Spark*. Evaluation metrics for the performance of regression models will be detailed here.

*Chapter 7, Building a Clustering Model with Spark*, explores how to create a clustering model as well as how to use related evaluation methodologies. You will learn how to analyze and visualize the clusters generated.

*Chapter 8, Dimensionality Reduction with Spark*, takes us through methods to extract the underlying structure from and reduce the dimensionality of our data. You will learn some common dimensionality-reduction techniques and how to apply and analyze them, as well as how to use the resulting data representation as input to another machine learning model.

*Chapter 9, Advanced Text Processing with Spark*, introduces approaches to deal with large-scale text data, including techniques for feature extraction from text and dealing with the very high-dimensional features typical in text data.

*Chapter 10, Real-time Machine Learning with Spark Streaming*, provides an overview of Spark Streaming and how it fits in with the online and incremental learning approaches to apply machine learning on data streams.

## What you need for this book

Throughout this book, we assume that you have some basic experience with programming in Scala, Java, or Python and have some basic knowledge of machine learning, statistics, and data analysis.

## Who this book is for

This book is aimed at entry-level to intermediate data scientists, data analysts, software engineers, and practitioners involved in machine learning or data mining with an interest in large-scale machine learning approaches, but who are not necessarily familiar with Spark. You may have some experience of statistics or machine learning software (perhaps including MATLAB, scikit-learn, Mahout, R, Weka, and so on) or distributed systems (perhaps including some exposure to Hadoop).

## Conventions

In this book, you will find a number of styles of text that distinguish between different kinds of information. Here are some examples of these styles, and an explanation of their meaning.

Code words in text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles are shown as follows: "Spark places user scripts to run Spark in the `bin` directory."



A block of code is set as follows:



```
val conf = new SparkConf()
  .setAppName("Test Spark App")
  .setMaster("local[4]")
val sc = new SparkContext(conf)
```

Any command-line input or output is written as follows:

```
>tar xfvz spark-1.2.0-bin-hadoop2.4.tgz
>cd spark-1.2.0-bin-hadoop2.4
```

**New terms** and **important words** are shown in bold. Words that you see on the screen, in menus or dialog boxes for example, appear in the text like this: "These can be obtained from the AWS homepage by clicking **Account** | **Security Credentials** | **Access Credentials**."

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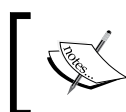
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# 1

## Getting Up and Running with Spark

Apache Spark is a framework for distributed computing; this framework aims to make it simpler to write programs that run in parallel across many nodes in a cluster of computers. It tries to abstract the tasks of resource scheduling, job submission, execution, tracking, and communication between nodes, as well as the low-level operations that are inherent in parallel data processing. It also provides a higher level API to work with distributed data. In this way, it is similar to other distributed processing frameworks such as Apache Hadoop; however, the underlying architecture is somewhat different.

Spark began as a research project at the University of California, Berkeley. The university was focused on the use case of distributed machine learning algorithms. Hence, it is designed from the ground up for high performance in applications of an iterative nature, where the same data is accessed multiple times. This performance is achieved primarily through caching datasets in memory, combined with low latency and overhead to launch parallel computation tasks. Together with other features such as fault tolerance, flexible distributed-memory data structures, and a powerful functional API, Spark has proved to be broadly useful for a wide range of large-scale data processing tasks, over and above machine learning and iterative analytics.



For more background on Spark, including the research papers underlying Spark's development, see the project's history page at <http://spark.apache.org/community.html#history>.



Spark runs in four modes:

- The standalone local mode, where all Spark processes are run within the same **Java Virtual Machine (JVM)** process
- The standalone cluster mode, using Spark's own built-in job-scheduling framework
- Using Mesos, a popular open source cluster-computing framework
- Using YARN (commonly referred to as NextGen MapReduce), a Hadoop-related cluster-computing and resource-scheduling framework

In this chapter, we will:

- Download the Spark binaries and set up a development environment that runs in Spark's standalone local mode. This environment will be used throughout the rest of the book to run the example code.
- Explore Spark's programming model and API using Spark's interactive console.
- Write our first Spark program in Scala, Java, and Python.
- Set up a Spark cluster using Amazon's **Elastic Cloud Compute (EC2)** platform, which can be used for large-sized data and heavier computational requirements, rather than running in the local mode.



Spark can also be run on Amazon's Elastic MapReduce service using custom bootstrap action scripts, but this is beyond the scope of this book. The following article is a good reference guide: <http://aws.amazon.com/articles/Elastic-MapReduce/4926593393724923>. At the time of writing this book, the article covers running Spark Version 1.1.0.

If you have previous experience in setting up Spark and are familiar with the basics of writing a Spark program, feel free to skip this chapter.

## Installing and setting up Spark locally

Spark can be run using the built-in standalone cluster scheduler in the local mode. This means that all the Spark processes are run within the same JVM – effectively, a single, multithreaded instance of Spark. The local mode is very useful for prototyping, development, debugging, and testing. However, this mode can also be useful in real-world scenarios to perform parallel computation across multiple cores on a single computer.

As Spark's local mode is fully compatible with the cluster mode, programs written and tested locally can be run on a cluster with just a few additional steps.

The first step in setting up Spark locally is to download the latest version (at the time of writing this book, the version is 1.2.0). The download page of the Spark project website, found at <http://spark.apache.org/downloads.html>, contains links to download various versions as well as to obtain the latest source code via GitHub.



The Spark project documentation website at <http://spark.apache.org/docs/latest/> is a comprehensive resource to learn more about Spark. We highly recommend that you explore it!

Spark needs to be built against a specific version of Hadoop in order to access **Hadoop Distributed File System (HDFS)** as well as standard and custom Hadoop input sources. The download page provides prebuilt binary packages for Hadoop 1, CDH4 (Cloudera's Hadoop Distribution), MapR's Hadoop distribution, and Hadoop 2 (YARN). Unless you wish to build Spark against a specific Hadoop version, we recommend that you download the prebuilt Hadoop 2.4 package from an Apache mirror using this link: <http://www.apache.org/dyn/closer.cgi/spark/spark-1.2.0/spark-1.2.0-bin-hadoop2.4.tgz>.

Spark requires the Scala programming language (version 2.10.4 at the time of writing this book) in order to run. Fortunately, the prebuilt binary package comes with the Scala runtime packages included, so you don't need to install Scala separately in order to get started. However, you will need to have a **Java Runtime Environment (JRE)** or **Java Development Kit (JDK)** installed (see the software and hardware list in this book's code bundle for installation instructions).

Once you have downloaded the Spark binary package, unpack the contents of the package and change into the newly created directory by running the following commands:

```
>tar xfvz spark-1.2.0-bin-hadoop2.4.tgz
>cd spark-1.2.0-bin-hadoop2.4
```

Spark places user scripts to run Spark in the `bin` directory. You can test whether everything is working correctly by running one of the example programs included in Spark:

```
>./bin/run-example org.apache.spark.examples.SparkPi
```



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