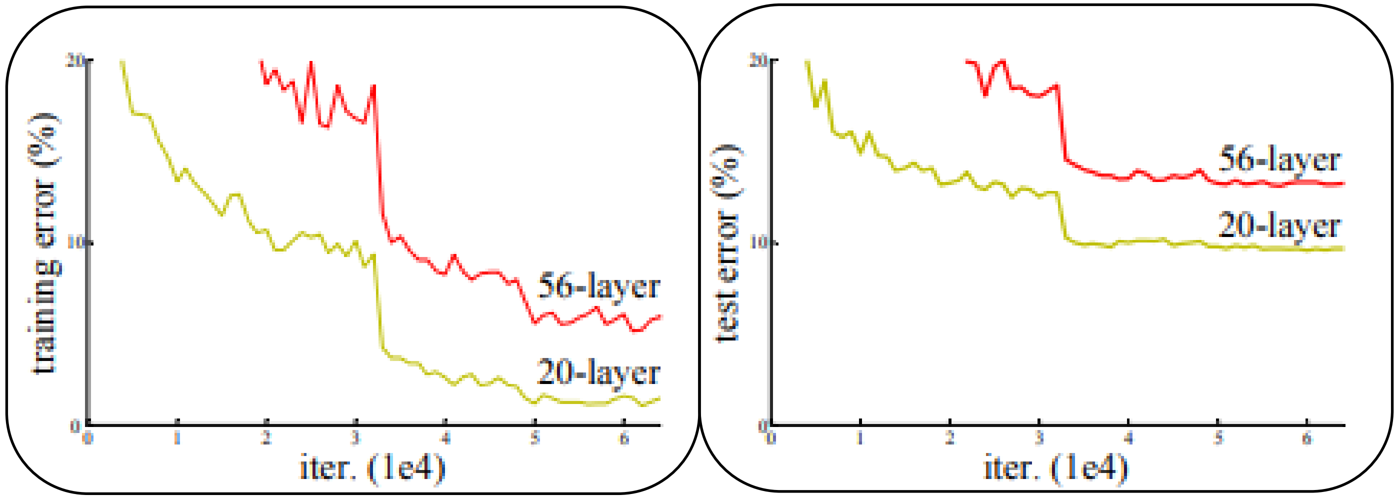
# Deep Residual Learning for Image Recognition (CVPR 2016)

- **연구동기:**
  더 많은 layer를 쌓는 것(Network Depth)만큼 network 성능이 좋아지는가?
  => **Degradation problem** 발생 -> Overfitting? X, training error 증가
  이러한 Degradation problem 발생을 해결하기 위해 **Residual 학습**을 제안.

**<CIFAR-10 Training ,Test error>**




**Degradation problem**

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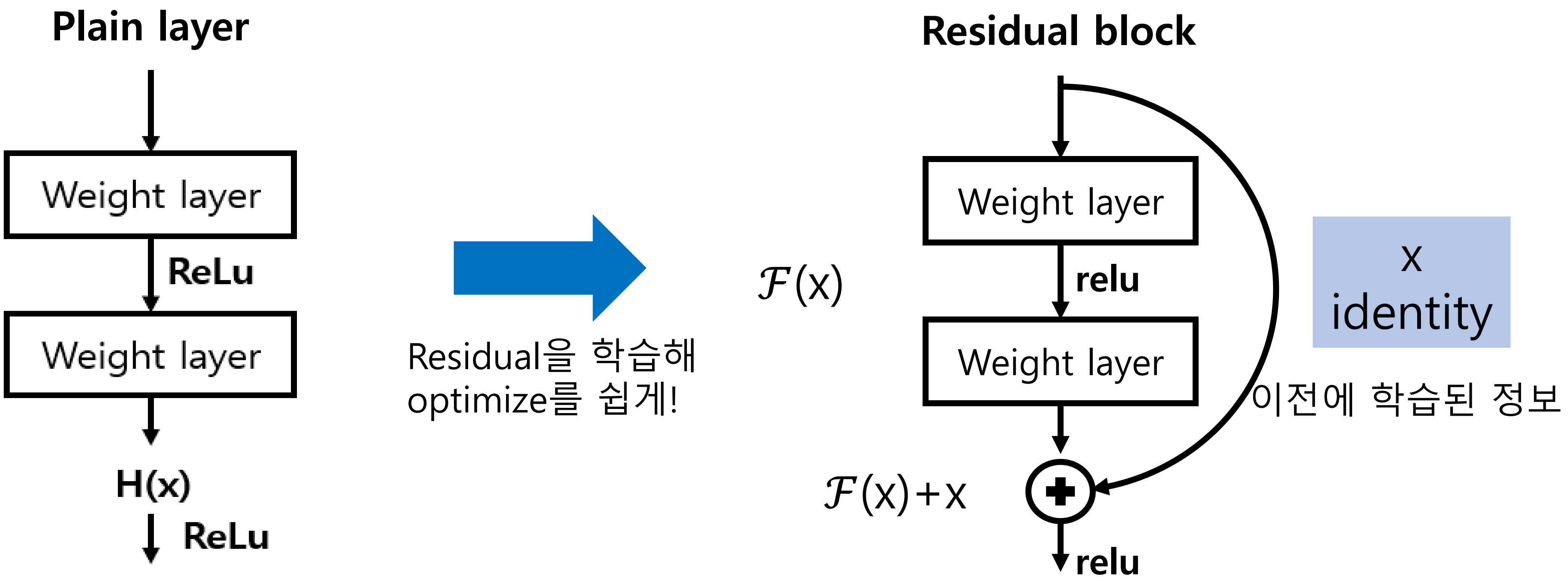
- **Method:**
  Residual block이 기존의 mapping보다 optimize 하기 쉽다는 것을 가정
  Residual method (gradient = 최소 1) + Shortcut connection (연산 간단화)



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- **Method:**
  Residual block이 기존의 mapping보다 optimize 하기 쉽다는 것을 가정
  문제: 기존의 mapping이 예측한 H(x)는 네트워크가 깊어질수록 **gradient vanishing** 현상 발생.
  문제 해결: Residual block 은 F(x)가 0이 되도록 학습시키고 마지막에 x identity 를 더해
  H(x)가 x가 되도록 학습해 미분을 해도 x 자체는 미분값 1을 갖게 되어 최소 gradient=1

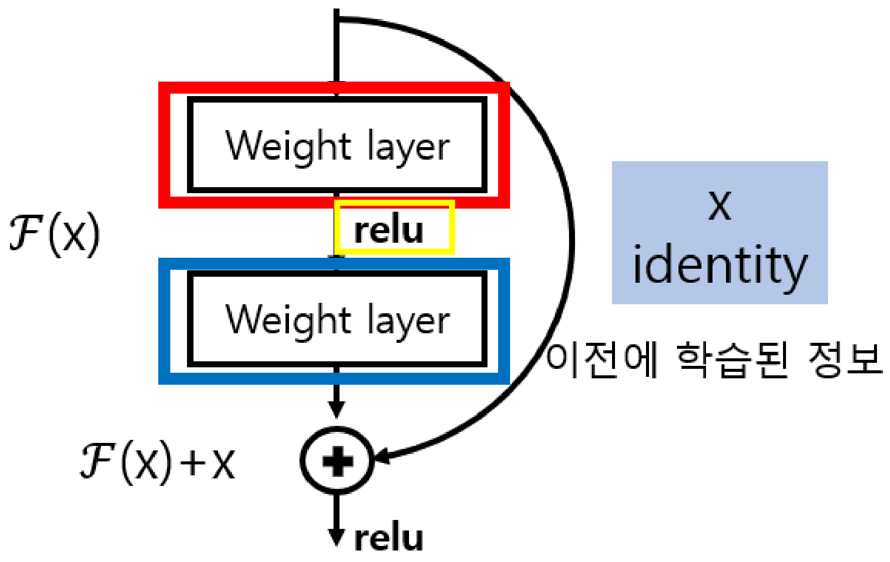
$$\begin{aligned} \boldsymbol{H(x)} &= \boldsymbol{F(x) + id(x)} \\ &= \boldsymbol{F(x) + x} \end{aligned}$$

$$\boldsymbol{F} = \boxed{\boldsymbol{W_2}}\,\boxed{\boldsymbol{\sigma}}(\boxed{\boldsymbol{W_1}}\,\boldsymbol{x})$$

$$\boldsymbol{y} = \boldsymbol{F(x, \{W_i\})} + \underline{\boldsymbol{W_s x}}$$

Shortcut connection

**Residual block**



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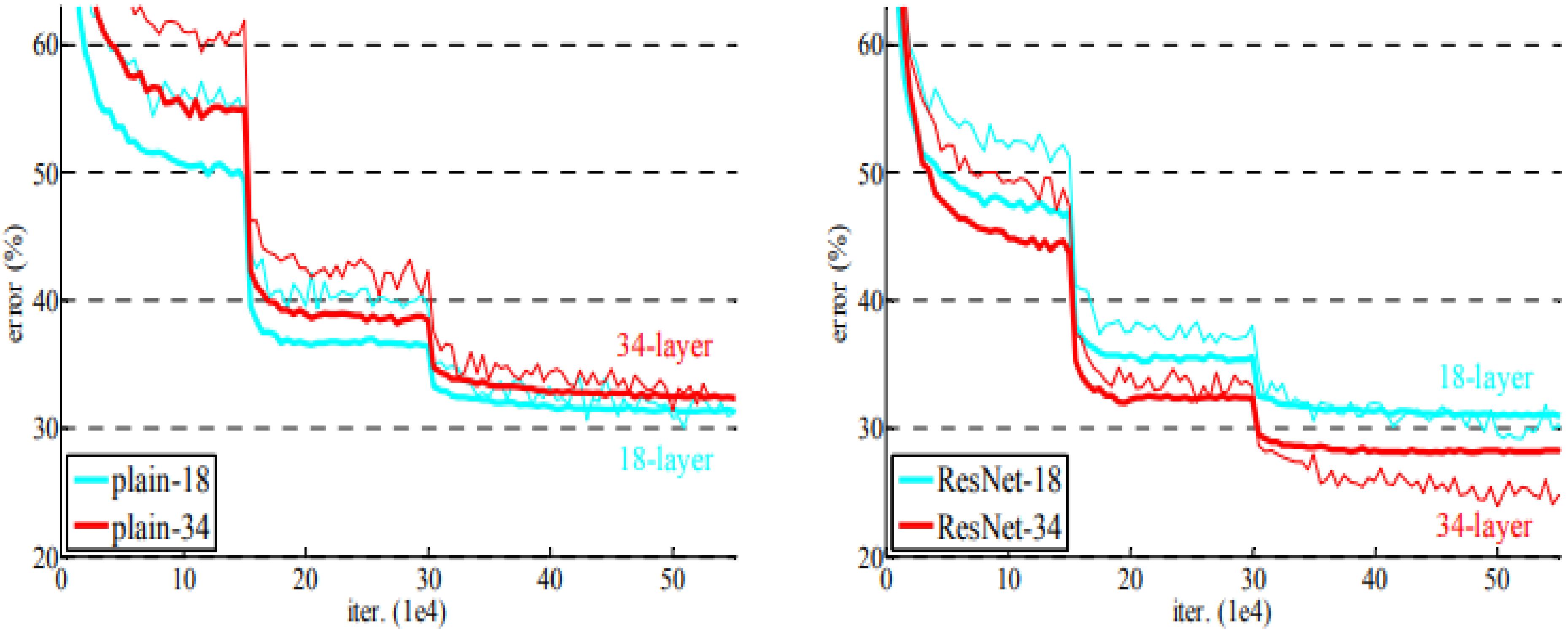
**Experiment:**

Network depth가 깊어져도 성능의 향상 (Degradation을 적절히 조절)

**Training Error in Plain Network and ResNet**



# Deep Residual Learning for Image Recognition (CVPR 2016)

## **Experiment:** 네트워크가 과도하게 깊어지면 성능이 감소하는 문제 발생.

**Top-1 error on ImageNet Validation**
**: Plain layer vs ResNet**

| | plain | ResNet |
|---|---|---|
| 18 layers | 27.94 | 27.88 |
| 34 layers | 28.54 | **25.03** |

**Top-1, Top-5 error on ImageNet Validation**
**: single-model**

| method | top-1 err. | top-5 err. |
|---|---|---|
| VGG [40] (ILSVRC'14) | - | 8.43† |
| GoogLeNet [43] (ILSVRC'14) | - | 7.89 |
| VGG [40] (v5) | 24.4 | 7.1 |
| PReLU-net [12] | 21.59 | 5.71 |
| BN-inception [16] | 21.99 | 5.81 |
| ResNet-34 B | 21.84 | 5.71 |
| ResNet-34 C | 21.53 | 5.60 |
| ResNet-50 | 20.74 | 5.25 |
| ResNet-101 | 19.87 | 4.60 |
| ResNet-152 | **19.38** | **4.49** |

**Top-5 error on ImageNet Test**
**: Ensembles**

| method | top-5 err. (**test**) |
|---|---|
| VGG [40] (ILSVRC'14) | 7.32 |
| GoogLeNet [43] (ILSVRC'14) | 6.66 |
| VGG [40] (v5) | 6.8 |
| PReLU-net [12] | 4.94 |
| BN-inception [16] | 4.82 |
| **ResNet (ILSVRC'15)** | **3.57** |

**error rate(%) on CIFAR-10**
**: Residual-110 vs Residual-1202**