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# Case Studies

## Why look at case studies?

# Outline

## Classic networks:

- LeNet-5 ←
- AlexNet ←
- VGG ←

ResNet (152)

Inception

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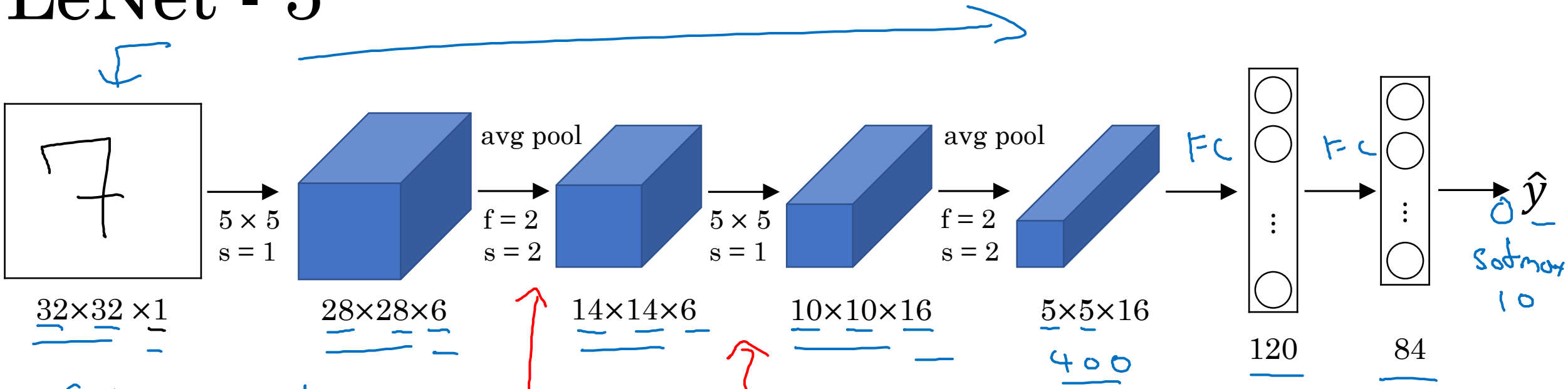
# Case Studies

# Classic networks

# LeNet - 5




60k parameters.

$n_H, n_w \downarrow$ $n_c \uparrow$

Non-linearity after pooling

$n_{H} \times n_{w} \times n_c$ $f \times f \times n_c$

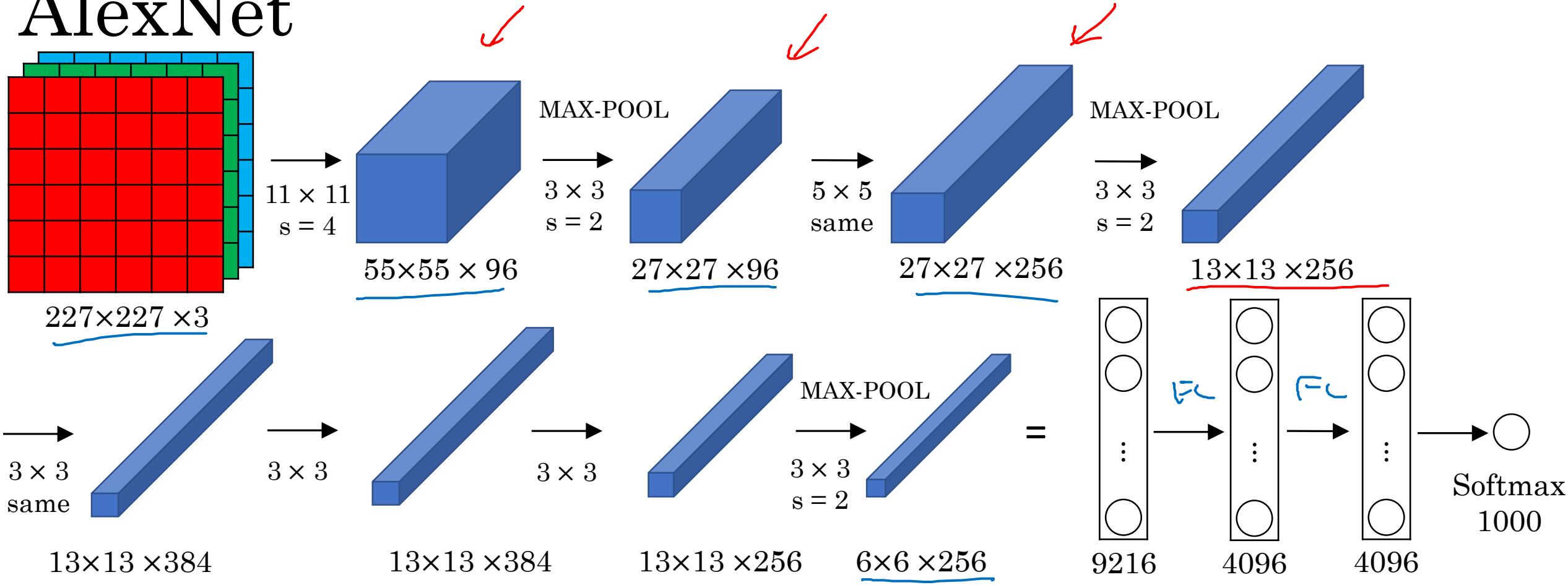
conv pool conv pool fc fc output

Activation: sigmoid/tanh ReLU

II III

[LeCun et al., 1998. Gradient-based learning applied to document recognition]

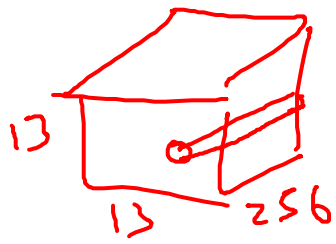
# AlexNet




- Similar to LeNet, but much bigger.
- ReLU
- Multiple GPUs.
- Local Response Normalization (LRN)

9216

60M parameters




[Krizhevsky et al., 2012. ImageNet classification with deep convolutional neural networks]

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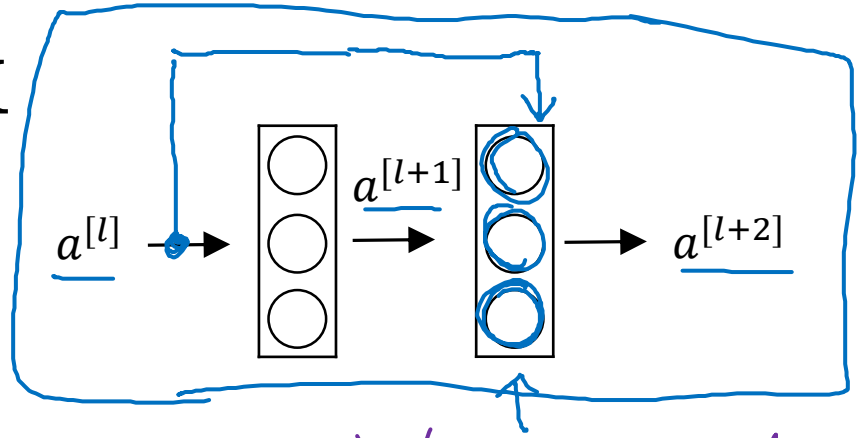
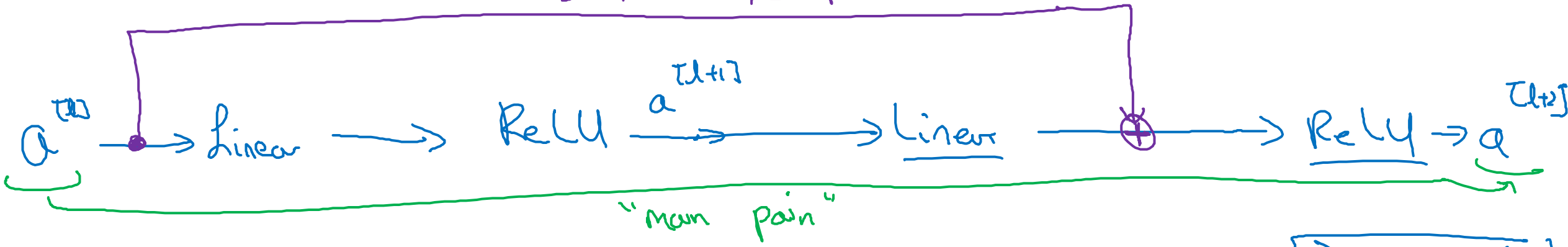
# Case Studies

# Residual Networks (ResNets)

# Residual block




"short cut" / skip connection

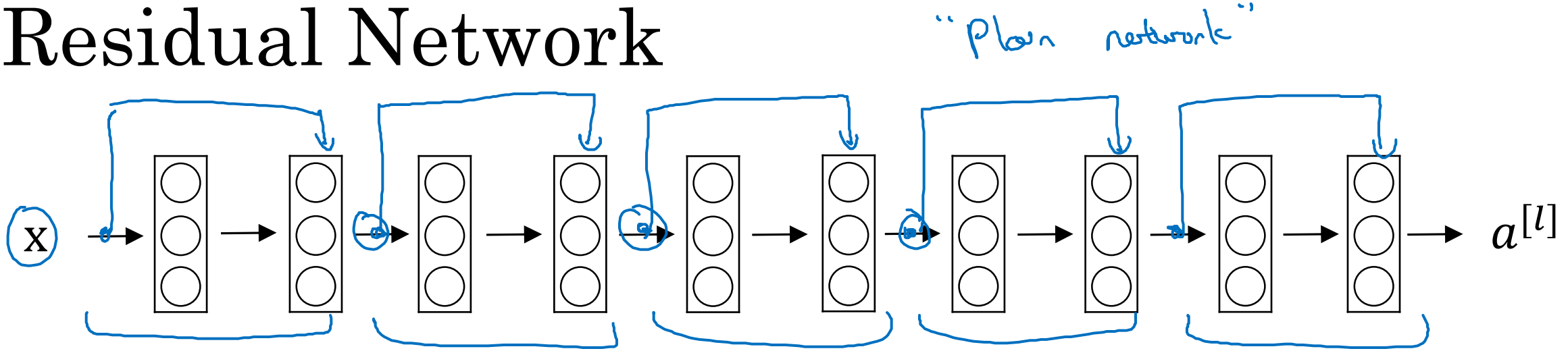


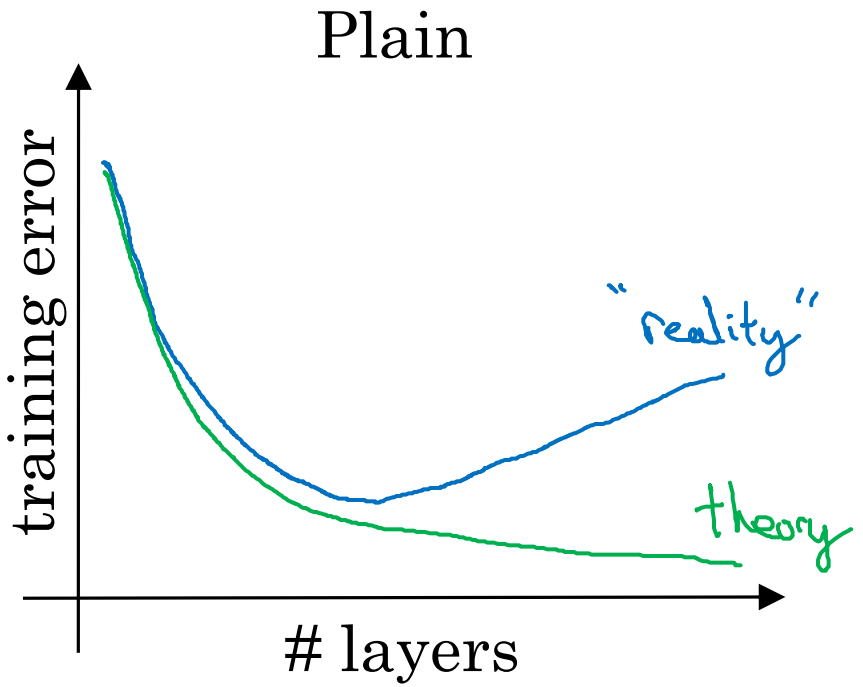

$$z^{[l+1]} = W^{[l+1]} a^{[l]} + b^{[l+1]} \qquad a^{[l+1]} = g(z^{[l+1]}) \qquad z^{[l+2]} = W^{[l+2]} a^{[l+1]} + b^{[l+2]} \qquad \cancel{a^{[l+2]} = g(z^{[l+2]})}$$

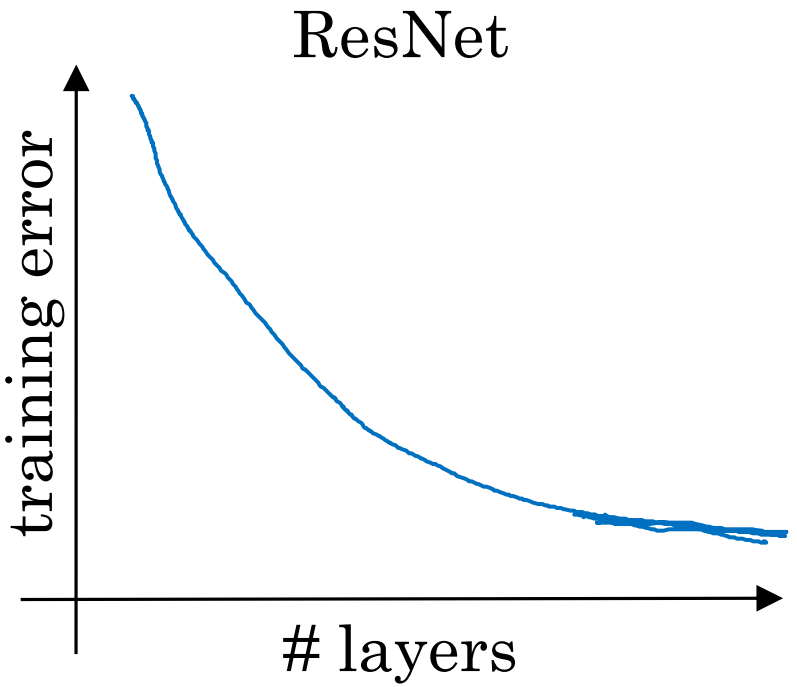
$$a^{[l+2]} = g\left(z^{[l+2]} + a^{[l]}\right)$$

[He et al., 2015. Deep residual networks for image recognition]

# Residual Network




[He et al., 2015. Deep residual networks for image recognition]

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# Case Studies

# Network in Network and 1×1 convolutions

# Why does a 1 × 1 convolution do?

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 6 | 5 | 8 |
| 3 | 5 | 5 | 1 | 3 | 4 |
| 2 | 1 | 3 | 4 | 9 | 3 |
| 4 | 7 | 8 | 5 | 7 | 9 |
| 1 | 5 | 3 | 7 | 4 | 8 |
| 5 | 4 | 9 | 8 | 3 | 5 |

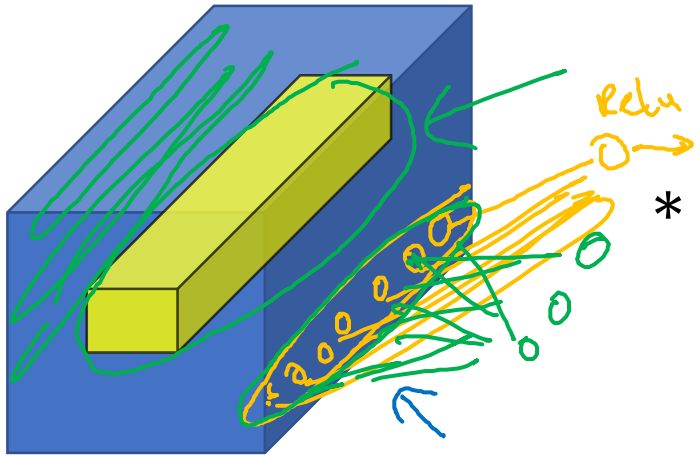
6 × 6 × 1

*

2

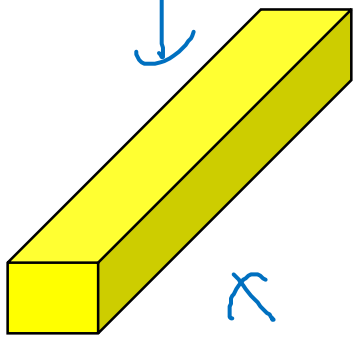
=

| | | | | | |
|---|---|---|---|---|---|
| 2 | 4 | 6 | ... | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |




6 × 6 × 32

*

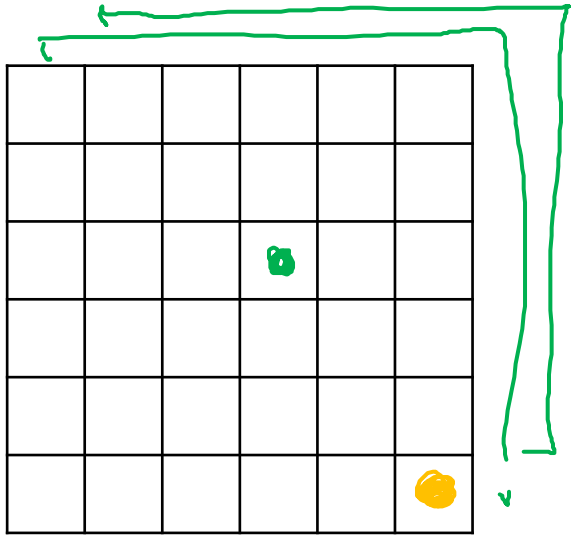


1 × 1 × 32

=

32 → # filters.

$n_c^{[l+1]}$



6 × 6 × # filters

ReLU

Network in Network

[Lin et al., 2013. Network in network]

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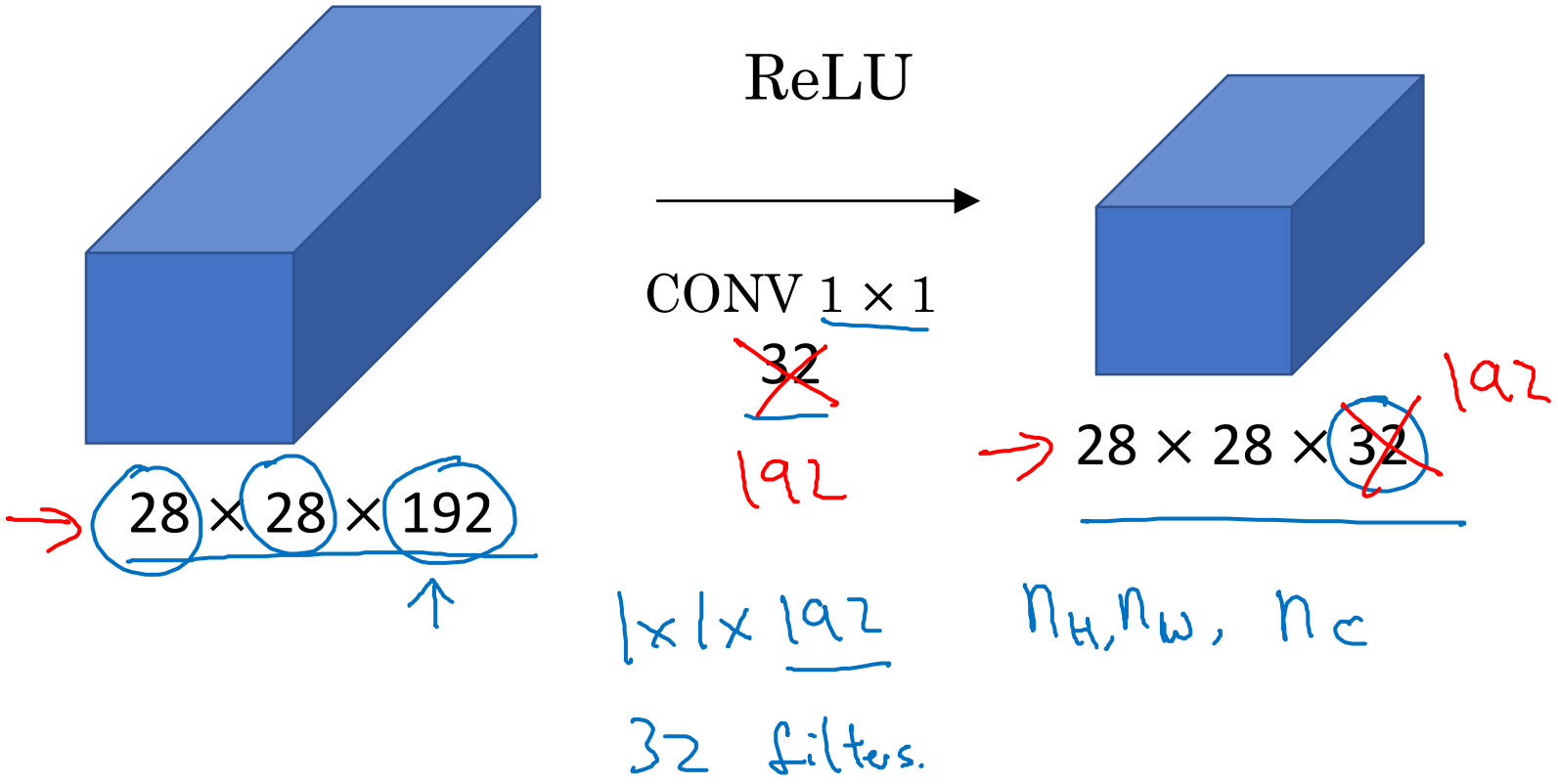
# Using 1×1 convolutions




[Lin et al., 2013. Network in network]

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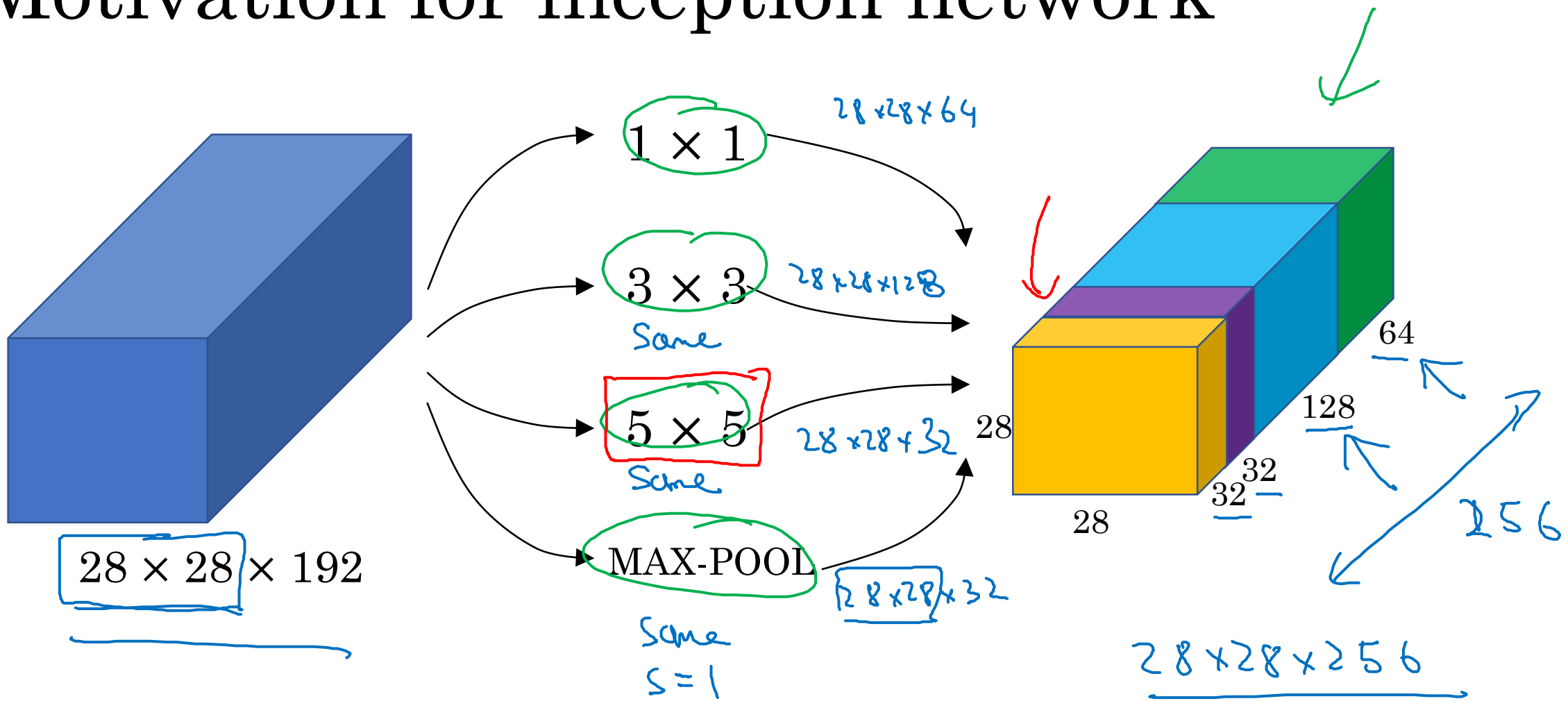
# Case Studies

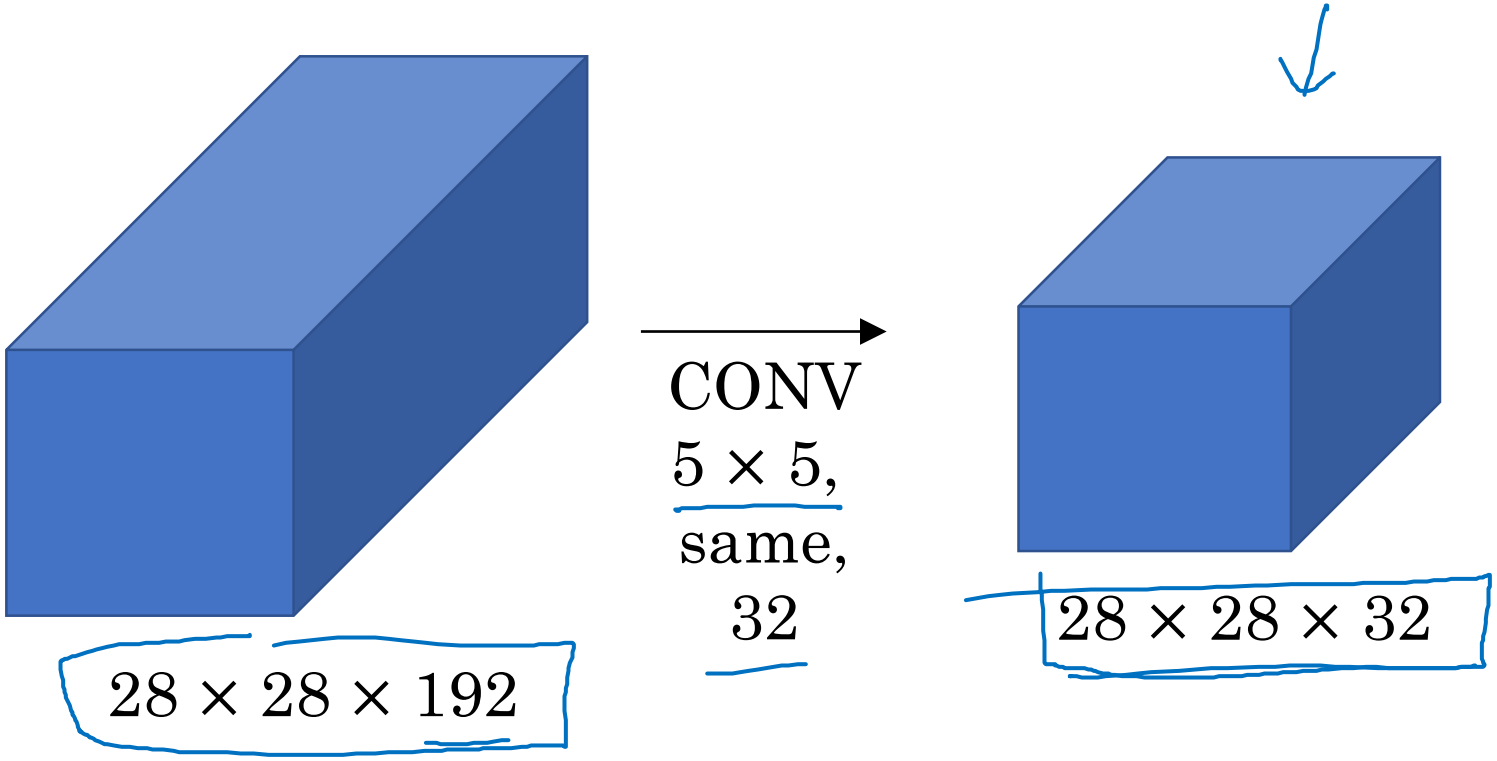
## Inception network motivation

# Motivation for inception network




[Szegedy et al. 2014. Going deeper with convolutions]

# The problem of computational cost




32 filters. filter one 5×5×192.

28×28×32 × 5×5×192 = 120M.

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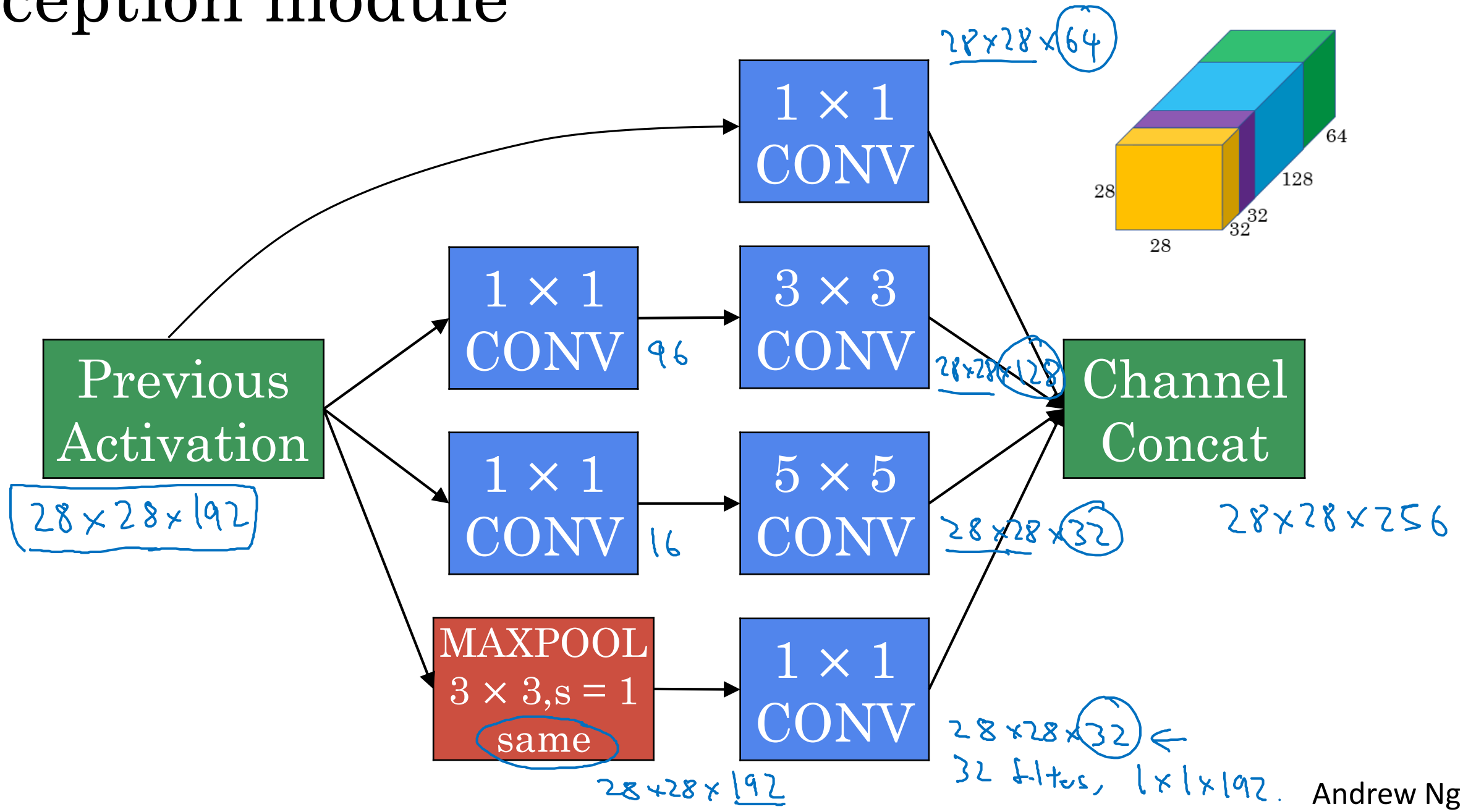
# Inception network

# Inception module

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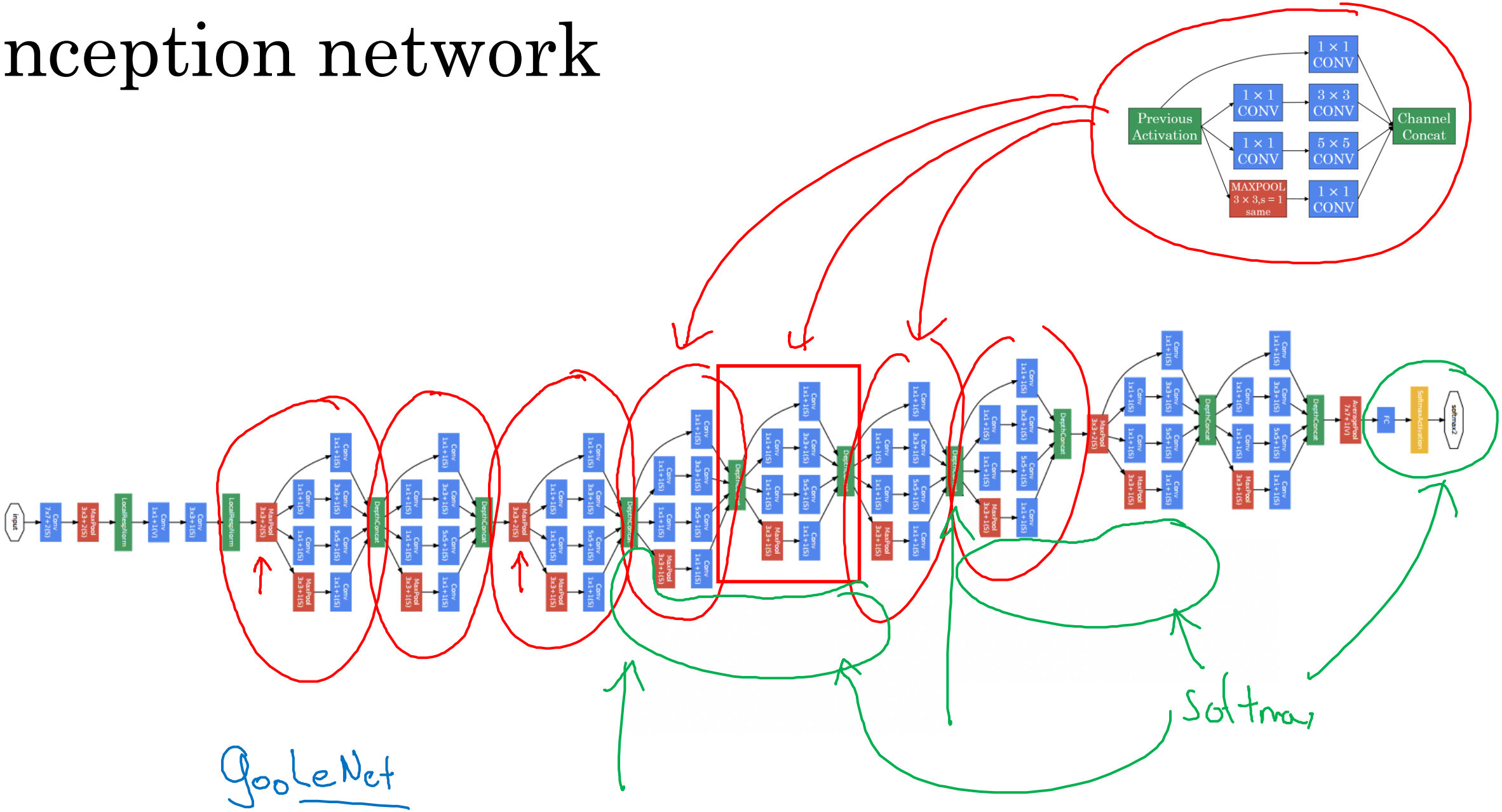
# Inception network




[Szegedy et al., 2014, Going Deeper with Convolutions]