

# Applied Artificial Intelligence

## Session 18: Convolutional Neural Networks CNNs

Fall 2018

NC State University

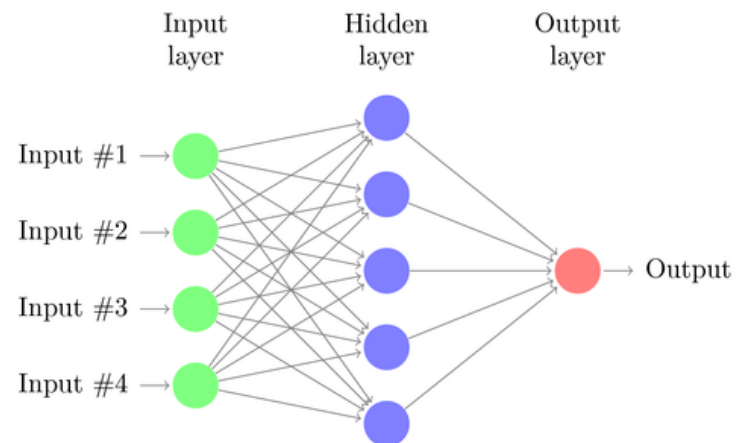
Lecturer: Dr. Behnam Kia

Course Website: <https://appliedai.wordpress.ncsu.edu/>

# Deep Feedforward Neural Networks' Problems

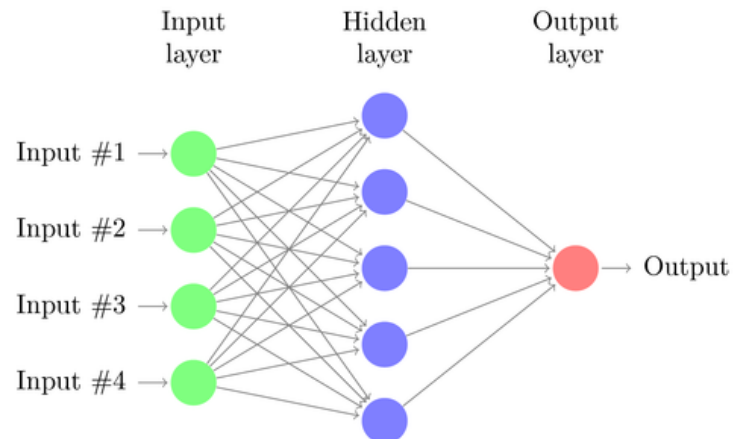
# Deep Feedforward Networks' Problems

- Size:
  - Imagine an image of 1000\*1000 pixel.
  - And the input layer has 1000 neurons.
  - We are going to have  $10^9$  connections and parameters to learn.



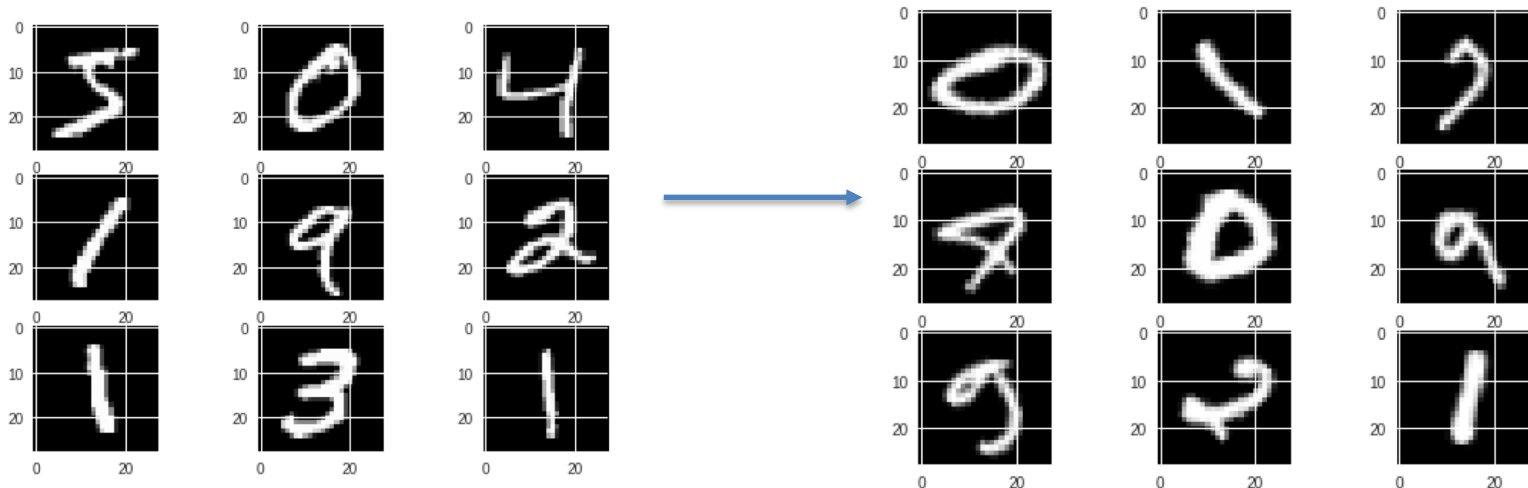
# Deep Feedforward Networks' Problems

- This fully connected network doesn't pay attention to spatial or temporal structure of the input.
  - For example, shuffle the pixels in all images in the data set in the same, result unrecognizable for human eye, but network will still classify them.



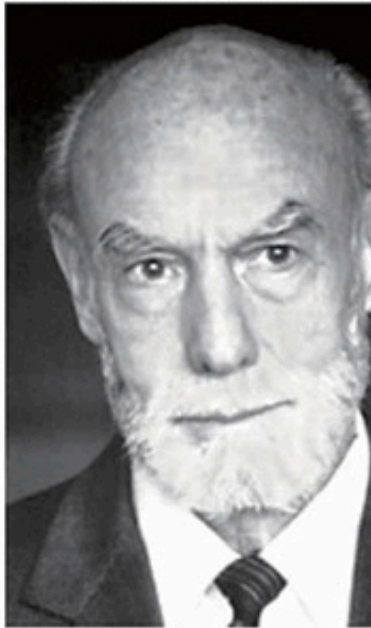
# Deep Feedforward Networks' Problems

- DNNs expect the patterns (or objects) in the exact location and in the exact orientation that they were trained for.
- Translate or rotate the patterns and DNN might fail to recognize it.



# Solution is Coming from Neuroscience

"for his discoveries concerning the functional specialization of the cerebral hemispheres"  
"for their discoveries concerning information processing in the visual system"



**Roger W. Sperry**

🏆 1/2 of the prize

USA

California Institute of  
Technology (Caltech)  
Pasadena, CA, USA

b. 1913  
d. 1994



**David H. Hubel**

🏆 1/4 of the prize

USA

Harvard Medical School  
Boston, MA, USA

b. 1926  
(in Windsor, ON, Canada)



**Torsten N. Wiesel**

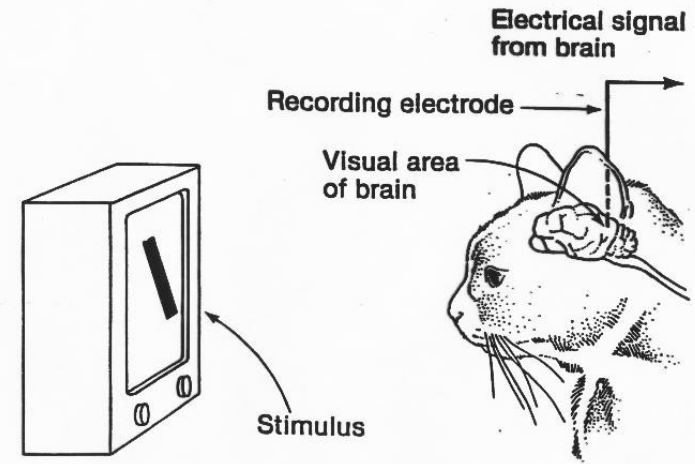
🏆 1/4 of the prize

Sweden

Harvard Medical School  
Boston, MA, USA

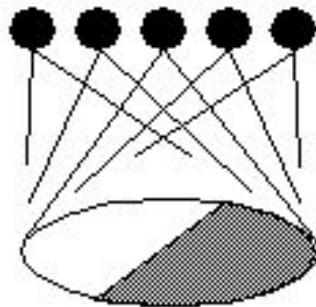
b. 1924

# Solution is Coming from Neuroscience



## Hubel & Weisel

topographical mapping

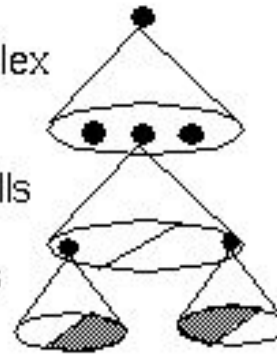


## featural hierarchy

hyper-complex cells

complex cells

simple cells



high level

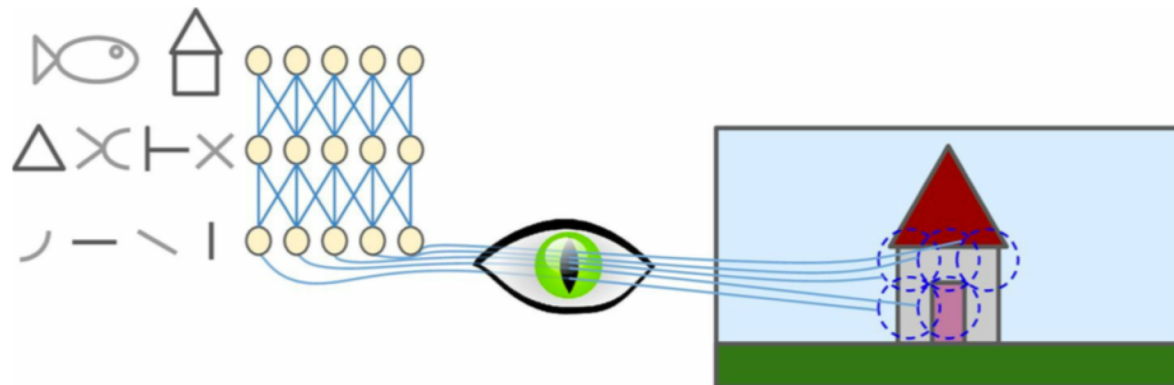
mid level

low level

low level

# Solution is Coming from Neuroscience

- In visual cortex:
  - Many neurons have small local receptive fields.
  - Some neurons react to a specific feature, whereas some others react to another feature.
  - Some higher level neurons have a larger receptive field, and react to more complex patterns produced by a combination of simpler patterns of neighboring low level neurons.

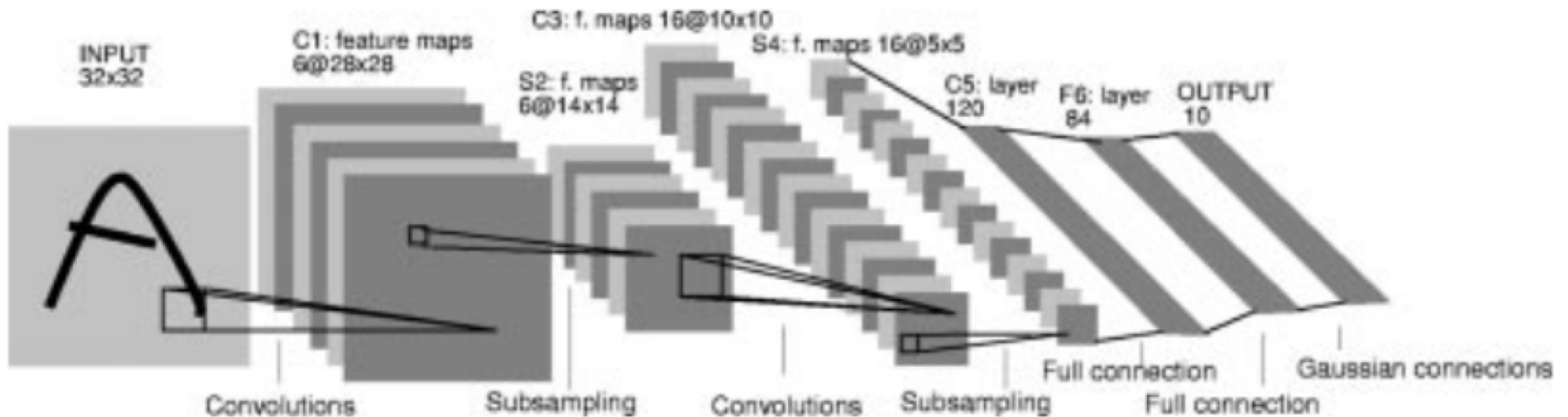




# Gradient-Based Learning Applied to Document Recognition

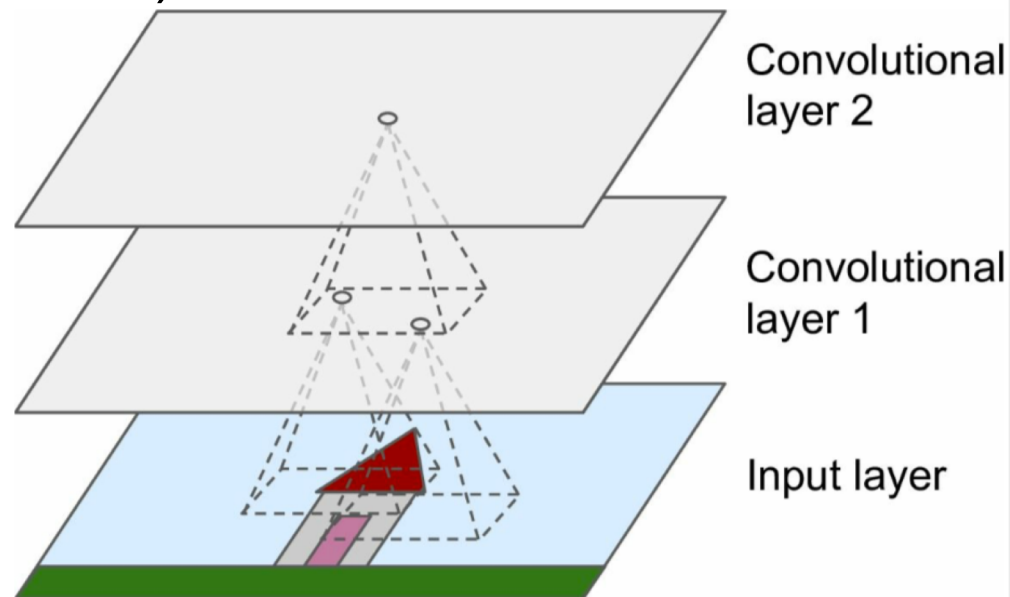
YANN LECUN, MEMBER, IEEE, LÉON BOTTOU, YOSHUA BENGIO, AND PATRICK HAFFNER

*Invited Paper*

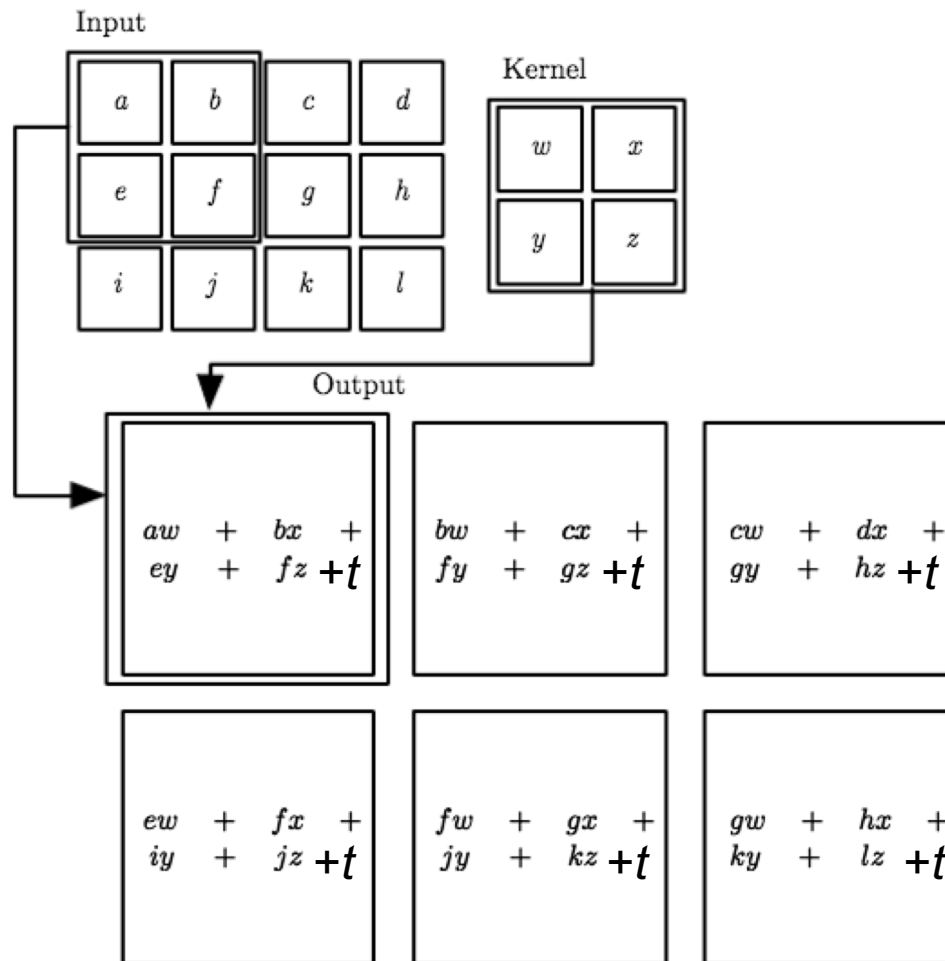


# Convolutional Layer

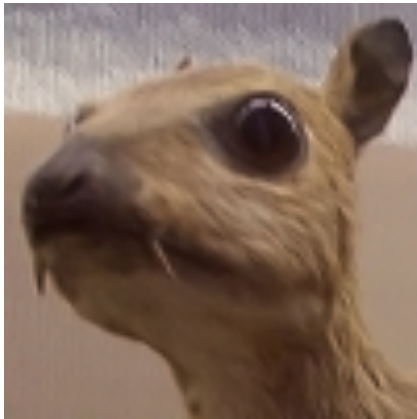
- Each neuron in a convolutional layer 1 is connected to pixels in its receptive fields (not to all pixels).
- And each neuron in convolutional layer 2 is connected to convolutional layer 1 neurons in its receptive field (not to all neurons).



# Convolutional Layer: Filter



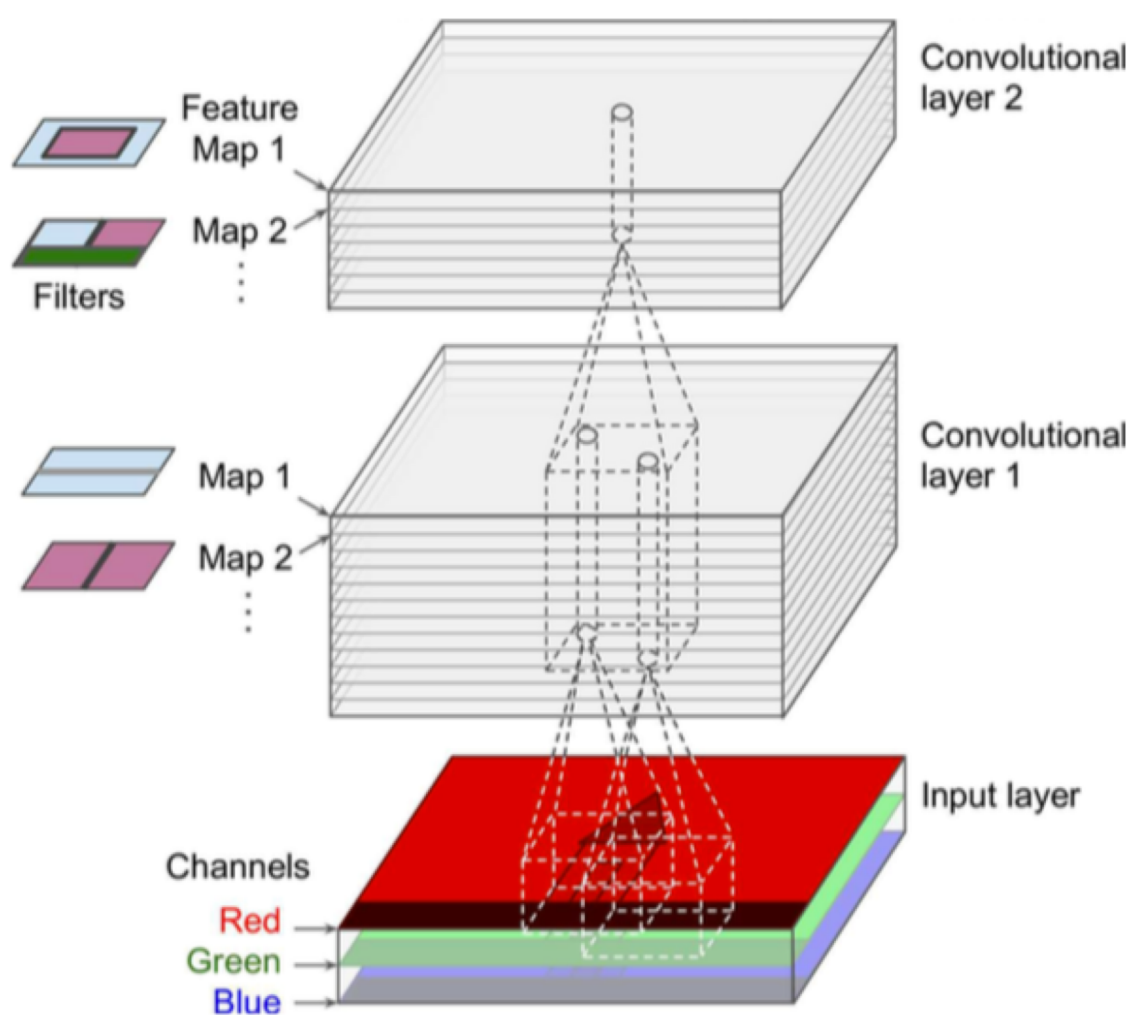
# Image Processing



$$\textit{Kernel} = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$



# Stacking Convolutional Layers



# Pooling Layer

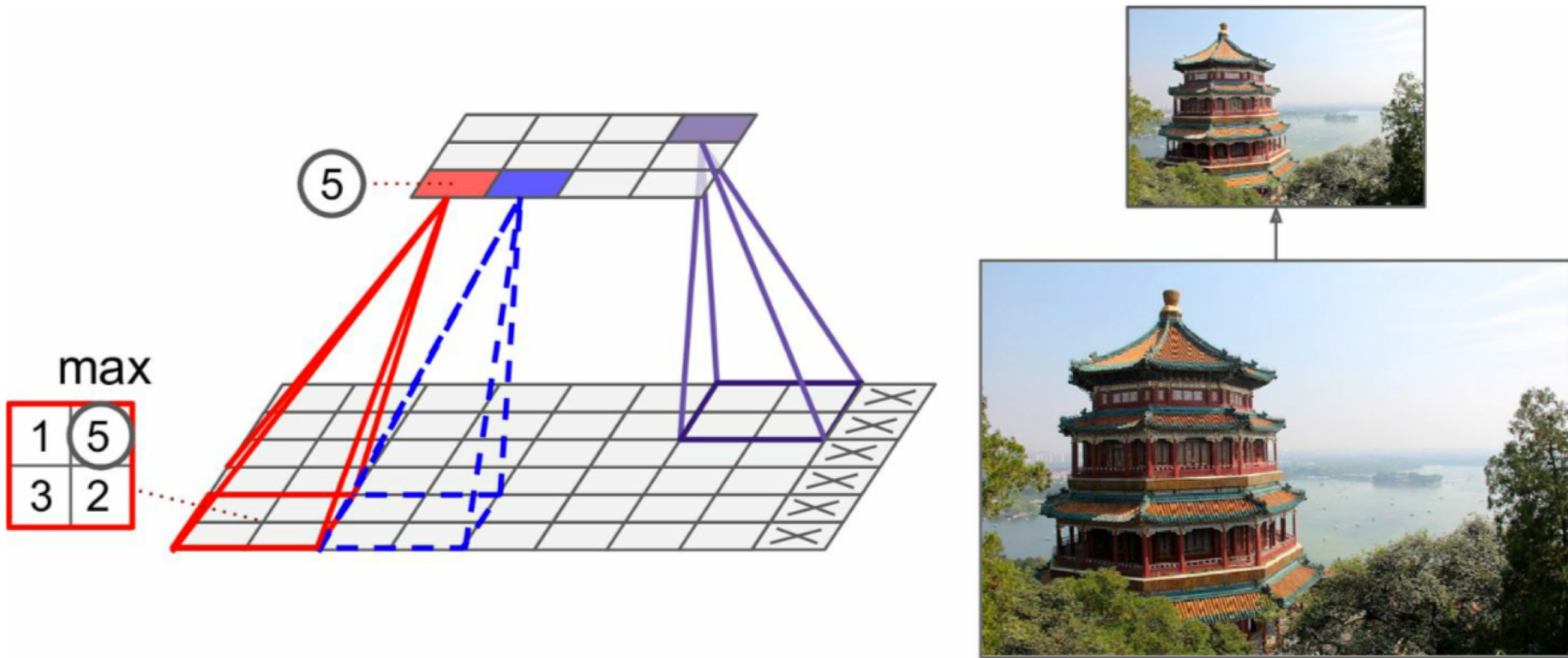


Figure 13-8. Max pooling layer ( $2 \times 2$  pooling kernel, stride 2, no padding)

# CNN Architecture

