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Deep Learning from Scratch

Building with Python from First Principles

Seth Weidman

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by Seth Weidman

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

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September 2019: First Edition

Revision History for the First Edition

- 2019-09-06: First Release

Chapter 1. Foundations

> Don't memorize these formulas. If you understand the concepts, you can invent your own notation.
>
> John Cochrane, *Investments Notes* 2006

The aim of this chapter is to explain some foundational mental models that are essential for understanding how neural networks work. Specifically, we'll cover nested mathematical functions and their derivatives. We'll work our way up from the simplest possible building blocks to show that we can build complicated functions made up of a "chain" of constituent functions and, even when one of these functions is a matrix multiplication that takes in multiple inputs, compute the derivative of the functions' outputs with respect to their inputs. Understanding how this process works will be essential to understanding neural networks, which we technically won't begin to cover until Chapter 2.

As we're getting our bearings around these foundational building blocks of neural networks, we'll systematically describe each concept we introduce from three perspectives:

- Math, in the form of an equation or equations
- Code, with as little extra syntax as possible (making Python an ideal choice)
- A diagram explaining what is going on, of the kind you would draw on a whiteboard during a coding interview

As mentioned in the preface, one of the challenges of understanding neural networks is that it requires multiple mental models. We'll get a sense of that in this chapter: each of these three perspectives excludes certain essential features of the concepts we'll cover, and only when taken together do they provide a full picture of both how and why nested mathematical functions work the way they do. In fact, I take the uniquely strong view that any attempt to explain the building blocks of neural networks that excludes one of these three perspectives is incomplete.

With that out of the way, it's time to take our first steps. We're going to start with some extremely simple building blocks to illustrate how we can understand different concepts in terms of these three perspectives. Our first building block will be a simple but critical concept: the function.

Functions

What is a function, and how do we describe it? As with neural nets, there are several ways to describe functions, none of which individually paints a complete picture. Rather than trying to give a pithy one-sentence description, let's simply walk through the three mental models one by one, playing the role of the blind men feeling different parts of the elephant.

Math

Here are two examples of functions, described in mathematical notation:

- $f_1(x) = x^2$
- $f_2(x) = max(x, 0)$

This notation says that the functions, which we arbitrarily call f_1 and f_2, take in a number x as input and transform it into either x^2 (in the first case) or $max(x, 0)$ (in the second case).

Diagrams

One way of depicting functions is to:

1. Draw an x-y plane (where x refers to the horizontal axis and y refers to the vertical axis).