MATH 6380p Project 2: DCF-Net Exploration on CIFER-10

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1. Introduction

DCF Net is a new proposed convolutional layer structure, which replaces the convolutional filter used in convolutional neural networks by linear combination of fixed basis, greatly reducing the model parameters while keeping a comparable performance.

We compared the performance of DCF based CNN and their original version on CIFAR 10. The result shows that it reduces the overfitting phenomenon of VGG-16 but has less effect on ResNet-18.

2. Data set and Network structure

CIFAR 10: The CIFAR-10 dataset consists of 60,000 32x32 colour images in 10 classes, with 6000 images per class. There are 50,000 training images and 10,000 test images.

VGG16: A classic convolution neural network with 16 convolution layers.

ResNet18 : A residual learning framework with 18 layers.

For above two architectures, we trained all layers using original networks and DCF version based networks on CIFAR 10.

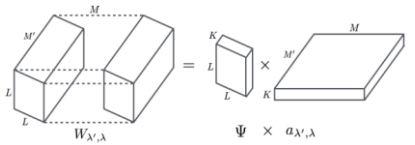
DCFNet: Decomposed Convolutional Filters (DCFNET) in CNN are a truncated expansion with pre-fixed bases, where the expansion coefficients remain learned from data.

3. DCFNet

DCF structure basically;

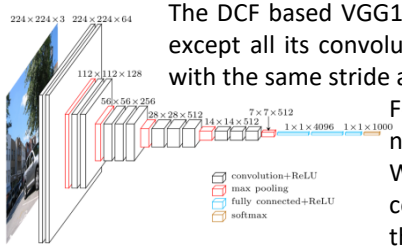
- Reduces the number of trainable parameters and computation.
- Imposes filter regularity by bases truncation.

In DCFNet, $L \times L \times M' \times M$ convolutional layer is decomposed into the product of K bases of size $L \times L$ (Ψ) and $KM' \times M$ coefficients (a), where Ψ is pre-fixed, and a is learned from data. The basis can carry prior structure if available. By representing the filters in terms of functional bases, rather than as pixel values, the number of trainable parameters is reduced to the expansion coefficients



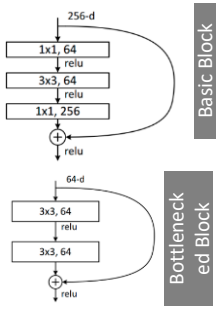
DCFNet: Decomposed Convolution Filters

4. DCF Based VGG16 and DCF Based Resnet



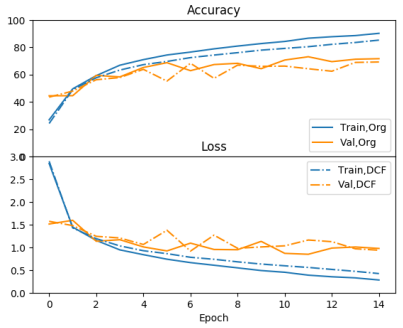
The DCF based VGG16 has exactly the same architecture with original VGG, except all its convolutional layer are replaced by the DCF convolution layer with the same stride and channel numbers.

For Resnet, 2 types of basic blocks with or without 'bottle neck' layer of with 1x1 convolutional filters are modified. We replaced all 3x3 convolutional layer with DCF convolutional layers, while keeping the 1x1 bottle neck in the original convolution structure.

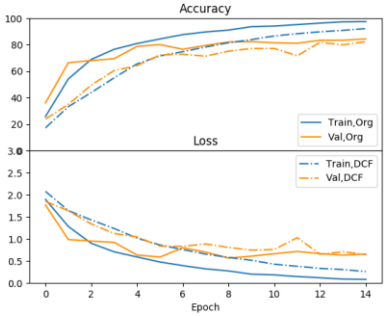


5. Results

Network	Test Accuracy (%)
VGG-16	84.4
DCF-VGG16	82.3
ResNet-18	71.6
DCF-ResNet-18	69.3



Resnet



Vgg

Project Source Code: https://github.com/UsmanMaqbool/MATH-6380p

5. Analysis

Both VGG and ResNet experiencing severe overfitting on CIFAR-10.

For DCF-VGG, the training accuracy is significantly lower than the original version, while the validation accuracy keeps the same. The overfitting phenomenon is reduced significantly.

However for ResNet, the effect is small, since ResNet uses small convolution kernel, which already reduced the overfitting phenomenon.

6. Conclusion

Through experiments, we consistently observe that DCFNet maintains accuracy for image classification tasks with a significant reduction of model parameters, particularly with Fourier-Bessel (FB) bases, and even with random bases.

Theoretically, we analyze the representation stability of DCFNet with respect to input variations, and prove representation stability under generic assumptions on the expansion coefficients. The analysis is consistent with the empirical observations

7. References

[1] Qiu, Qiang, et al. "DCFNet: Deep Neural Network with Decomposed Convolutional Filters." arXiv preprint arXiv:1802.04145 (2018).

[2] Simonyan, Karen, and Andrew Zisserman. "Very deep convolutional networks for large-scale image recognition." arXiv preprint arXiv:1409.1556 (2014)..

[3] He, Kaiming, et al. "Deep residual learning for image recognition." Proceedings of the IEEE conference on computer vision and pattern recognition. 2016.