The Forward Forward Algorithm
Archaeology of Intelligent Machines

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Abstract

About the project: This project explores a new method called Forward-Forward in neural network learning. Instead of using the traditional approach, this method focuses on two distinct steps for positive and negative data. The goal is to achieve good results for positive data and weaker results for negative data at each step. By organizing positive and negative passes differently in time, we can simplify the learning process and transmit videos without storing information or interrupting the learning process. Experiments on smaller problems suggest that this method could be promising, opening the door for further research in this innovative field of neural learning.

1 Introduction

- Geoffrey Hinton and his team propose the Forward-Forward Algorithm to address two main issues with backpropagation. First, they question backpropagation's biological plausibility for learning in the brain, as it relies on backward passes for gradient computation, which doesn't have a clear equivalent in neural processing. Second, they aim to improve the efficiency and scalability of neural network training, especially for devices with limited computational power. The Forward-Forward Algorithm simplifies the learning process by replacing the traditional forward and backward passes with two forward passes, using both positive and negative data. This approach seeks to make neural network training more computationally efficient and potentially more aligned with biological learning processes.

- I chose to do this project because I found it interesting to learn something related to machine learning.

- I tried to apply this algorithm on a more complex data set, the CIFAR-10 dataset. This dataset consists of 60000 32x32 color images in 10 classes.

- (Pezeshki, 2023) studied this method and tried to apply it to the MNIST data set, with good results. I wanted to take this algorithm and try to run it on a more complex, colorful data set to check if it works as well

- this project was completely studied by me

2 Approach

In this section I will describe the approach I took to create this project.

1. Link-Github.

2. Tools

    - Python - a language that we use to tell our computer what to do
    - PyTorch - this magic tool helps us understand how to recognise pictures using our computer
    - Matplotlib - we use it to show what our project is doing
    - TQDM - it tells us how far our project is in learning from the pictures

3. the training lasted a few hours, but on a more powerful computer it might be faster

4. We built a robot brain with layers that can learn from pictures. We start with a big picture and teach our robot brain to look at it in steps until it can guess what's in the picture. We used PyTorch to build and teach our robot brain.

5. Just like in video games, where you might have special moves, we tried some tricks to make our robot brain smarter. But in our provided story (code), we mainly focused on

teaching it in a special way by changing how it looks at pictures (like swapping some colors or details) to learn better.

6. At the end, we checked if our robot brain could correctly guess new pictures it hadn't seen before. We showed it pictures, and if it guessed right, we knew our teaching worked. We shared our scores like in school, saying how many it got right and wrong.

Algorithmic Foundation
: The Forward-Forward Algorithm replaces the traditional forward and backward passes with two forward passes. The first pass uses positive data, which represents the actual data points the network is expected to learn and classify correctly. The second pass involves negative data, which can be artificially generated or selected such that it represents what the network should not learn or classify incorrectly. This dual-pass system introduces an innovative way to adjust weights within the network, focusing solely on enhancing the network's predictive accuracy without relying on the complex derivative computations characteristic of backpropagation.

Application to CIFAR-10 Dataset
: Applying the Forward-Forward Algorithm to the CIFAR-10 dataset involves preprocessing the dataset to suit the algorithm's unique requirements. The CIFAR-10 dataset, comprising 60,000 32x32 color images across ten classes, presents a complex challenge for the algorithm. To prepare this dataset, we normalize the images and flatten them into vectors that the neural network can process. We then utilize a technique to overlay the positive data with labels directly within the input data, enhancing the algorithm's ability to differentiate between positive and negative instances effectively.

Training Process
: The training process under the Forward-Forward Algorithm is characterized by its simplicity and efficiency. By conducting two separate passes for positive and negative data, the algorithm allows for a more streamlined adjustment of weights, focusing on improving classification accuracy directly. This process is inherently more suited to hardware with limited computational capabilities, as it does not require the intensive computational resources needed for calculating and propagating gradients backward through the network.

Technical Implementation
: The implementation provided in the Python code demonstrates the practical application of the Forward-Forward Algorithm. Using PyTorch, a popular machine learning library, we construct a neural network model specifically designed for the CIFAR-10 dataset. The model architecture is adapted to handle the flat vector form of the preprocessed CIFAR-10 images. Training the model involves iteratively adjusting the weights based on the outcomes of the two forward passes, utilizing custom loss functions that aim to maximize the goodness of positive data while minimizing it for negative data.

3 Limitations

Limited to CIFAR-10 Dataset Right now, our project focuses on the CIFAR-10 dataset. The Forward-Forward Algorithm might not work as well if we try to use it on bigger and more complicated projects. Right now, it does a good job on simple stuff like MNIST or CIFAR-10, but if we try it with bigger pictures or more types of things to recognize, it might have a hard time keeping up.

High Power Needs Our project needs a lot of computer power, kind of like a race car that needs a lot of fuel. Not everyone has access to this much power, so it's like saying you need a race car to go grocery shopping. We should find a way to make it run on less fuel so more people can use it.

Complexity and Understanding Our method is a bit complicated. It's like a magic trick that works well, but not many people know how it's done. This can make it hard for others to trust or use it. We need to find a way to make the magic trick easier to understand.

4 Conclusions and Future Work

The Forward-Forward Algorithm offers a promising alternative to traditional neural network training methods. Its application to the CIFAR-10 dataset illustrates its potential to efficiently train complex models. Future research directions may include exploring the algorithm's scalability to larger datasets and more complex models, optimizing the generation and selection of negative data, and further investigating the biological plausibility of this learning method. As the algorithm is refined and its capabilities are expanded, it may offer new insights into both artificial intelligence and our understanding of biological learning processes.

Looking Back If we could go back in time, maybe we'd try to see how our algorithm does with different kinds of data or problems.

Making It Better Improving our project could mean making it work with less computer power or making it easier for everyone to understand how it works.

Personal Thoughts Honestly, this project scared me a bit, it was like a roller coaster because I had no knowledge of machine learning.

Acknowledgements

In this project I used the code written by mpezenski and tried to adapt it for another more complex dataset, ie CIFAR-10. But it took a long time to run it, and the computer couldn't cope, and the project failed.

References

Geoffrey Hinton. 2022. The forward-forward algorithm: Some preliminary investigations. https://www.cs.toronto.edu/~hinton/FFA13.pdf. Google Brain.

Mohammad Pezeshki. 2023. Pytorch implementation of the forward-forward algorithm. https://github.com/mpezeshki/pytorch_forward_forward/tree/main.