Pázmány Péter Catholic University
Faculty of Information Technology and Bionics

Building, testing and visualizing neural networks from scratch

Csaba Botos

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Advisor: PhD. István Z. Reguly

Abstract

Recently a special branch of Machine Learning, a model based on living organic systems called Deep Neural Networks is overtaking previous paradigm of algorithmic problem solving. It gained larger attention when better results were achieved than task-specific, handcrafted models in feature extraction. The reason behind its success is its scalability: the latest architectures are able to exploit the capacity of cutting-edge GPU hardware since the abstraction of the data is accomplished by succeeding neural nodes performing elementary operations, which can be easily paralellized.

It is of the utmost importance to understand the main concept of such networks to contribute to the breakthroughs of the fourth industrial revolution. To this purpose, building a framework from the base unit blocks of the newest models is the best introduction to Machine Learning. In my research I have disassembled black-box representated networks to the very basic, intuitive level and reorganized it in objectoriented manner, where each neural layer is treated as an entity derived from a common ancestor, therefore information flow and processes of the system are easily traced. My design and implementation is based on the principals of the components used by networks built for ImageNet classification, such as Convolutional, ReLU, Max-Pooling, Fully-Connected, Dropout, DropConnect, Softmax and k-Winner-Takes-All layers. Furthermore, the following training methods and policies were adapted: cross validated, minibatch, on-line, L_p regularized and basic Stochastic Gradient Descent training.

For testing the framework, the parameter space of Fully Connected networks was exhaustively explored. After training and evaluating sessions - mainly performed on the MNIST and self-acquired datasets - the results were gathered to analyze the performance of different architectures. For further investigation the best performing models were compared to each other to find pros and cons of different capacity, layout and training of networks.

Besides architectural experiments, a non-trivial task targeted by many recent research of visualizing the inner representation of information, understanding transient activation patterns was studied as well. Previously mentioned candidate networks were also visualized individually to retrieve information about characteristics of the processes in their Hidden Layers. My implementation proposes a simplification of the DeconvNet derived from Gradient Ascent, an efficient algorithm to reveal patterns recognized by nodes in the hidden layers of Neural Networks, to produce adversarial input samples.

Declaration

I, Botos Csaba, declare that this thesis titled 'Building, testing and visualizing neural networks from scratch', and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signature

Contents

1. Introduction

Overview

> *No one knows what the right algorithm is, but it gives us hope that if we can discover some crude approximation of whatever this algorithm is and implement it on a computer, that can help us make a lot of progress.*
>
> — Andrew Ng

Every time we are interacting with our environment, we get closer to understand it However, as a byproduct, questions arise for which pure logical (mathematical) solution is not available, or the problem is larger than to be solved by current ones. Luckily we can always turn back to nature for inspiration: biological systems have proven their efficiency, therefore their functions worths to be further analyzed even if there could be theoretically a better way to tackle obstacles. One of the many branches of artificial intelligence, Neural Network is based on the nerve systems of living organisms which is capable of self-learning.

Such a simple paradigm is playing a fundamental role in boosting the industry and researches of today, because introducing Machine Learning to any field of life results in great leap forward. Thanks to the recent technological advancements, even with the current computational capacity of a personal computer one can get encouraging results by simply exploring the core principles of the topic.

Main motivation. Using outer libraries [1, 3, 9], without diving deep into mathematical proofs, treating neural networks as black-boxes thousands of useful applications [7] are made. On the other hand, building such architectures from the very basics helps to clarify how simple units might be organized, taught [11], and function [8] as a large system. As complexity arises, the processes in the network becomes unclear and brings (yields?) the question: what is the purpose of each node? Methods to visualize how activation patterns formulate, and what information is held within them has been already investigated [12], and applied to improve performance [13]. My studies are mainly rely on recent publications, and researches in field of computer vision. The design of my own Deep Learning framework library is influenced by hot off press tutorials [6, 4, 10, 2, 5] and open-sources [1, 3, 9] available for anyone.

Primary goal. With my work I intend to bring closer, and demystify cutting-edge concepts of applied neural networkings for larger audiences. On related works and case studies I want to show what can be done by simply starting from the drawing board

Importance of understanding

Thesis outline and contributions

2. Literature

3. Designing

4. Implementation

5. Results

6. Conclusion

7. Summary

8. Future

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