Ministry of Education and Science of Ukraine
Dnipro University of Technology
Institute of Economics
Faculty of Management
Department of Foreign Languages
Research and Education Centre “Geotechnical Systems Stability: Processes, Phenomena, Risks”
Akademia Techniczno-Humanistyczna w Bielsku-Białej

WIDENING OUR HORIZONS

The 15th International Forum for Students and Young Researchers

May 20-21, 2020

Abstracts

Dnipro
Dnipro University of Technology
2020

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Top image classification accuracy through hyperparameter search

Artificial neural networks have revolutionized the field of computer vision. Scholars have showed an enormous number of architectures with hyperparameters to tune. That comes with a tough start to new researches or AI developers. The aim of this work is train top modern deep convolutional neural network architectures and to provide supervision on selecting optimal hyperparameters for practical use and to guide how to select them to achieve best accuracy for the given problem.

In recent years we have seen a major shift from algorithms that were fully based on hand-crafted features in early 2010s to neural-network based approaches. Why? For instance, to us the difference between an elephant and a mouse is obvious, but it’s hard to formalize that knowledge in a computer world, where all you get is three matrices of numbers (pixels): one for each of red, green and blue colors. Instead of manual feature engineering neural networks propose a self-learning approach, where a computer tries to learn directly from data.

Yet applying neural networks on practice is still complicated, there are many types, and each type has hyper-parameters to tune. Selecting them wrong might lead to either not-high-enough accuracy or to a model that doesn’t learn at all, furthermore one neural network training session can take hours. Here we present an extensive comparison of hyper-parameters used in modern neural networks and show performance comparison on a widely-used academic dataset.

For the neural-network hyperparameter comparison 3 key metrics will be considered: 1) classification accuracy; 2) training time; 3) model complexity.

To cover the widest possible range of the metrics described above, we have selected 2 models. One is AlexNet [1] International ImageNet [2] competition winner in 2012, offers a reasonably small and fast neural network algorithm. Another is ResNet [3] ImageNet winner in 2015, this network is large and quite slow to train, but it’s also highly tunable, so it might be possible to achieve a high classification accuracy with low-enough training time for a practical use. Both networks are deep AlexNet has “only” 8 layers and ResNet offers basic building blocks that can be used to compose neural networks of 18, 34, 50 and 101 layers deep. Neural network depth is one of the parameters we will optimize and give guidance on.

The training procedure will be conducted as follows: each of the neural network blocks will be attached to a Dropout regularization module [4] and then to a classification head, outputting probabilities for each of the target classes.

Dropout is a regularization method that aims to hide pieces of image from the classification head module, so that neural network trains to find auxiliary features to correctly classify an image. Dropout probability should be in range $[0;1)$, where zero means that no features will be dropped and one is that all features will be removed.

Lastly, we have selected Adaptive Momentum (or Adam) algorithm for training [5]. It has two main hyperparameters: learning rate and batch size. As for learning rate parameter, the same selection logic applies as for ordinary Stochastic Gradient Descent algorithm and can be found easily. We will use batch size as the third and final parameter we will provide a guidance on.

For training data, it has been decided to pick a complex dataset, which requires the network to learn fine-grained features that are hard to be manually characterized. A good pick for that matter is Oxford IIT Pets [6] academic dataset. It features examples of 25 different breeds of dogs and 12 cat breeds (37 classes in total).

The first experiment is to compare different neural network architectures based on Dropout regularization parameter. As is known, regularization is an important method to ensure that a complex neural network doesn't overfit, that is, it doesn't memorize training data and generalizes well to a validation dataset. As we found, AlexNet is the most dependent architecture on the Dropout parameter. This could be explained by the fact that AlexNet is a relatively simple neural network, which doesn't need much regularization and beyond that, excessive dropout damages its capability to train. Dropout as low as 0.25 should be used for AlexNet. All of the ResNet-like architectures from shallow to deep cluster closely around 0.94 accuracy point. Any regularization $\{0.25, 0.5, 0.75\}$ provides good results, yet when the hyperparameter value set too high, specifically to 0.9, the training procedure doesn't feed enough meaningful information for the network to pick up any useful features.

Next, from quality vs model depth comparison we conclude that AlexNet with accuracy above 86% is still worth to be tried in many practical applications, for instance, when your dataset is small, target system is inexpensive and is low on computational resources or you just don't target state-of-the-art accuracy for your application as it's fast to train (30 minutes on GPU). If that's not enough, attempt training ResNet-18. On datasets of practical size, it is still relatively fast with 49 minutes of training and achieves much higher accuracy. The largest network considered, namely ResNet-101 is mostly impractical to use with its nearly 2-hour training time (table 1).

Table 1 – Generalized architecture comparison

Architecture	**Depth**	**Train Loss**	**Validation Loss**	**Accuracy**	**Time to Train (s)**
alexnet	8	0,6392	0,4643	0,8633	1679
resnet18	18	0,2021	0,1999	0,9398	2872
resnet34	34	0,2420	0,1742	0,9472	4300
resnet50	50	0,3219	0,2187	0,9337	6646
resnet101	101	0,1523	0,1901	0,9384	9194

Similarly to the first experiment, we tried investigating whether Batch Size has any effect on neural network training. We have discovered an interesting feature:

increasing batch size greatly improves training time (fig. 1). This contradicts to the classical optimization theory Stochastic Gradient Descent algorithm. At this point the fact that training is performed on GPU should be mentioned. GPU compute is inherently parallel, thus feeding more data allows for the GPU compute engine to distribute workload more evenly and overlap computation for different samples in a batch simple. That means that low Batch Sizes simple do not fully utilize available resources. Thus, from this section, the recommendation would be to use batch size around 16, as higher values don't give any performance benefits.

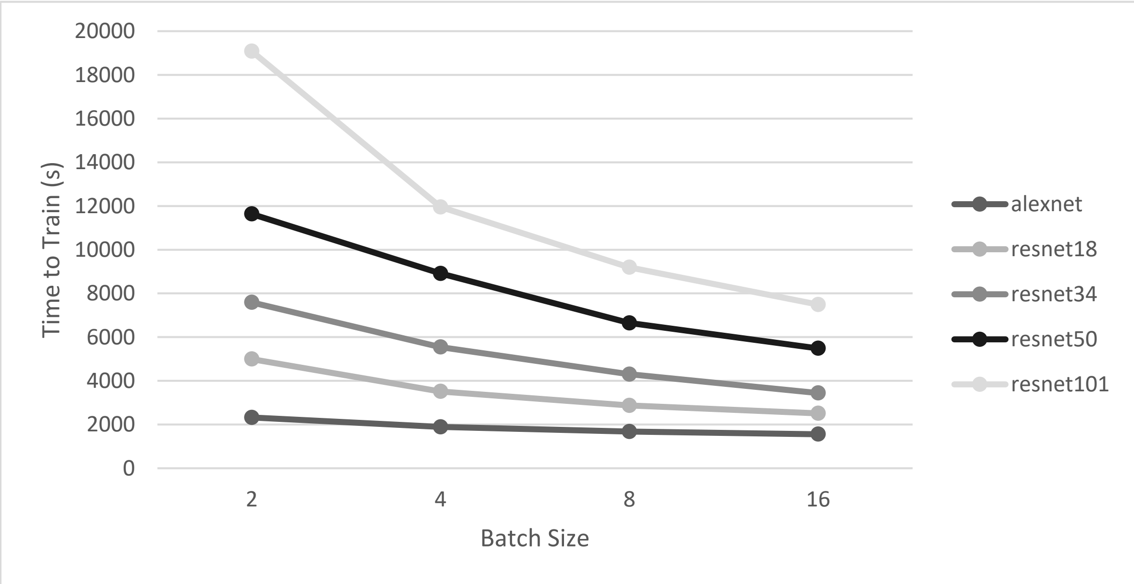

Figure 3 – Training time comparison by architecture and batch size.

Based on aforementioned observations, we have come up with recommendations for neural network architecture and key hyperparameters. As shown, AlexNet seems to be a good fit for small datasets and inexpensive systems with it's good-enough accuracy and low training time. ResNet-18 being 2.5 times deeper should be considered if AlexNet performance wasn't sufficient.

For Dropout, the general recommendation is the smaller the network the lower regularization should be. In the meantime, high values around 0.9 usually won't provide high accuracy, simpler neural network architecture should be considered instread.

Batch size, which has come with a surprise in its sleeve, specifically an improved performance on GPUs with batch size values up to 16, and higher classification accuracy with values up to 8. Also, neural networks with batch size of 2 fail to train.

A range of neural network architectures with their hyperparameters have been considered. Hyperparameters appear to have a crucial role for achieving state-of-the-art performance and to avoid a pitfall of getting a neural network architecture that fails to train. The ideas described in this paper can ease neural network usage for practitioners in different domains, providing a starting point to a successful enterprise application. While we focused on a single Oxford IIT Pets dataset, which provides a complex problem for a computer of discriminating between different cat and dog species (in many cases similar and hard to distinguish for a non-expert human), further research could focus on providing guidance for a wider range of datasets.

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