Paper Review

Deep Residual Learning for Image Recognition (2016 CVPR)

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Contents

Abstract

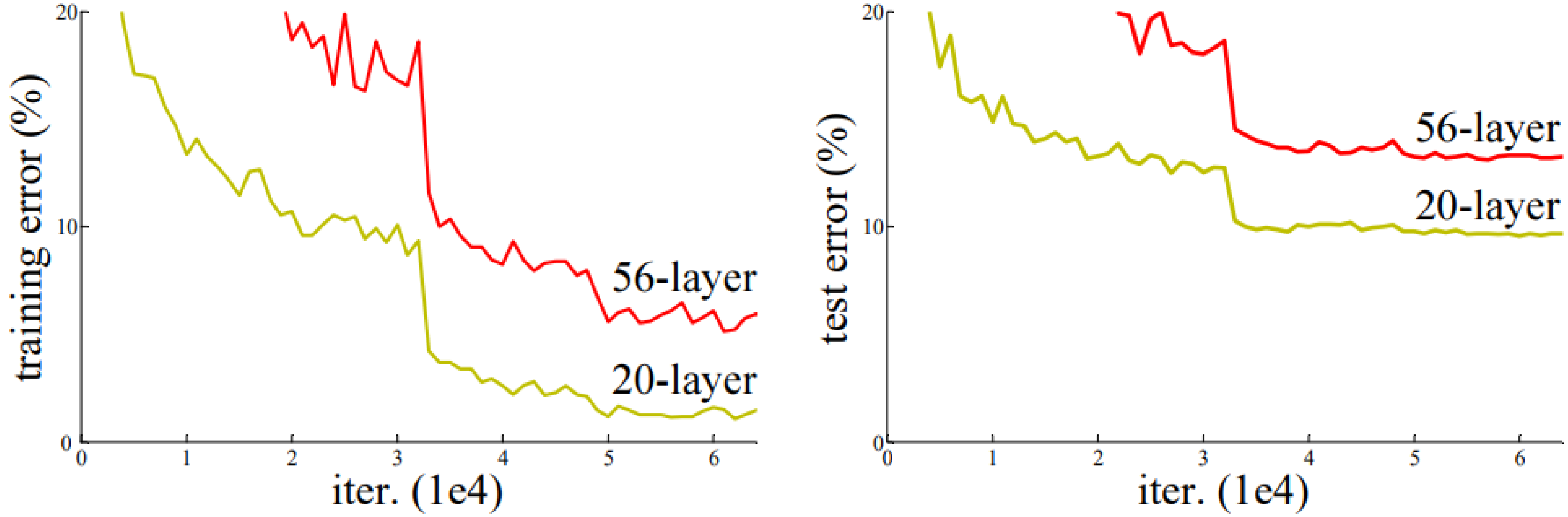

Figure 1. Training error (left) and test error (right) on CIFAR-10 with 20-layer and 56-layer "plain" networks. The deeper network has higher training error, and thus test error. Similar phenomena on ImageNet is presented in Fig. 4.

ResNet @ ILSVRC & COCO 2015 Competitions

1st places in all five main tracks

- ImageNet Classification : “Ultra-deep” 152-layer nets
- ImageNet Detection : 16% better than 2nd
- ImageNet Localization : 27% better than 2nd
- COCO Detection : 11% better than 2^{nd}
- COCO Segmentation : 12% better than 2nd

Is learning better networks
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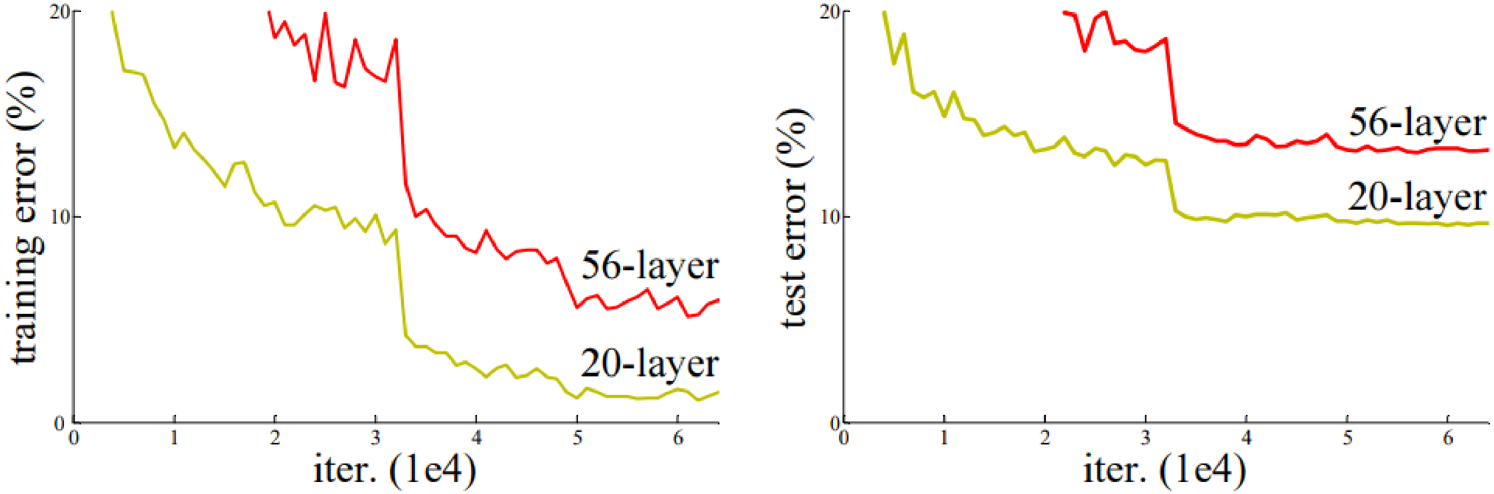

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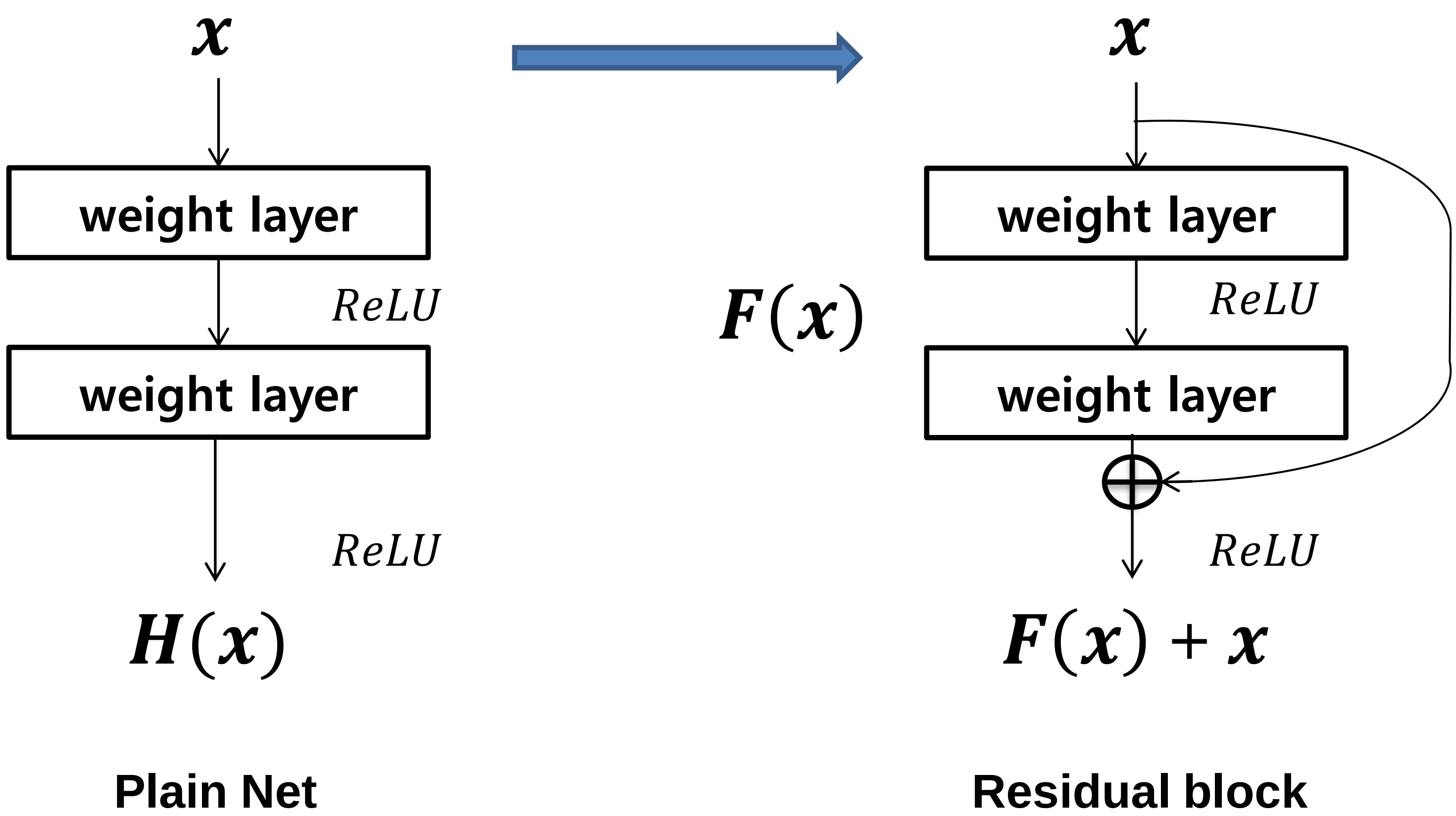
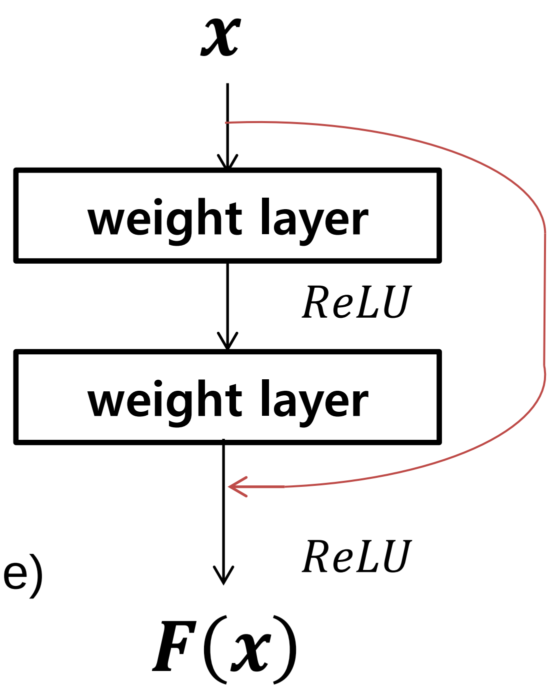
Introduction

$$F(x) := H(x) - x$$



Related Work

Shortcut Connection (Skip Connection)



GoogleNet vs ResNet

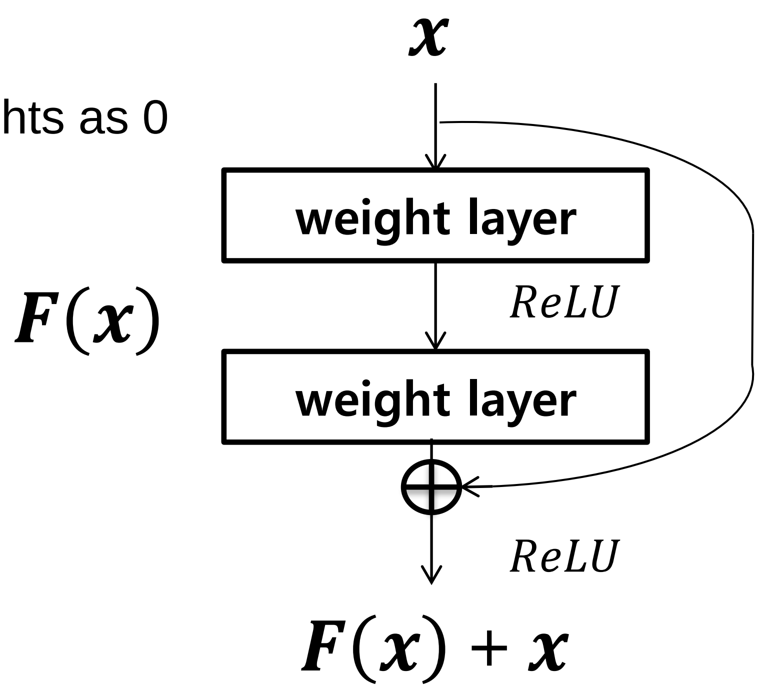
- Low parameter
- Not required Auxillary Classifier separately.

Highway Networks vs ResNet

- Low parameter (identity shortcut – parameter free)
- Not demonstrated accuracy gains with extremely increased depth (highway)

Residual Learning

- If identity were optimal, easy to set weights as 0
- If optimal mapping is closer to identify, easier to find small functions



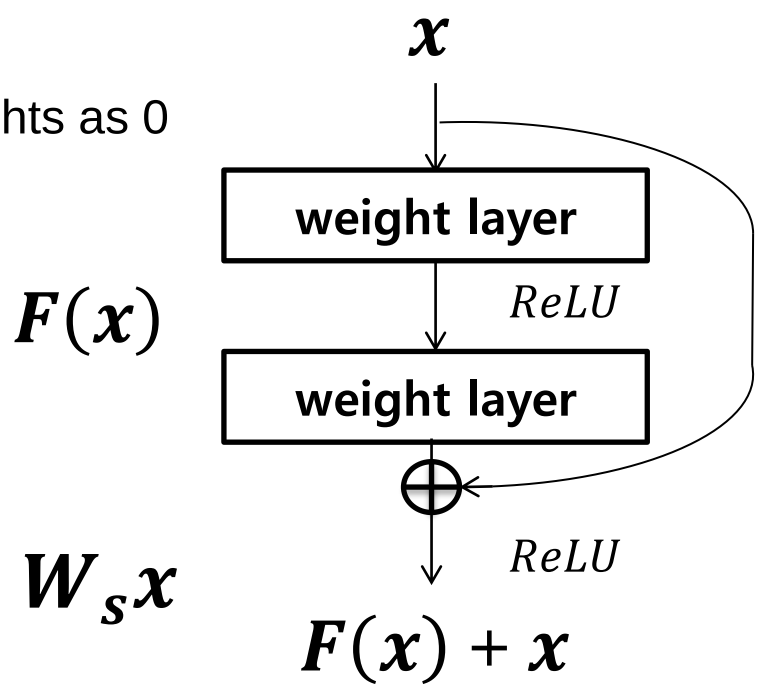
Residual block

Residual Learning

- If identity were optimal, easy to set weights as 0

- If optimal mapping is closer to identify, easier to find small functions

$$y = F(x, W_i) + W_s x$$



Residual block

Deep Residual Learning

Residual Learning

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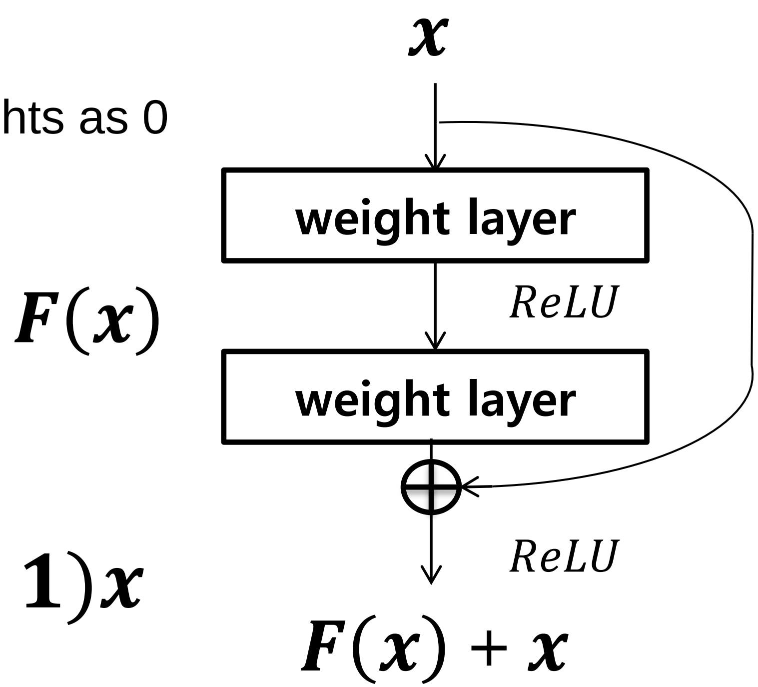


$$\boldsymbol{y = W_1 x + x = (W_1 + 1)x}$$

Residual block

Deep Residual Learning

Network Architectures

- **Keep it simple**
- **Basic design (VGG-style)**
  - All 3×3 conv (almost)
  - Spatial size / 2 => # filters × 2
  - Simple design; just deep!

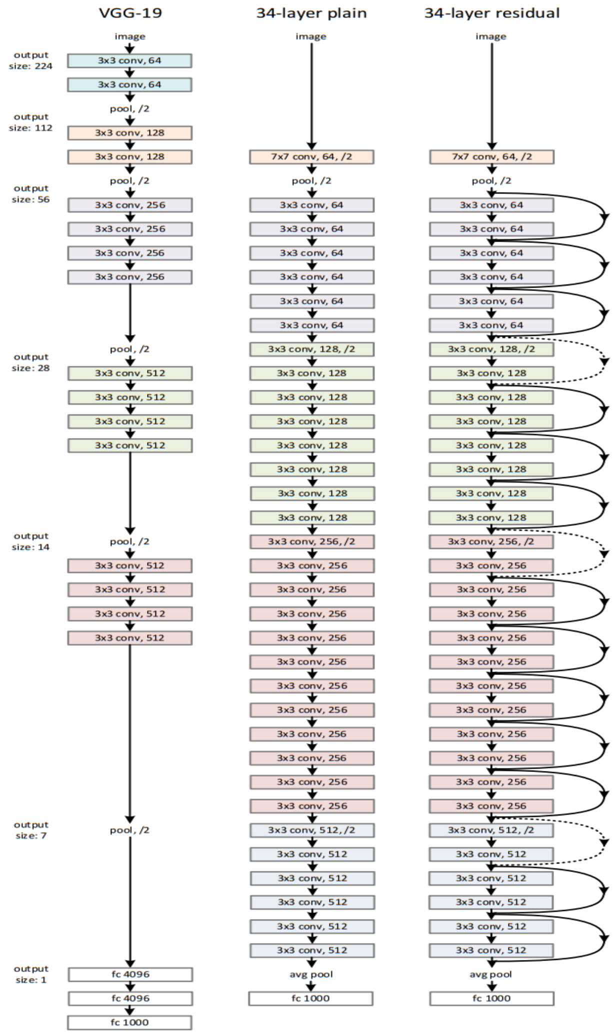
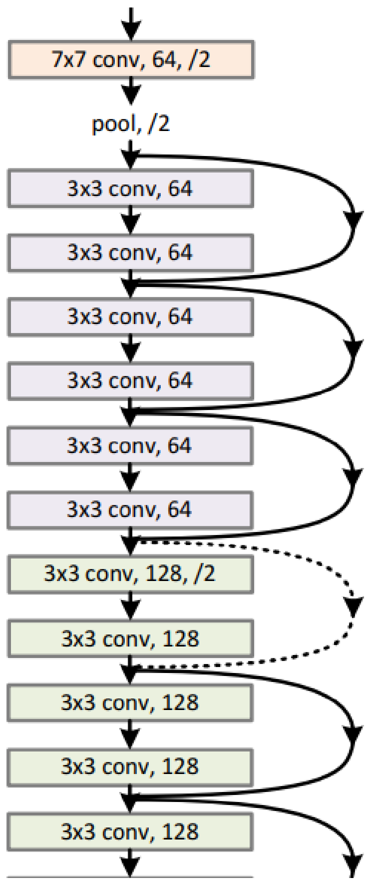


Figure 3. Example network architectures for ImageNet. **Left**: the VGG-19 model [41] (19.6 billion FLOPs) as a reference. **Middle**: a plain network with 34 parameter layers (3.6 billion FLOPs). **Right**: a residual network with 34 parameter layers (3.6 billion FLOPs). The dotted shortcuts increase dimensions. **Table 1** shows more details and other variants.

Deep Residual Learning

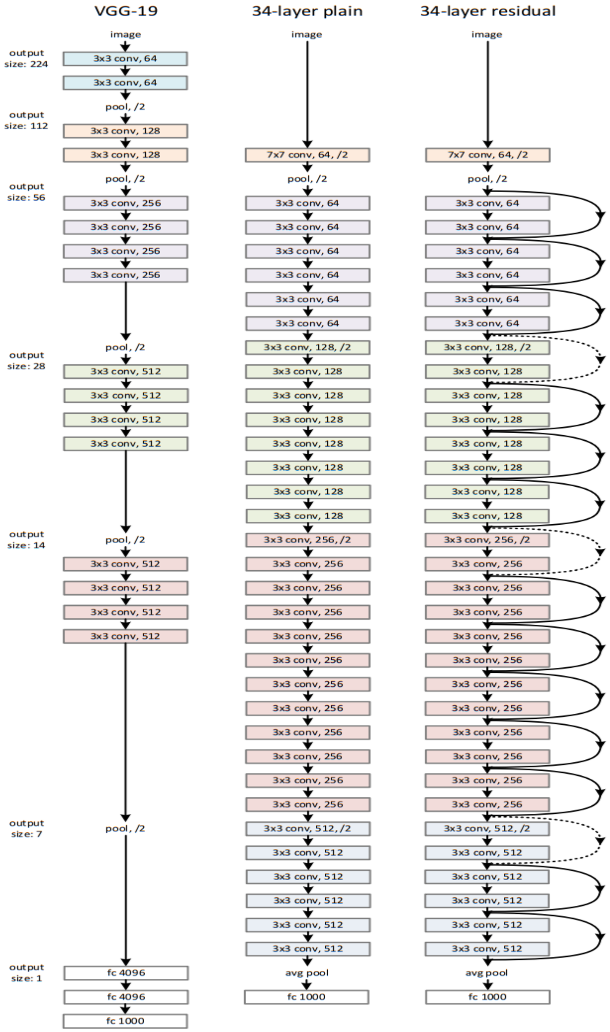
Network Architectures



Just added

Additional techniques

- **Zero padding → identity mapping**
- **Projection Shortcut**



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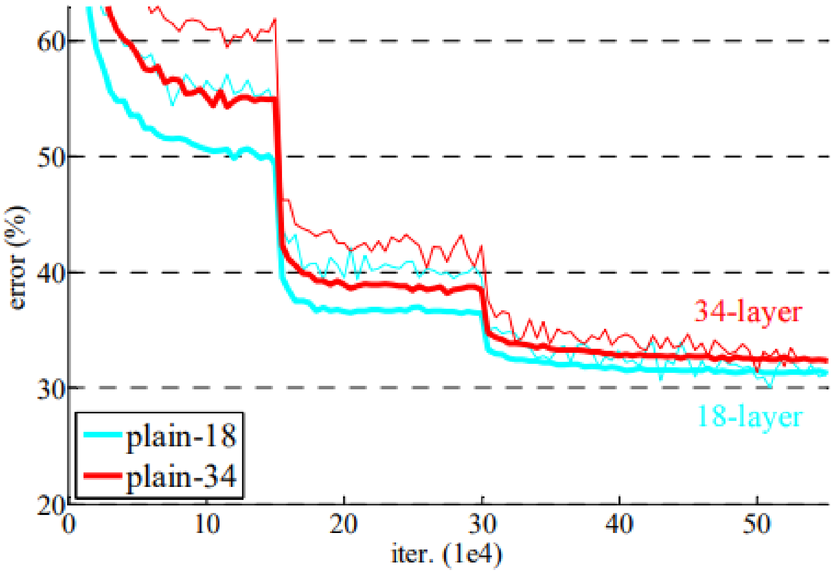
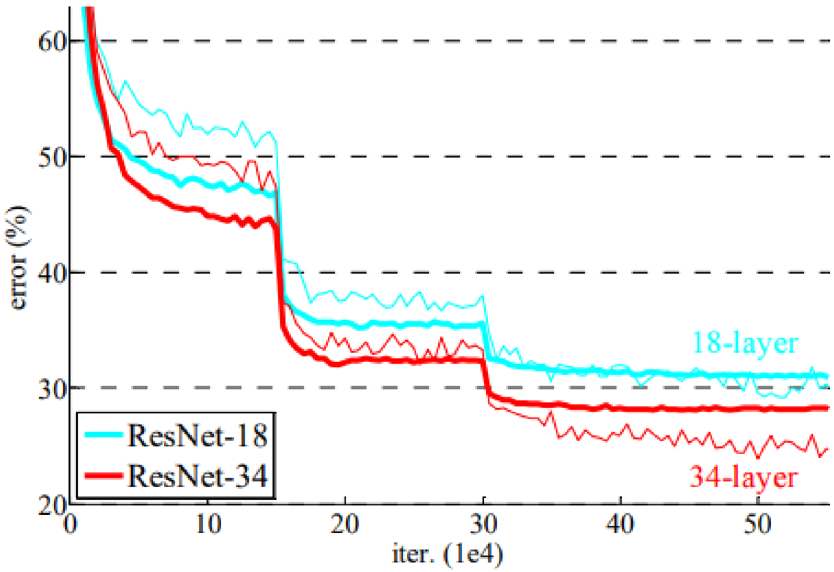
Experiments

ImageNet experiments





Plain networks of 18 and 34 layers.

ResNets of 18 and 34 layers.

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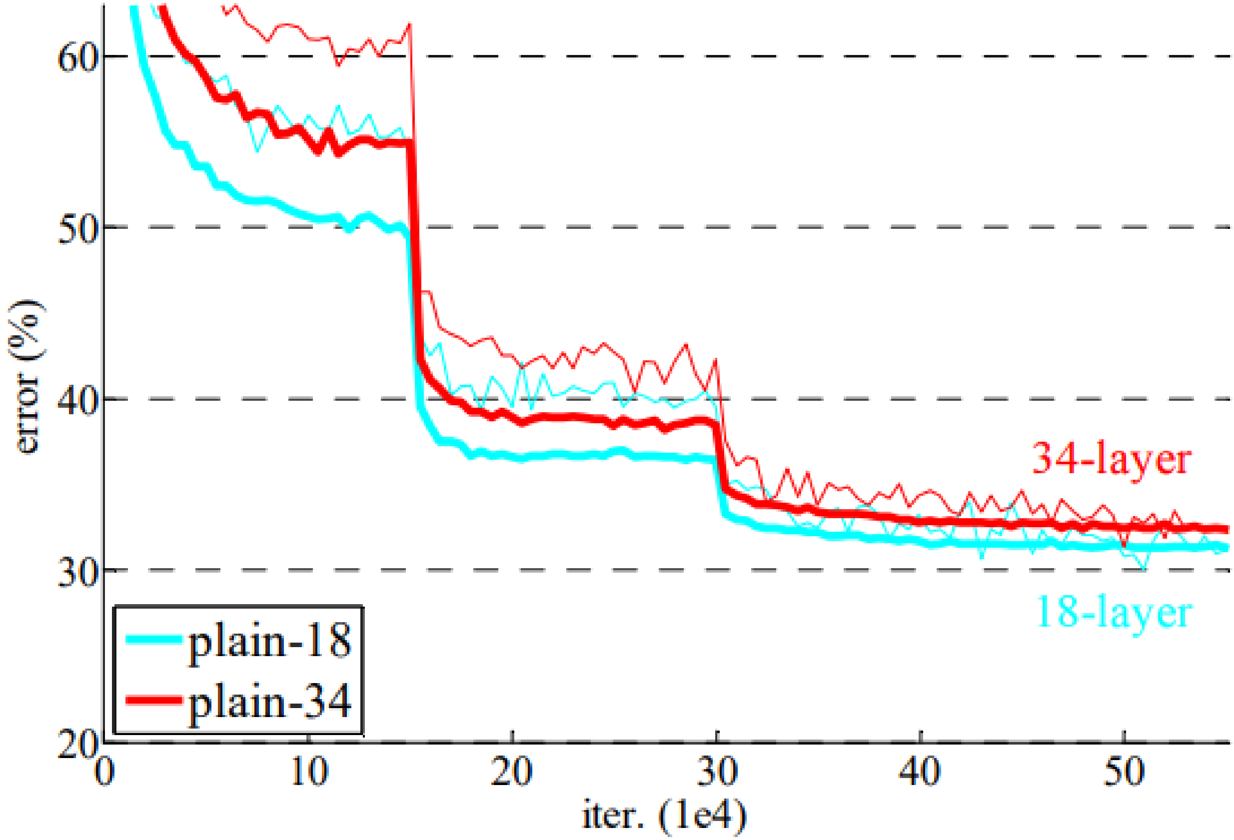
ImageNet experiments



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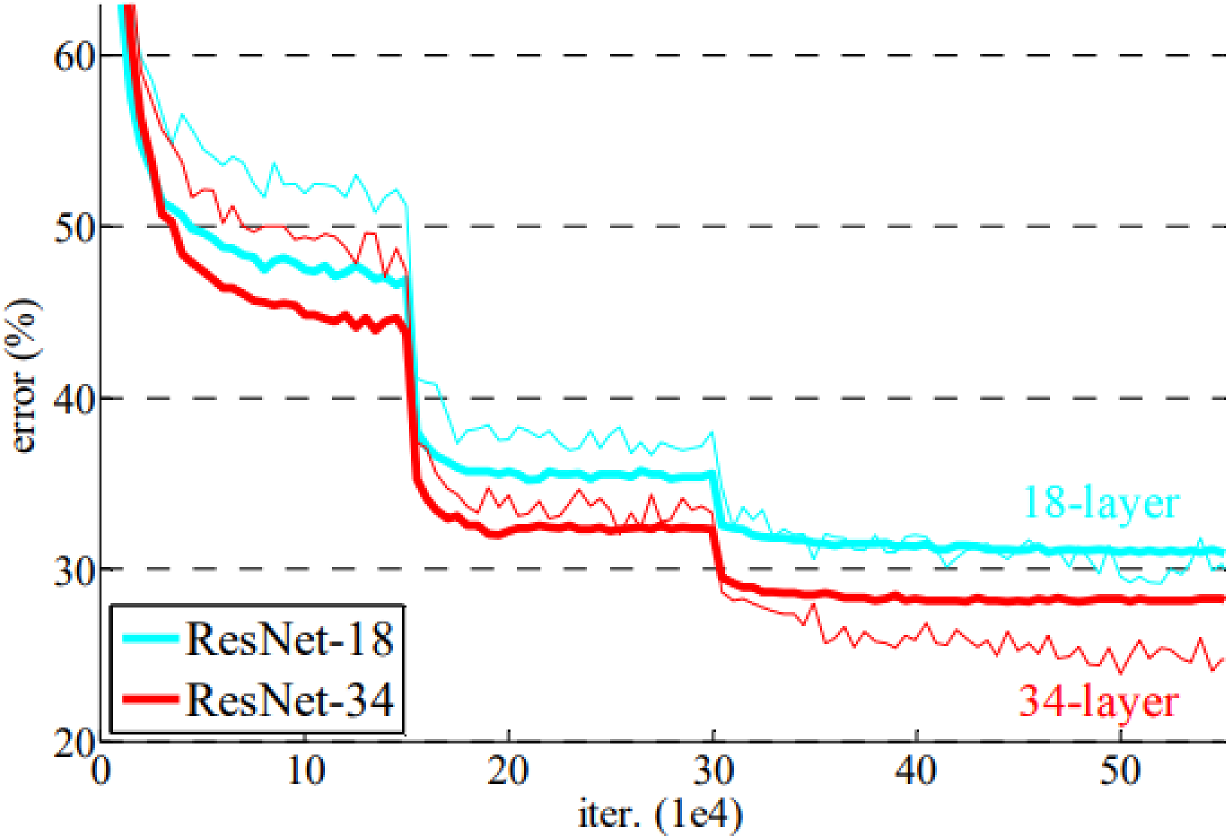
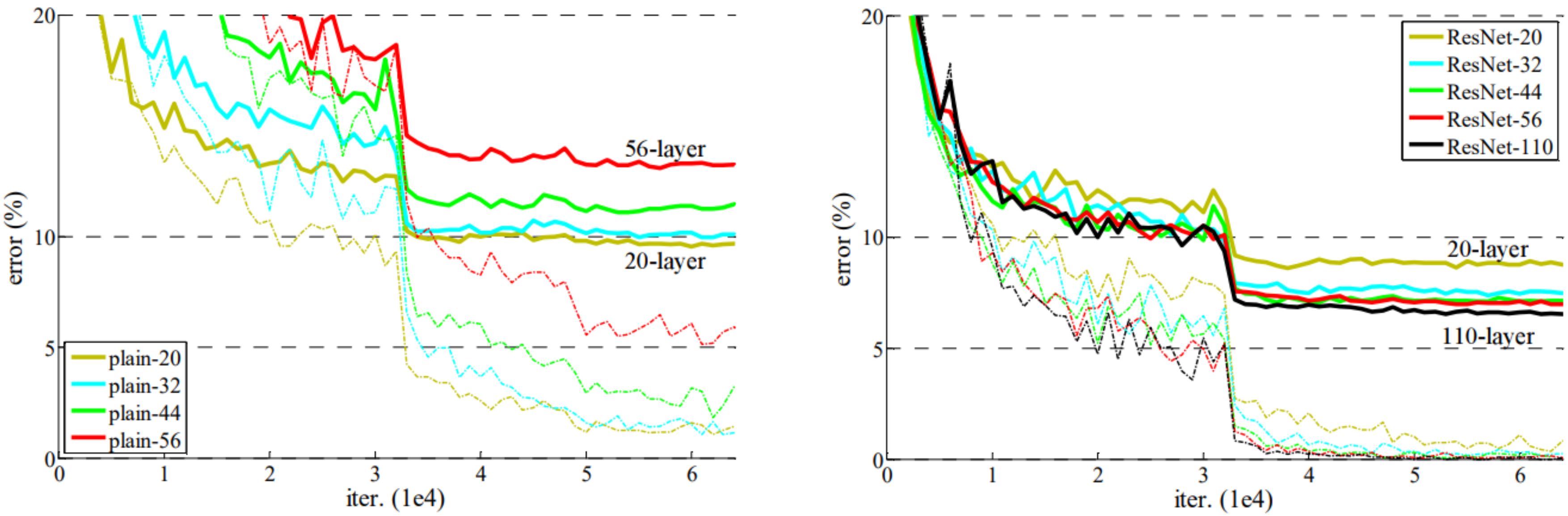


ResNets of 18 and 34 layers.

Experiments

CIFAR-10 experiments



- Deep ResNets can be trained without difficulties
- Deeper ResNets have lower training error, and also lower test error

Experiments

Does the performance continue to increase
if you continue to increase the layers of the model?

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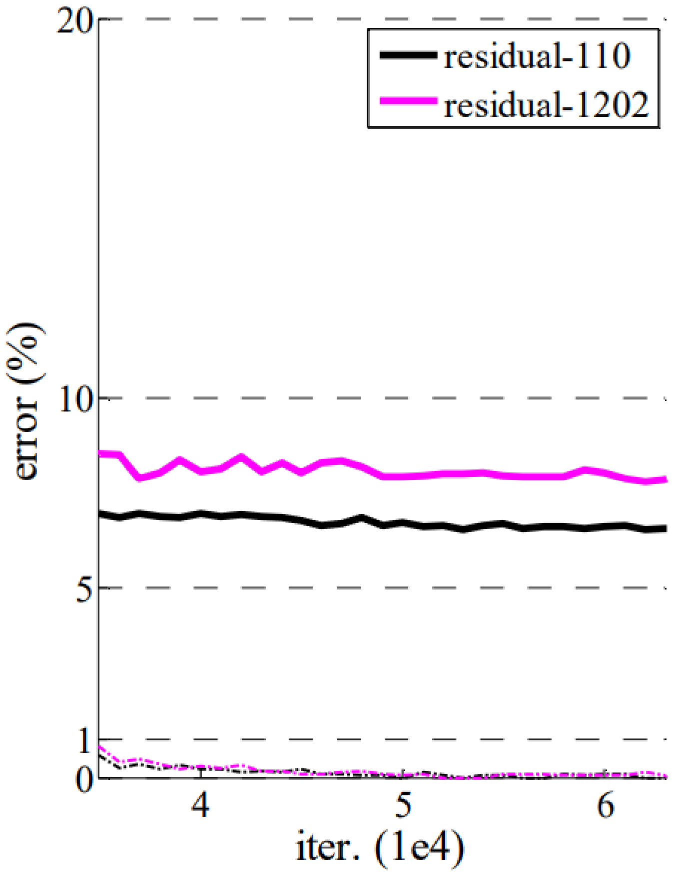

No → Because of **overfitting.**

But it could be studied by adding regularization**.**

Conclusions

- Deep Residual Networks:
  - Easy to train
  - Simply gain accuracy from depth
  - Well transferable