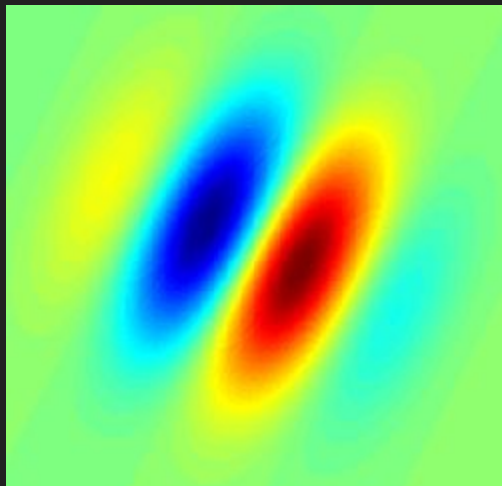


# **Convolutional Neural Networks**

# **A Brief History of C.N.N.s**

1959

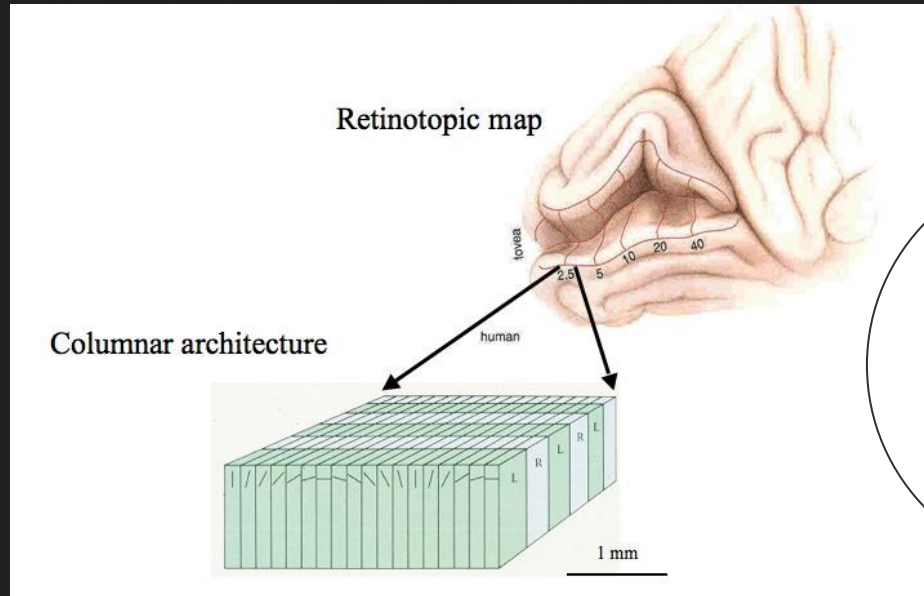


1962



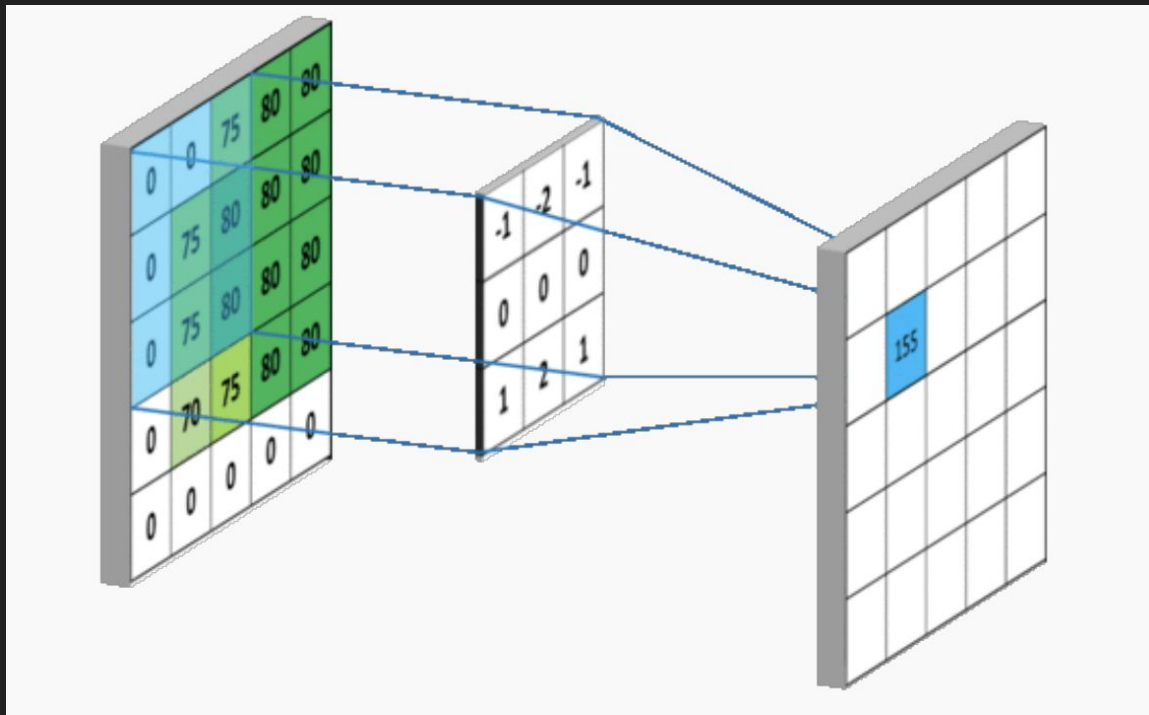
***Hubel and Wiesel.***

# V1

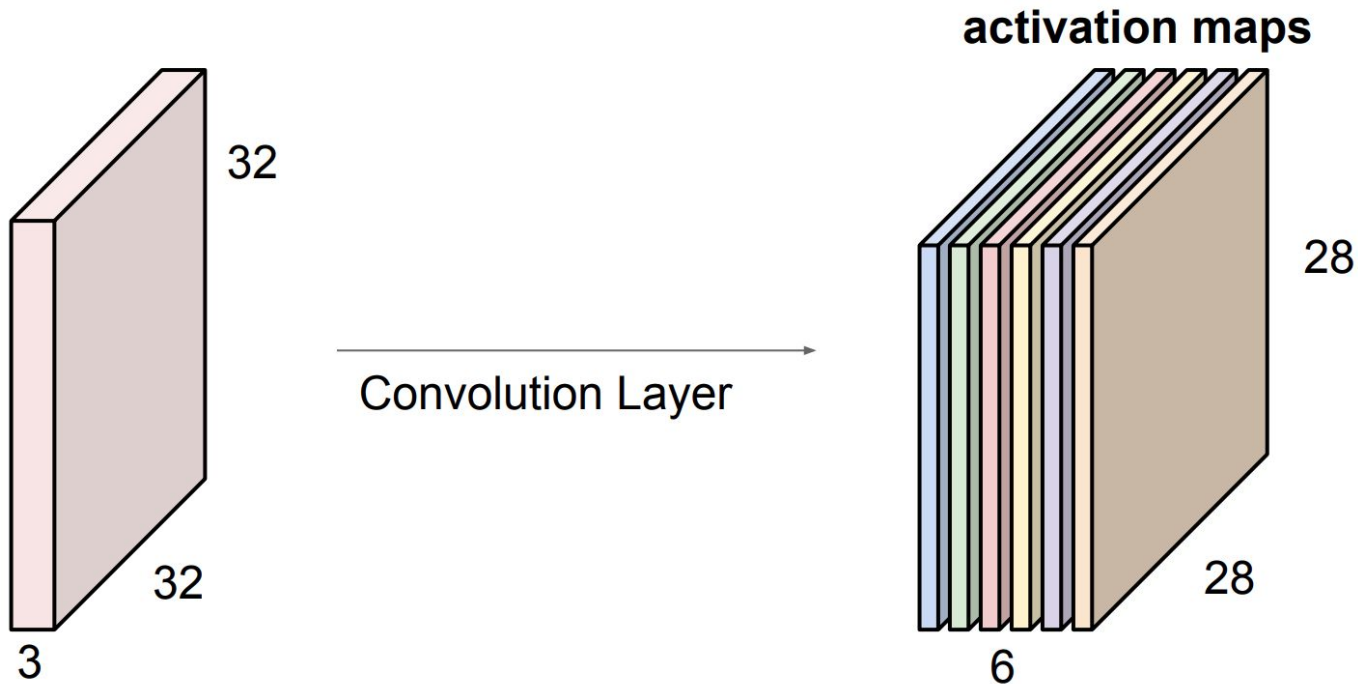


**Winner:  
Nobel Prize in  
Physiology and  
Medicine 1981**

# Convolutional Operations



# Convolutional Layer





*Problem*

The background image shows a document with a grid of numbers, likely a financial statement or a ledger. The numbers are arranged in rows and columns, with some handwritten text visible. The word 'Problem' is overlaid in a red box, suggesting a focus on a specific issue or a challenge related to the data presented.

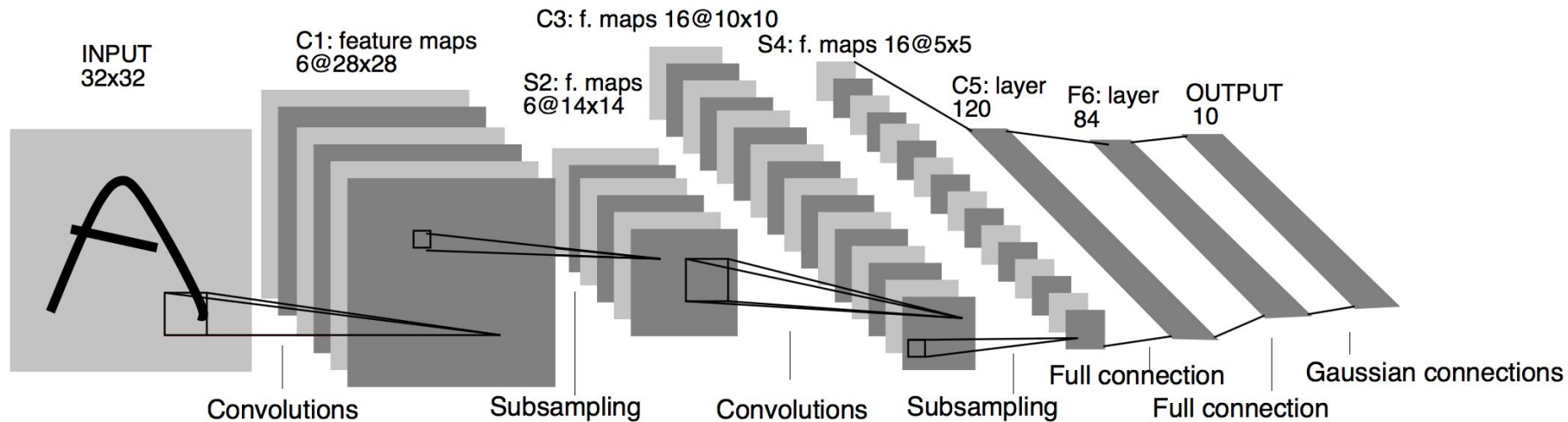




# 1998



# LeNet



# Subsampling (Max Pooling)

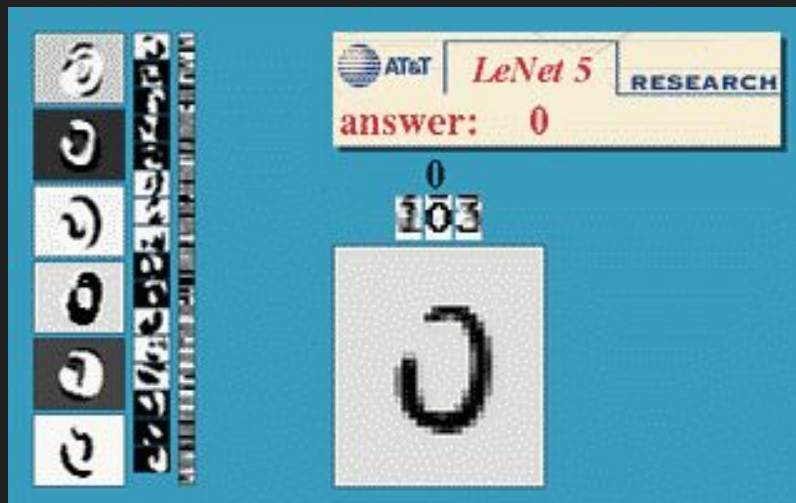
|     |     |    |    |
|-----|-----|----|----|
| 12  | 20  | 30 | 0  |
| 8   | 12  | 2  | 0  |
| 34  | 70  | 37 | 4  |
| 112 | 100 | 25 | 12 |

$2 \times 2$  Max-Pool

|     |    |
|-----|----|
| 20  | 30 |
| 112 | 37 |

reduce the number of parameters  
to be learned

# The first CNN



0.95% error rate



# 2009



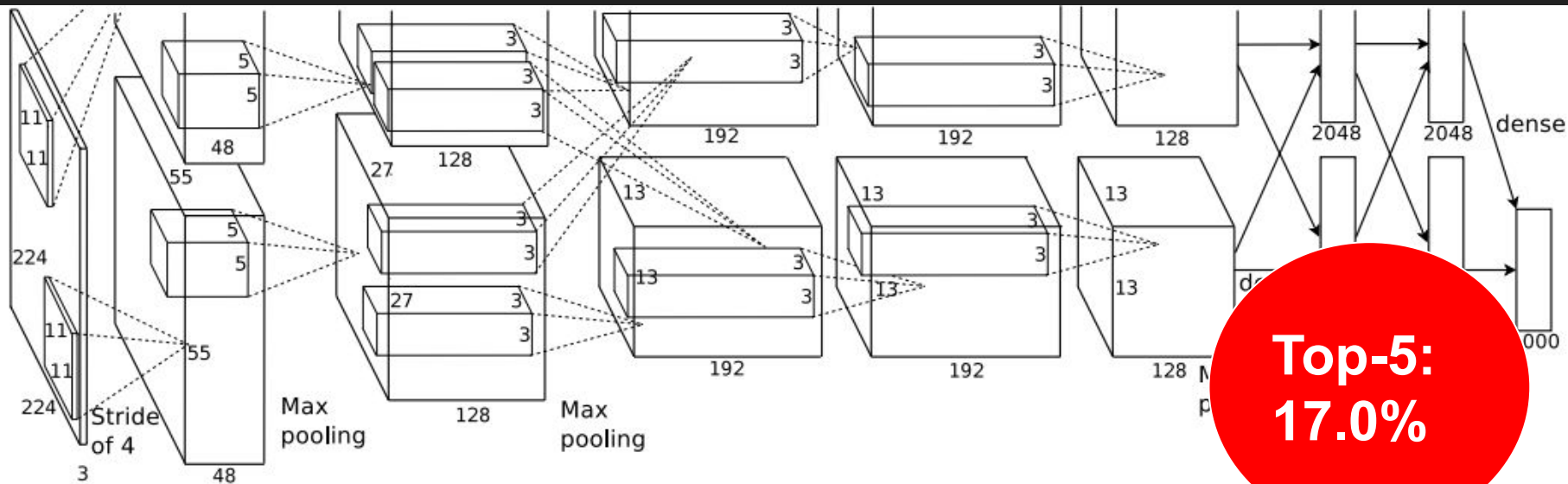
# 2010

IMGENET

***Large Scale Visual Recognition Challenge.***



## 2012 WINNER



**ReLU - accelerate training**

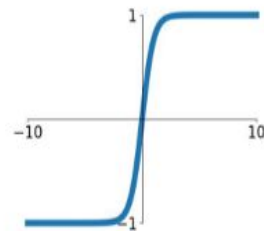
**2 parallel GPUs communicating  
between certain layers**

**Local Response Normalization**

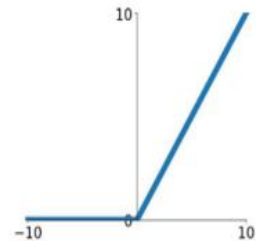
**Overlapping Pooling**

**Dropout - to reduce overfitting**

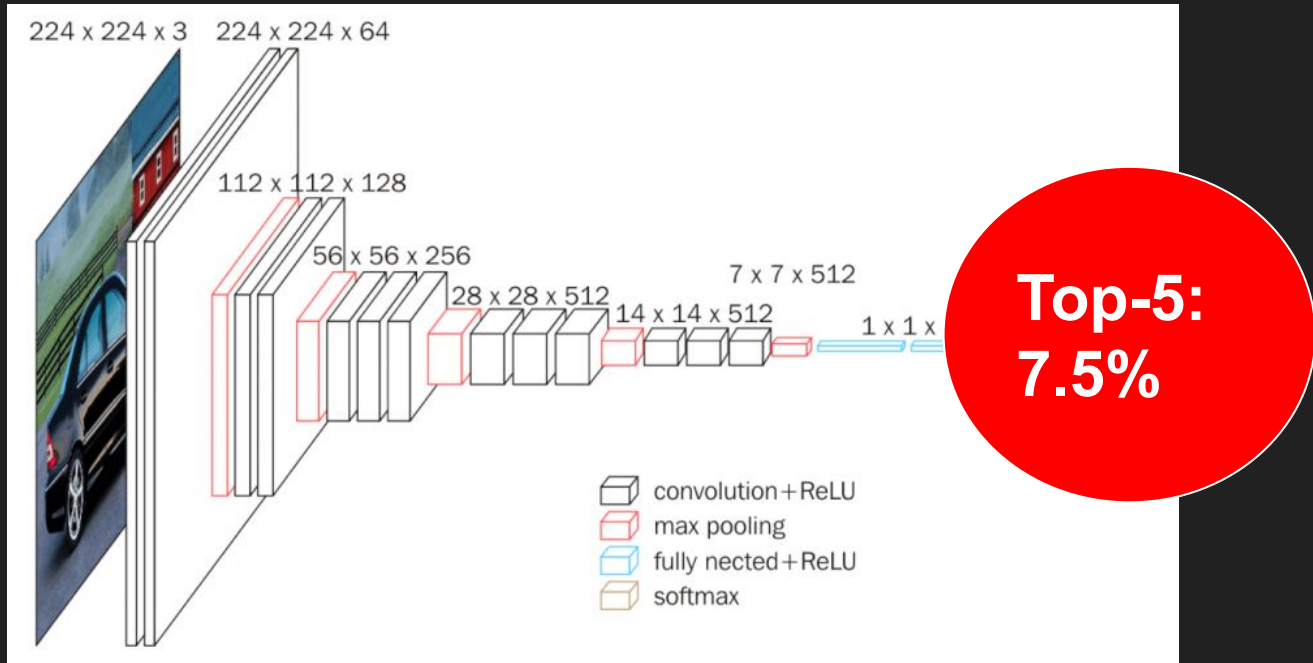
**tanh**  
 $\tanh(x)$



**ReLU**  
 $\max(0, x)$

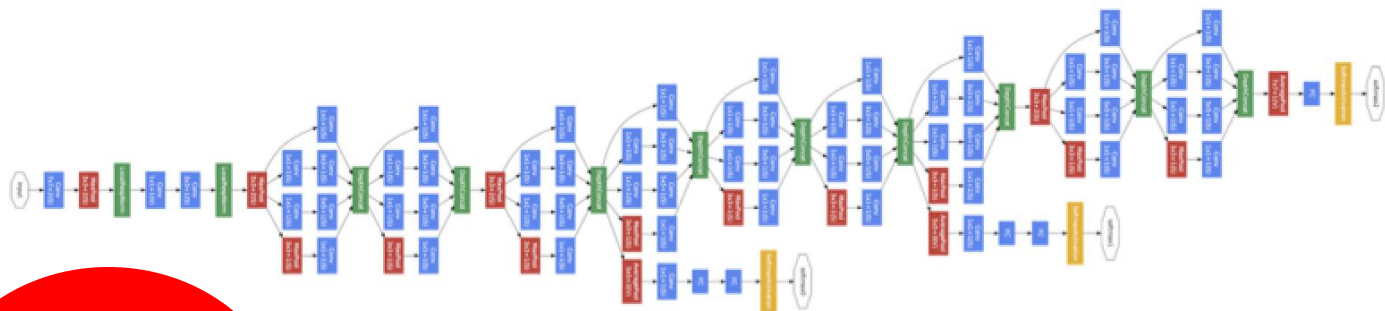


**2014**  
**V.G.G.**



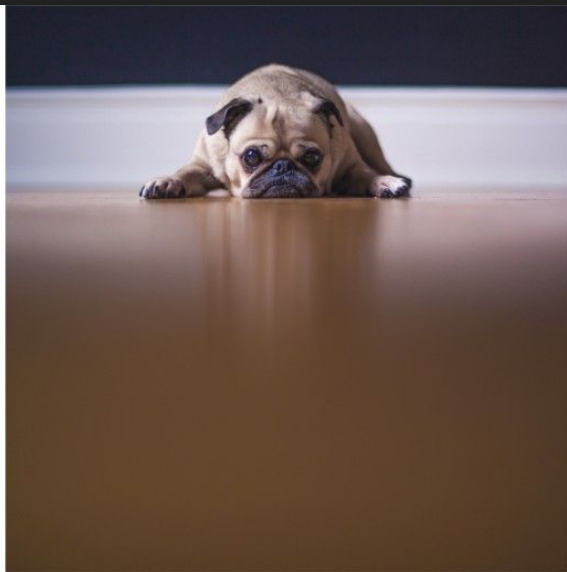
# 2015 GoogLeNet

2014 WINNER



Top-5:  
6.67%

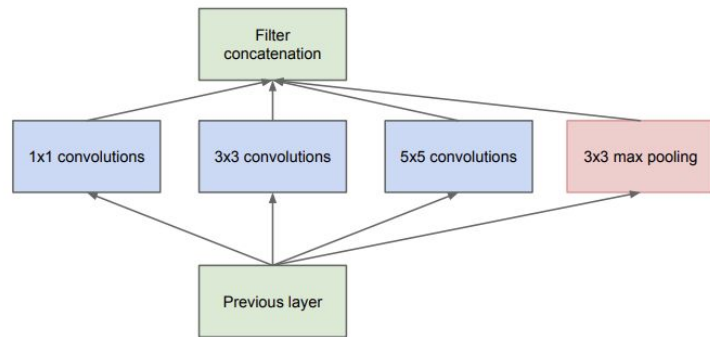
Convolution  
Pooling  
Softmax  
Other



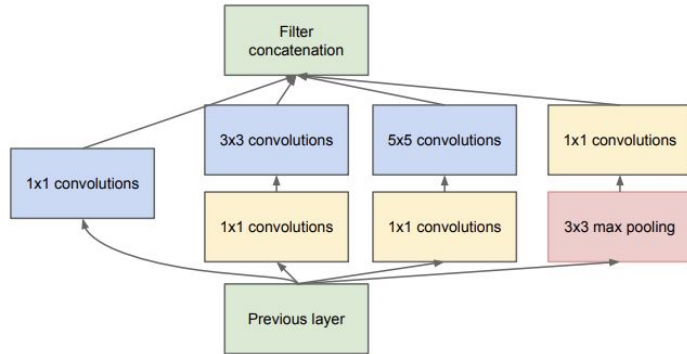
# Inception Module

At each layer make a choice:  
Pooling or perform a  
convolution.

Why not perform all and  
concatenate.



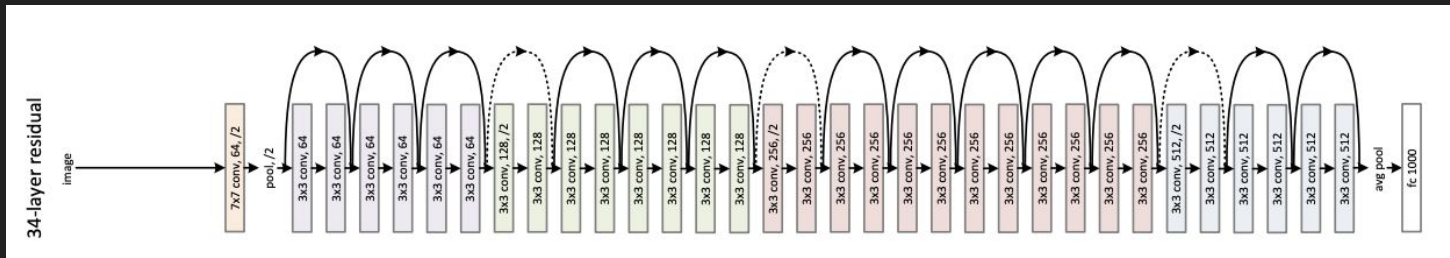
(a) Inception module, naïve version



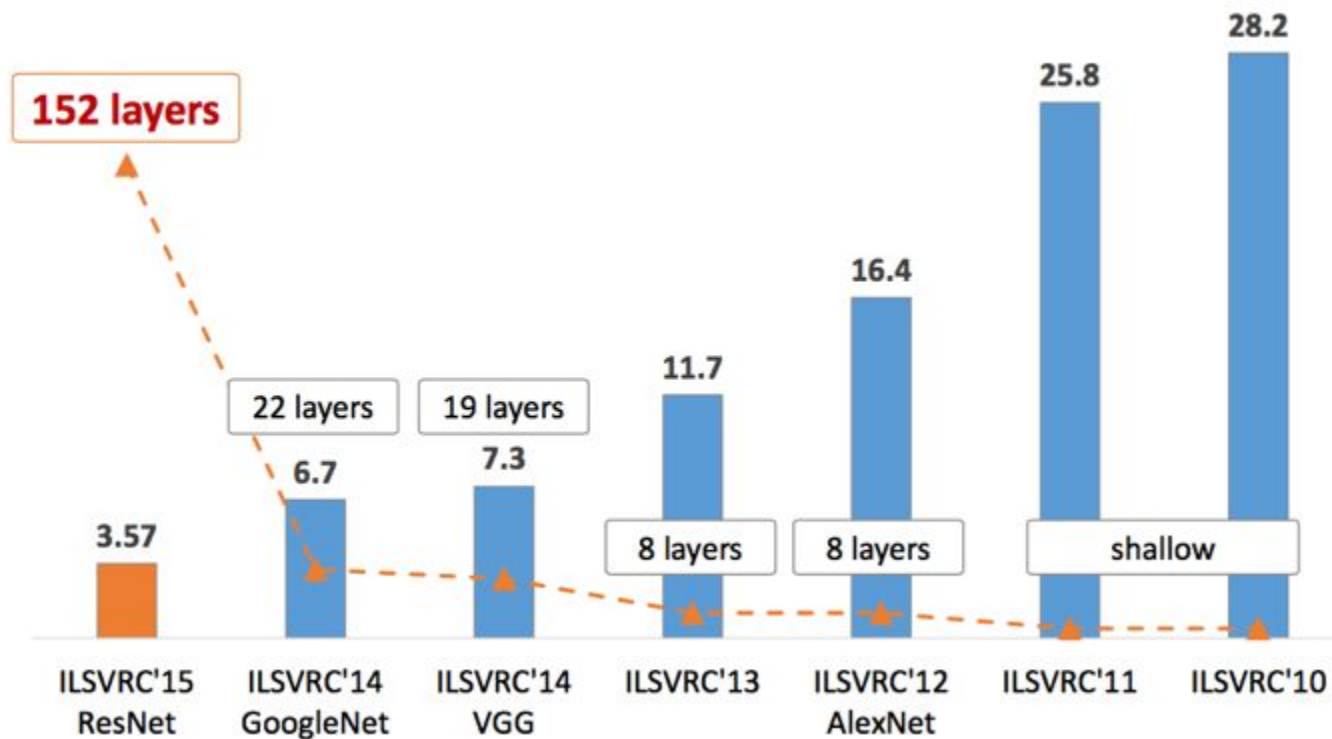
(b) Inception module with dimensionality reduction

# 2015 ResNet

## 2015 WINNER



**Top-5:  
3.57%**



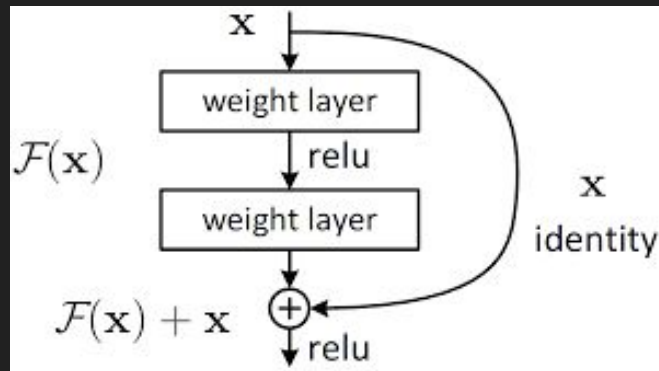


# Deep Residual Learning

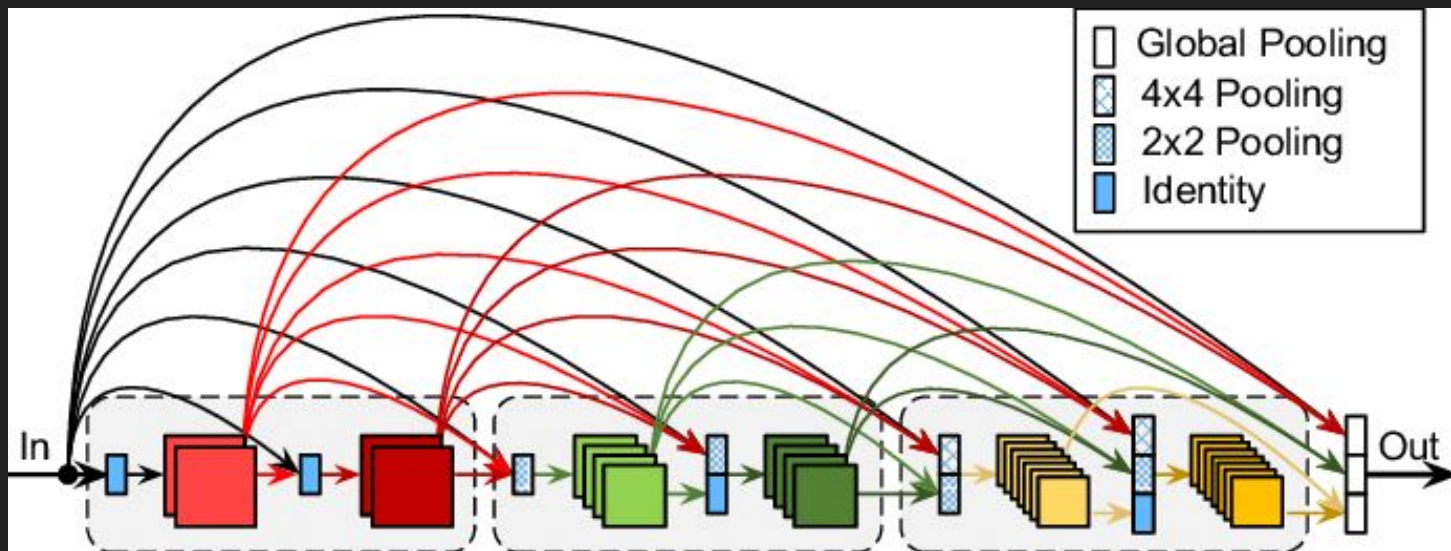
## Solution to Degradation

Append current output to the output n convolutional layers later.

Much deeper network

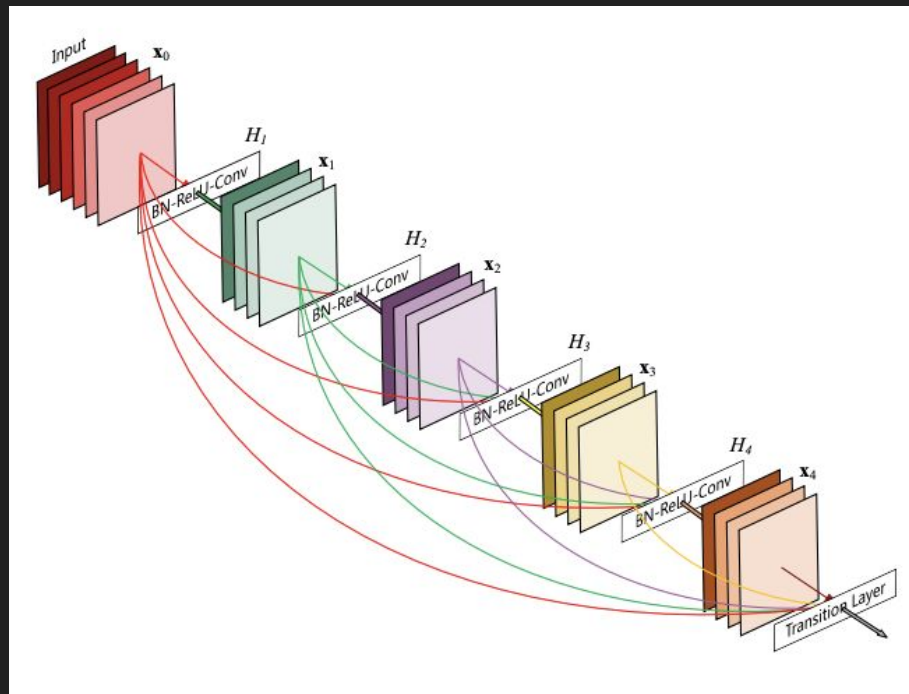


# 2017 DenseNet



# Dense Blocks

At each layer in the block take all preceding feature maps



**Questions**