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Multi-threaded learning control mechanism for neural networks

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HIGHLIGHTS

- New approach to training strategies for neural networks.
- Faster and more efficient learning for various neural architectures proceeds in a parallel way.
- Easy application and parameter setting.
- Tests and discussion on the proposed approach.

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ABSTRACT

Neural networks are applicable in many solutions for classification, prediction, control, etc. The variety of purposes is growing but with each new application the expectations are higher. We want neural networks to be more precise independently of the input data. Efficiency of the processing in a large manner depends on the training algorithm. Basically this procedure is based on the random selection of weights in which neurons connections are burdened. During training process we implement a method which involves modification of the weights to minimize the response error of the entire structure. Training continues until the minimum error value is reached — however in general the smaller it is, the time of weight modification is longer. Another problem is that training with the same set of data can cause different training times depending on the initial weight selection. To overcome arising problems we need a method that will boost the procedure and support final precision.

In this article, we propose the use of multi-threading mechanism to minimize training time by rejecting unnecessary weights selection. In the mechanism we use a multi-core solution to select the best weights between all parallel trained networks. Proposed solution was tested for three types of neural networks (classic, sparking and convolutional) using sample classification problems. The results have shown positive aspects of the proposed idea: shorter training time and better efficiency in various tasks.

1. Introduction

Machine Learning (ML) is one of the leading fields in modern computing, primarily related to practical applications in almost every area of technology. Among these methods neural networks have been proved in various systems for classifying, assisting in a variety of analyzes, decision support and predicting based on input data. These are important aspects which over time have more and more applications.

For medical systems [1] presented an analysis of the use of ML methods for fast detection of breast cancer. The authors declared that even relatively low number of labeled data is sufficient for detection of this disease. Research on medical applications of neural networks has huge potential and can make it possible to detect diseases in their embryo. Not only medicine but also mechanics is the scientific area where ML methods are useful. Acharya et al. [2] presented an experiment on a diesel engine, in which different amounts of diesel and biodiesel were injected to the engine under supervision of neural networks. The network controlled parameters of the engine to reduce the fumes toxicity and carbon monoxide due to the fuel mixture composition. Chan et al. [3] presented a neural speech recognizer called Listen, Attend and Spell (LAS). This system is capable to convert speech straight into characters. Obtained results are promising and confirm effectiveness of this approach in smart homes or as a help for blind people. It is possible to use neural networks in industrial process control, what was shown by Wang et al. [4]. They introduced nonlinear model for

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predictive control and confirmed productivity of this method on a continuous stirred tank reactor. He et al. [5] discussed an application of neural networks in cybernetics for the robotic system with full-state constraints, where neural networks co-worked with Lyapunov function. Another important application is computer vision which can be applied in traffic to catch road pirates or at airports to search for criminals. One of these is scene text recognition what was presented and widely discussed by Shi et al. [6]. Also sensor networks can be controlled by neural networks for optimal packet dropouts and quantization [7]. Since computers are more powerful also deep learning techniques are much often used. Deep learning makes it possible to analyze inputs with more details and conclude from the model after broader analysis. Deep convolutional neural networks were reported by Lu et al. [8] to serve as reconstructors for underwater images, while Li and Shen [9] presented deep learning methodology for skin melanoma detection. Distributed attacks in Internet of Things environments can be detected by activity scanners based on deep learning as proposed by Diro and Chilamkurti [10]. Ker et al. [11] presented a discussion on devoted deep learning for medical systems.

Modern computing use parallelization of various aspects to boost the systems and improve efficiency. Various aspects of applications for parallel and distributed computing were presented by Li et al. [12]. Zhou et al. [13] presented parallelization of heuristic methodology where optimization processes were distributed to several cores for faster processing in multi dimensional object spaces. Also scalability of multi processing can efficiently improve processes. Bochenina et al. [14] discussed parallelization of dynamic processes by the use of scalable calculations for large stochastic problems. Similarly Wang et al. [15] presented a novel scalable parallel methodology where atmospheric data was distributed among multi-core clusters. Novel computer systems also use devoted runtime environments where multi-core computer architectures are managed by the use of special work-fames, these aspects were presented by Janetschek et al. [16].

1.1. Related works

Novel computer applications benefit from the development in neural networks, thus the new theoretical issues of ML methods are important in today's research. The innovative ideas, modifications, acceleration of actions and new learning processes for different structures support new applications. First and foremost, the flexibility of ML solutions with possible improvements to the training time are most wanted features. Neural network is a mathematical model of neuronal activity that happens in human brain during thinking and deciding. The most important issue for efficient processing is learning process of these complex structures. Sun et al. [17] presented an adaptation of the classic Back-Propagation Algorithm for improved type of neural classifiers. Authors compare the performance of their approach with others and point to the universality of this process as a key feature. Hossain et al. [18] proposed a hybrid learning method based on classical algorithm and indicated faster convergence to the expected values as the biggest advantage for reduction of learning time. The idea of approximation of the method for learning deep structures was described in Negrov et al. [19]. The authors reported a different approach to achieve faster convergence of the whole process by the use of special synaptic plasticity. Some researchers model learning methods by focusing on prevailing trends. Veeriah et al. [20] have modeled a new neural network learning algorithm based on the analysis of incoming weights from hidden neurons. An interesting design was showed in Lillicrap et al. [21], where was described a simple blame assignment mechanism. The authors said that their solution can help to solve the assumptions about algorithmic constraints in ML.

Spiking Neural Network (SNN) and Convolutional Neural Network (CNN) are the most known architectures that have special purposes in most classification problems. Spiking type increases the level of naturalness in the way the network operates [22]. SNN is based on the mechanisms that takes place in the real, human nerves neural network. It assumes, that neuron must generate an impulse and, depending on the strength of this impulse, the information is passed on to the neighbors. In Dora et al. [23], the idea of a self-regulating evolving network is presented and tested as a tools for classification problems. Moreover in Morro et al. [24], the authors described a stochastic version of this network showing benefits for different benchmark test problems. Convolutional Neural Network (CNN) is dedicated for image processing, where most of the layers are processing directly the input image file. Sharma et al. [25] presented how to modulate a patch based improvement to this structure for remote image sensing. The authors of Lavin and Gray [26] proposed the algorithm to decrease computational cost using Winograd's minimal filtering algorithms. Another important element of the research is to combine different ML techniques to obtain the hybrid methods. The idea of combining fuzzy system with neural networks is shown in Plerou et al. [27] where neuro-fuzzy system was trained by the use of special version of the Back-Propagation Algorithm. M. and Połap [28] presented a hybrid design by combining the heuristic algorithm with the neural system for simulation and control of dynamic systems. The methods used to improve learning abilities of neural structures consider various aspects from synchronization to the pattern output and sophisticated mechanisms for adaption of each processing stage. In Wu et al. [29] was discussed how output synchronization works for heterogeneous network. The authors proposed a technique to synchronize the output from the neural network to the proposed pattern by adaptive reference. Synchronization between various stages of neural processing can be also achieved by dimensional stability as discussed in Wu and Lu [30] or by using derivate of the distributed control law as proposed in Wu and Lu [31]. System dynamics can also influence average dwell time therefore in Zhang et al. [32] was proposed to estimation error for noise signal corrections. While in Zhang and Yu [33] was proposed to use Markovian model of neural networks state switching for minimization of the noise error what gave a mean-square exponentially stable neural architecture.

In this article, we present a novel control mechanism for selecting the best weights among parallel trained architectures. The proposed solution is based on the competition of the same network trained with different weights in parallel on many threads with a comparative control mechanism to select the winning composition. The novelty of this idea is based on adaptation of the parallel calculations for constant comparisons between trained neural structures. We introduce a control core that supervises all training threads, which present results at the end of each iteration to the supervisor. The threads compute the weights for each of the cloned networks. After iteration supervisor core selects the best one which wins a competition after each training stage. The selected best set of weights is copied to the memory for comparisons after next training. The new values are introduced to the parallel processes and new training epoch begins. Continuation of this process on multi cores let us find the best values for connections weights and therefore achieve the minimum error in the most efficient way. Proposed training model uses special coefficients that indicate which of the parallel trained structures show most significant improvement in the current epoch and therefore becomes a pattern for other competitors. Proposed solution was tested on three types of neural networks classic, SNN and CNN for two different popular types of training algorithms. As the benchmark sets were used classic test sets from various areas to examine our idea in details. The results show efficiency in correction of the weights and prove that proposed method can be used for various types of neural networks training models.