

# About This Book

## Why This Book

I believe that deep learning is here to stay and that we have only scratched the surface of what neural networks can actually do. The line between software 1.0 (that is, manually written code) and software 2.0 (learned neural networks) is getting fuzzier and fuzzier, and neural networks are participating in safety-critical, security-critical, and socially-critical tasks. Think, for example, healthcare, self-driving cars, malware detection, etc. But neural networks are fragile and so we need to prove that they are well-behaved when applied in critical settings.

Over the past few decades, the formal methods community has developed a plethora of techniques for automatically proving properties of programs, and, well, neural networks are programs. So there is a great opportunity to port verification ideas to the software 2.0 setting. This book offers the first introduction of foundational ideas from automated verification as applied to deep neural networks and deep learning. I hope that it will inspire verification researchers to explore correctness in deep learning and deep learning researchers to adopt verification technologies.

## Who Is This Book For

Given that the book's subject matter sits at the intersection of two pretty much disparate areas of computer science, one of my main design goals is to make it as self-contained as possible. This way the book can serve as an introduction to the field for first-year graduate students even if they have not been exposed to deep learning or verification.

## What Does This Book Cover

The book is divided into four parts:

- Part 1** defines neural networks as data-flow graphs of operators over real-valued inputs. This formulation will serve as our basis for the rest of the book. Additionally, we will survey a number of correctness properties that are desirable of neural networks and place them in a formal framework.
- Part 2** discusses *constraint-based* techniques for verification. As the name suggests, we construct a system of constraints and solve it to prove (or disprove) that a neural network satisfies some properties.
- Part 3** discusses *abstraction-based* techniques for verification. Instead of executing a neural network on a single input, we can actually execute it on an *infinite* set and show that all of those inputs satisfy desirable correctness properties.
- Part 4** Finally, we will discuss verification technology as applied to deep reinforcement learning tasks, where neural networks are used as controllers in a dynamical system.

Parts 2 and 3 are disjoint; the reader can go directly from Part 1 to Part 3.

## Bibliography

Michael A. Nielsen. *Neural Networks and Deep Learning*. Determination Press, 2018. URL <http://neuralnetworksanddeeplearning.com/>.