

# Pro Deep Learning with TensorFlow

A Mathematical Approach to Advanced  
Artificial Intelligence in Python



Santanu Pattanayak

Apress®

## ***Pro Deep Learning with TensorFlow***

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*To my wife, Sonia.*

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# About the Author



**Santanu Pattanayak** currently works at GE, Digital as a senior data scientist. He has ten years of overall work experience, with six of years of experience in the data analytics/data science field. He also has a background in development and database technologies. Prior to joining GE, Santanu worked at companies such as RBS, Capgemini, and IBM. He graduated with a degree in electrical engineering from Jadavpur University, Kolkata in India and is an avid math enthusiast. Santanu is currently pursuing a master's degree in data science from Indian Institute of Technology (IIT), Hyderabad. He also devotes his time to data science hackathons and Kaggle competitions, where he ranks within the top five hundred across the globe. Santanu was born and raised in West Bengal, India, and currently resides in Bangalore, India, with his wife. You can visit him at <http://www.santanupattanayak.com/> to check out his current activities.

# About the Technical Reviewer



**Manohar Swamynathan** is a data science practitioner and an avid programmer, with over thirteen years of experience in various data science-related areas, including data warehousing, business intelligence (BI), analytical tool development, ad-hoc analysis, predictive modeling, data science product development, consulting, formulating strategy, and executing analytics programs. His career has covered the life cycle of data across different domains, such as US mortgage banking, retail/e-commerce, insurance, and industrial Internet of Things (IoT). He has a bachelor's degree with a specialization in physics, mathematics, and computers, as well as a master's degree in project management. He's currently living in Bengaluru, the Silicon Valley of India.

He authored the book *Mastering Machine Learning with Python in Six Steps*. You can learn more about his various other activities at <http://www.mswamynathan.com>.

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# Introduction

*Pro Deep Learning with TensorFlow* is a practical and mathematical guide to deep learning using TensorFlow. Deep learning is a branch of machine learning where you model the world in terms of a hierarchy of concepts. This pattern of learning is similar to the way a human brain learns, and it allows computers to model complex concepts that often go unnoticed in other traditional methods of modeling. Hence, in the modern computing paradigm, deep learning plays a vital role in modeling complex real-world problems, especially by leveraging the massive amount of unstructured data available today.

Because of the complexities involved in a deep-learning model, many times it is treated as a black box by people using it. However, to derive the maximum benefit from this branch of machine learning, one needs to uncover the hidden mystery by looking at the science and mathematics associated with it. In this book, great care has been taken to explain the concepts and techniques associated with deep learning from a mathematical as well as a scientific viewpoint. Also, the first chapter is totally dedicated toward building the mathematical base required to comprehend deep-learning concepts with ease. TensorFlow has been chosen as the deep-learning package because of its flexibility for research purposes and its ease of use. Another reason for choosing TensorFlow is its capability to load models with ease in a live production environment using its serving capabilities.

In summary, *Pro Deep Learning with TensorFlow* provides practical, hands-on expertise so you can learn deep learning from scratch and deploy meaningful deep-learning solutions. This book will allow you to get up to speed quickly using TensorFlow and to optimize different deep-learning architectures. All the practical aspects of deep learning that are relevant in any industry are emphasized in this book. You will be able to use the prototypes demonstrated to build new deep-learning applications. The code presented in the book is available in the form of iPython notebooks and scripts that allow you to try out examples and extend them in interesting ways. You will be equipped with the mathematical foundation and scientific knowledge to pursue research in this field and give back to the community.

## Who This Book Is For

- This book is for data scientists and machine-learning professionals looking at deep-learning solutions to solve complex business problems.
- This book is for software developers working on deep-learning solutions through TensorFlow.
- This book is for graduate students and open source enthusiasts with a constant desire to learn.

## What You'll Learn

The chapters covered in this book are as follows:

**Chapter 1 — *Mathematical Foundations*:** In this chapter, all the relevant mathematical concepts from linear algebra, probability, calculus, optimization, and machine-learning formulation are discussed in detail to lay the mathematical foundation required for deep learning. The various concepts are explained with a focus on their use in the fields of machine learning and deep learning.

**Chapter 2 — *Introduction to Deep-Learning Concepts and TensorFlow*:** This chapter introduces the world of deep learning and discusses its evolution over the years. The key building blocks of neural networks, along with several methods of learning, such as the perceptron-learning rule and backpropagation methods, are discussed in detail. Also, this chapter introduces the paradigm of TensorFlow coding so that readers are accustomed to the basic syntax before moving on to more-involved implementations in TensorFlow.

**Chapter 3 — *Convolutional Neural Networks*:** This chapter deals with convolutional neural networks used for image processing. Image processing is a computer vision issue that has seen a huge boost in performance in the areas of object recognition and detection, object classification, localization, and segmentation using convolutional neural networks. The chapter starts by illustrating the operation of convolution in detail and then moves on to the working principles of a convolutional neural network. Much emphasis is given to the building blocks of a convolutional neural network to give the reader the tools needed to experiment and extend their networks in interesting ways. Further, backpropagation through convolutional and pooling layers is discussed in detail so that the reader has a holistic view of the training process of convolutional networks. Also covered in this chapter are the properties of equivariance and translation invariance, which are central to the success of convolutional neural networks.

**Chapter 4 — *Natural Language Processing Using Recurrent Neural Networks*:** This chapter deals with natural language processing using deep learning. It starts with different vector space models for text processing; word-to-vector embedding models, such as the continuous bag of words method and skip-grams; and then moves to much more advanced topics that involve recurrent neural networks (RNN), LSTM, bidirection RNN, and GRU. Language modeling is covered in detail in this chapter to help the reader utilize these networks in real-world problems involving the same. Also, the mechanism of backpropagation in cases of RNNs and LSTM as well vanishing-gradient problems are discussed in much detail.

**Chapter 5 — *Unsupervised Learning with Restricted Boltzmann Machines and Auto-encoders*:** In this chapter, you will learn about unsupervised methods in deep learning that use restricted Boltzmann machines (RBMs) and auto-encoders. Also, the chapter will touch upon Bayesian inference and Markov chain Monte Carlo (MCMC) methods, such as the Metropolis algorithm and Gibbs sampling, since the RBM training process requires some knowledge of sampling. Further, this chapter will discuss contrastive divergence, a customized version of Gibbs sampling that allows for the practical training of RBMs. We will further discuss how RBMs can be used for collaborative filtering in recommender systems as well as their use in unsupervised pre-training of deep belief networks (DBNs).

In the second part of the chapter, various kinds of auto-encoders are covered, such as sparse encoders, denoising auto-encoders, and so forth. Also, the reader will learn about how internal features learned from the auto-encoders can be utilized for dimensionality reduction as well as for supervised learning. Finally, the chapter ends with a little brief on data pre-processing techniques, such as PCA whitening and ZCA whitening.

**Chapter 6 — *Advanced Neural Networks*:** In this chapter, the reader will learn about some of the advanced neural networks, such as fully convolutional neural networks, R-CNN, Fast R-CNN, Faster, U-Net, and so forth, that deal with semantic segmentation of images, object detection, and localization. This chapter also introduces the readers to traditional image segmentation methods so that they can combine the best of both worlds as appropriate. In the second half of the chapter, the reader will learn about the Generative Adversarial Network (GAN), a new schema of generative model used for producing synthetic data like the data produced by a given distribution. GAN has usages and potential in several fields, such as in image generation, image inpainting, abstract reasoning, semantic segmentation, video generation, style transfer from one domain to another, and text-to-image generation applications, among others.

To summarize, the key learnings the reader can expect from this book are as follows:

- Understand full-stack deep learning using TensorFlow and gain a solid mathematical foundation for deep learning
- Deploy complex deep-learning solutions in production using TensorFlow
- Carry out research on deep learning and perform experiments using TensorFlow