Lecture 25

Agenda

Convolutional Neural Networks (CNN)

- Motivation
- Convolutions
  - Stride
  - Dilation
- Padding
  - Zero
  - Reflection
- Pooling
- Receptive Field
- LeNet

Motivation

Deep Big Simple Neural Nets Excel on Hand- written Digit Recognition

Table 1: Error rates on MNIST test set.

ID	architecture (number of neurons in each layer)	test error for best validation [%]	best test error [%]	simulation time [h]	weights [milions]
1	1000, 500, 10	**0.49**	0.44	23.4	1.34
2	1500, 1000, 500, 10	**0.46**	0.40	44.2	3.26
3	2000, 1500, 1000, 500, 10	**0.41**	0.39	66.7	6.69
4	2500, 2000, 1500, 1000, 500, 10	**0.35**	0.32	114.5	12.11
5	9×1000, 10	**0.44**	0.43	107.7	8.86

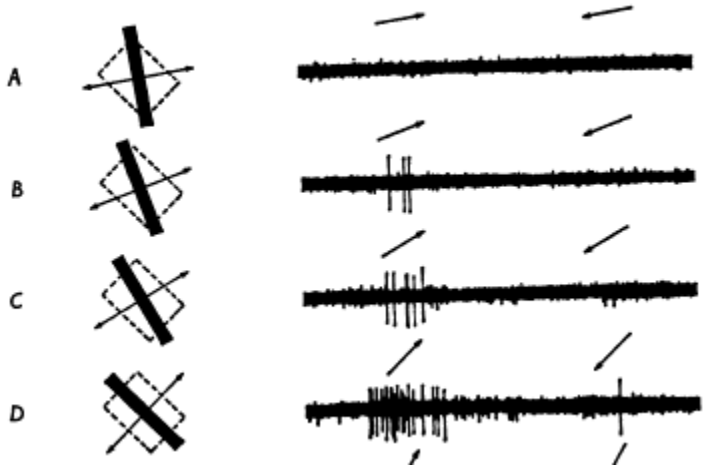
`https://arxiv.org/abs/1003.0358`

Motivation

J Physiol. 1959 Sep 2; 147(2): 226–238.2.
doi: 10.1113/jphysiol.1959.sp006238

Single unit activity in striate cortex of unrestrained cats

D. H. Hubel



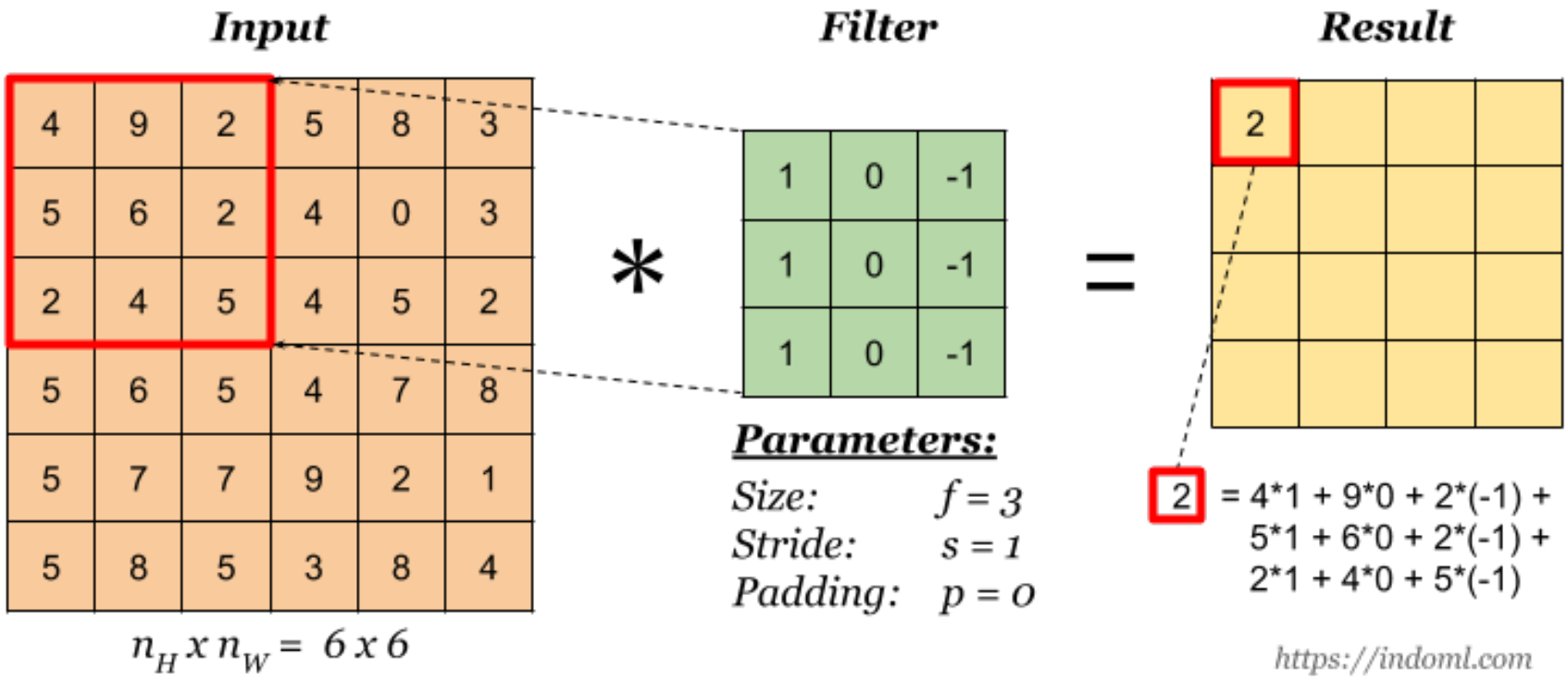
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1357023/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1557912/

Filters

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} - \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix} - \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

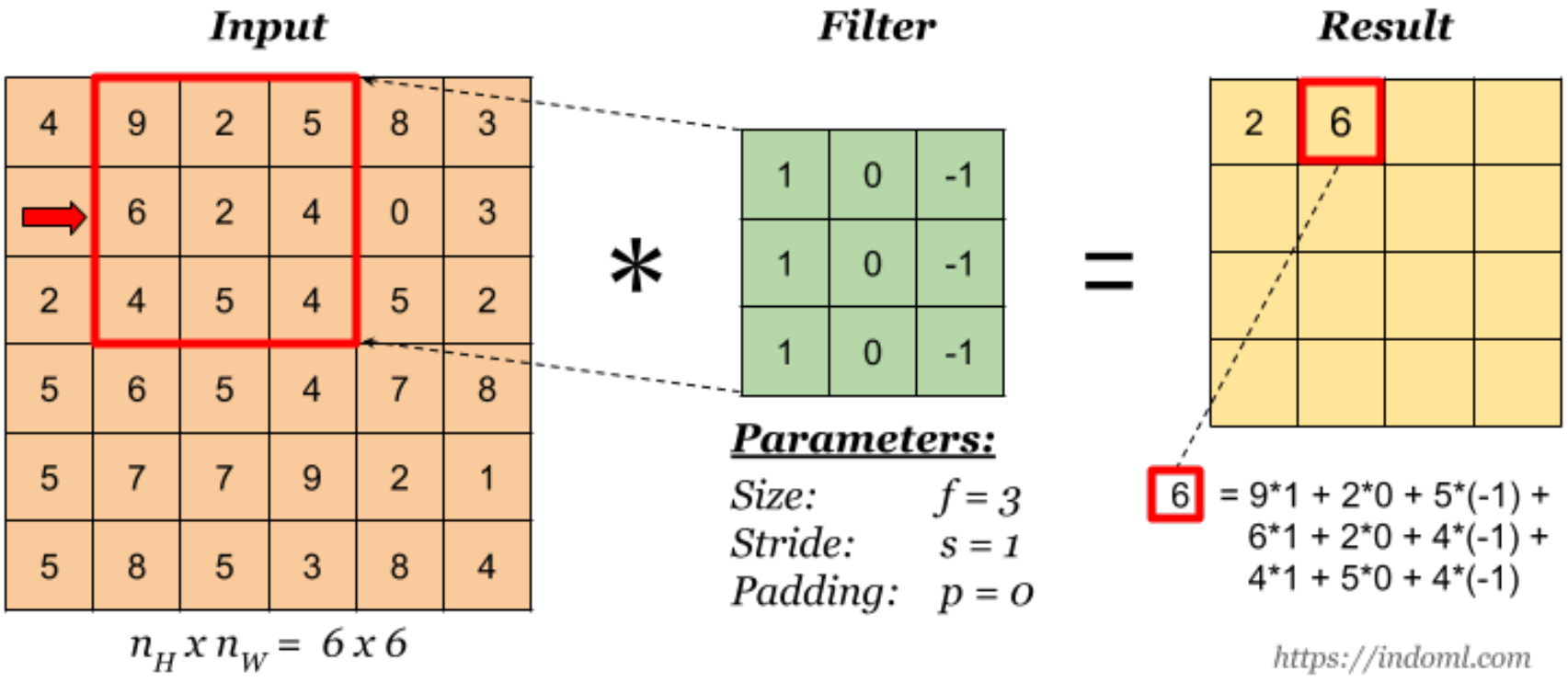
https://ai.stanford.edu/~syyeung/cvweb/tutorial1.html

Convolution



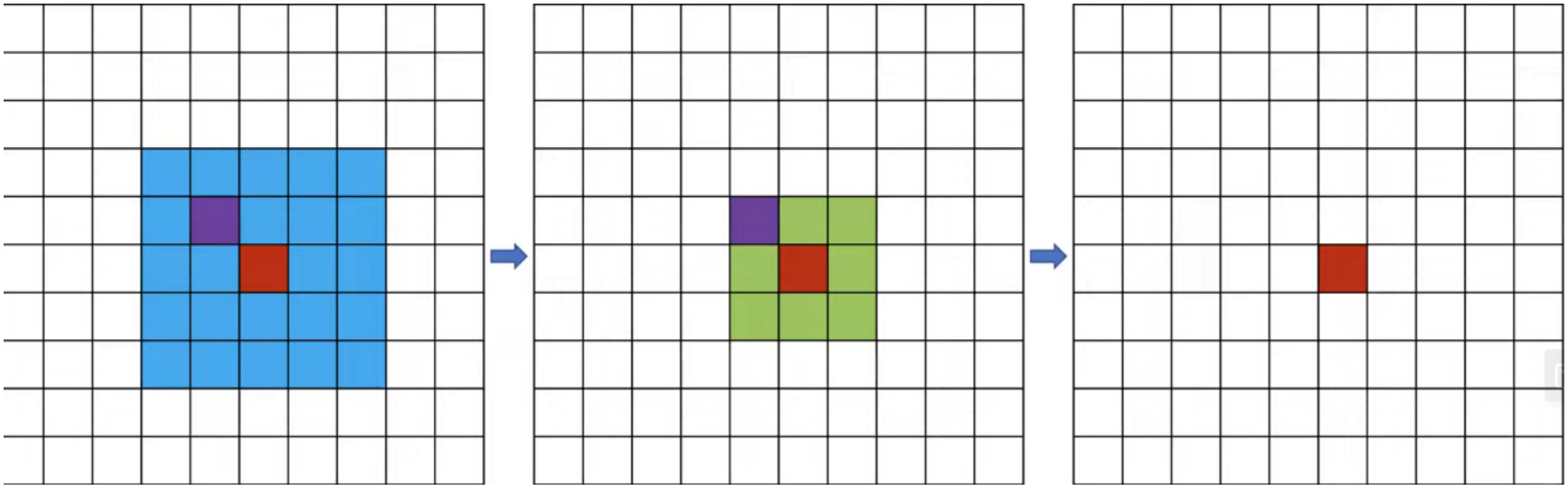
https://indoml.com/2018/03/07/student-notes-convolutional-neural-networks-cnn-introduction/

Convolution



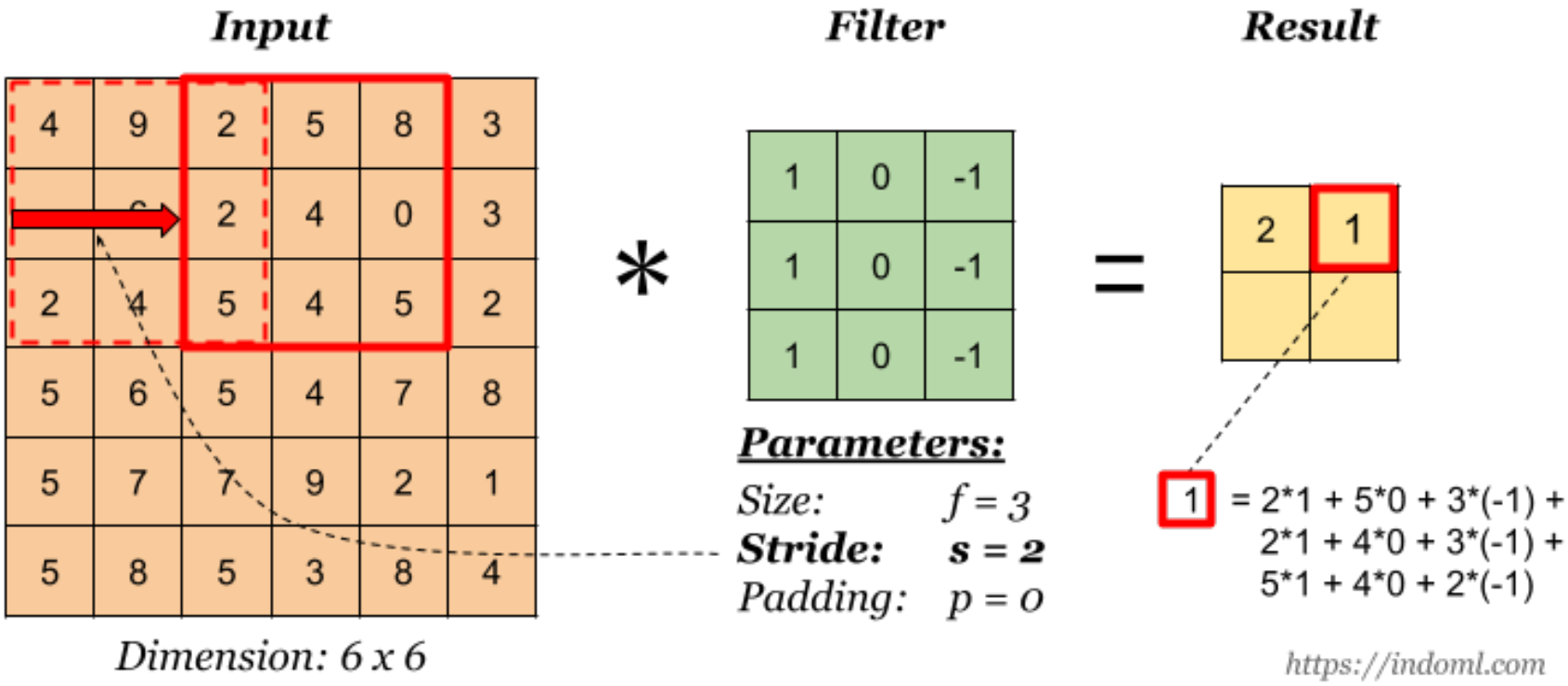
https://indoml.com/2018/03/07/student-notes-convolutional-neural-networks-cnn-introduction/

Convolution and Receptive Field



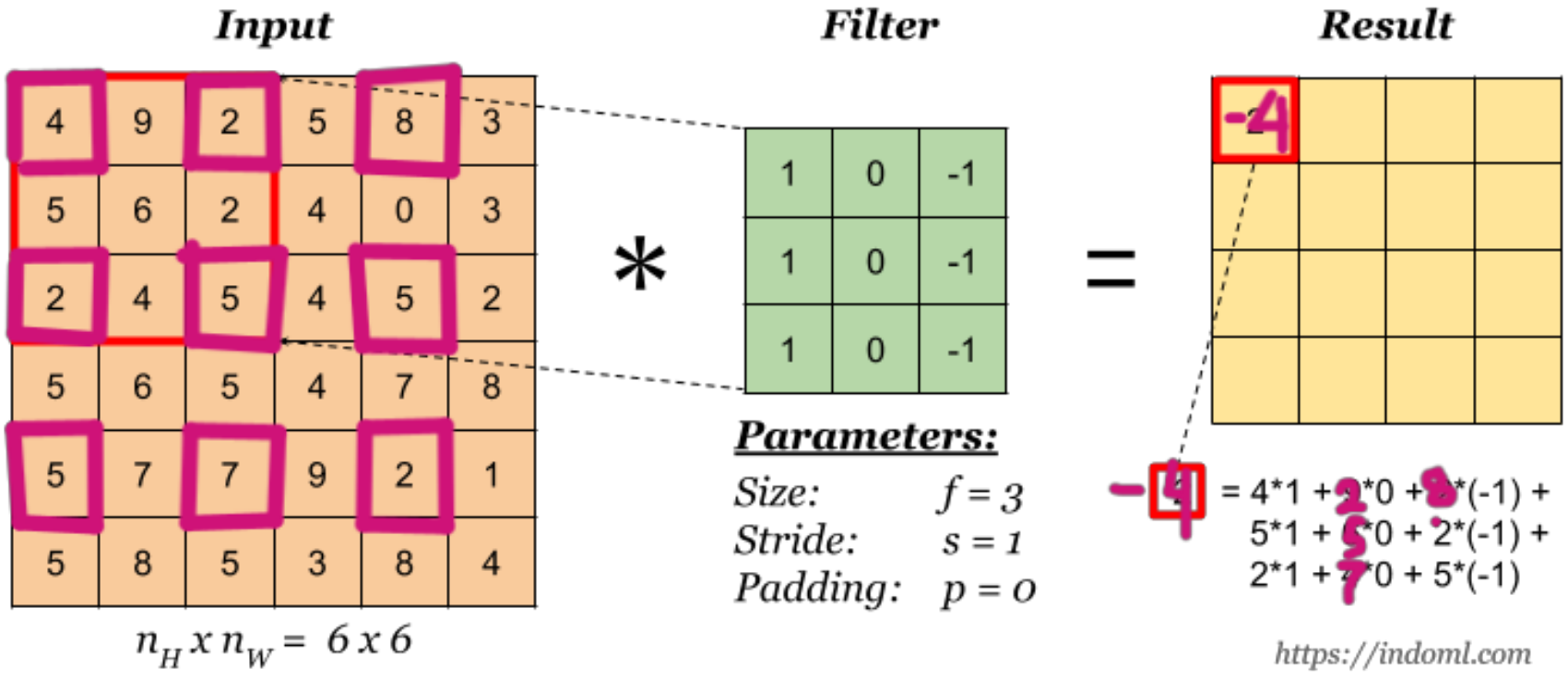
Source: `https://youtu.be/G3VjGWTsoSA?si=pMqaaL89hA_rCvDq`

Convolution with Stride

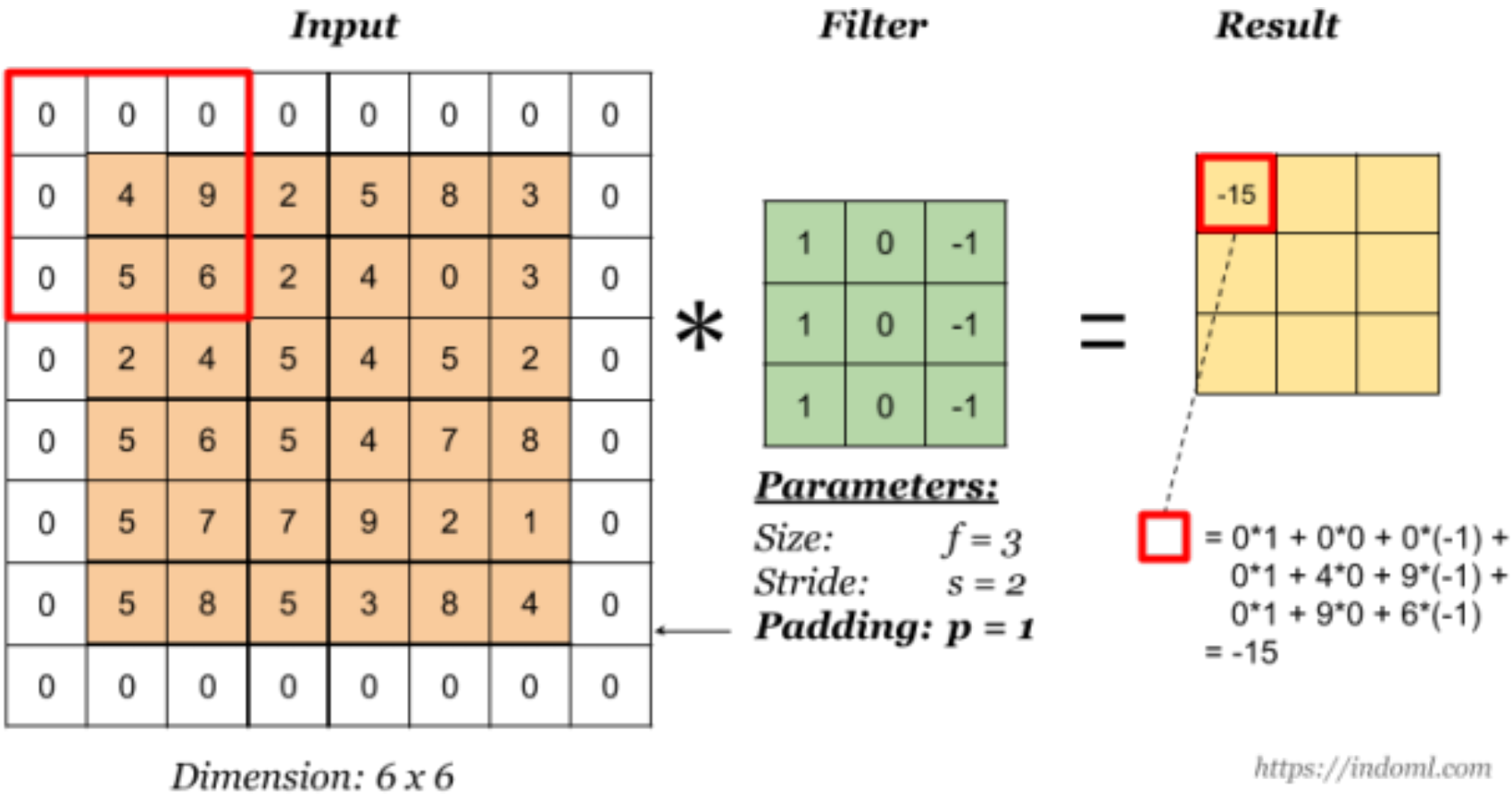


https://indoml.com/2018/03/07/student-notes-convolutional-neural-networks-cnn-introduction/

Dilated Convolution

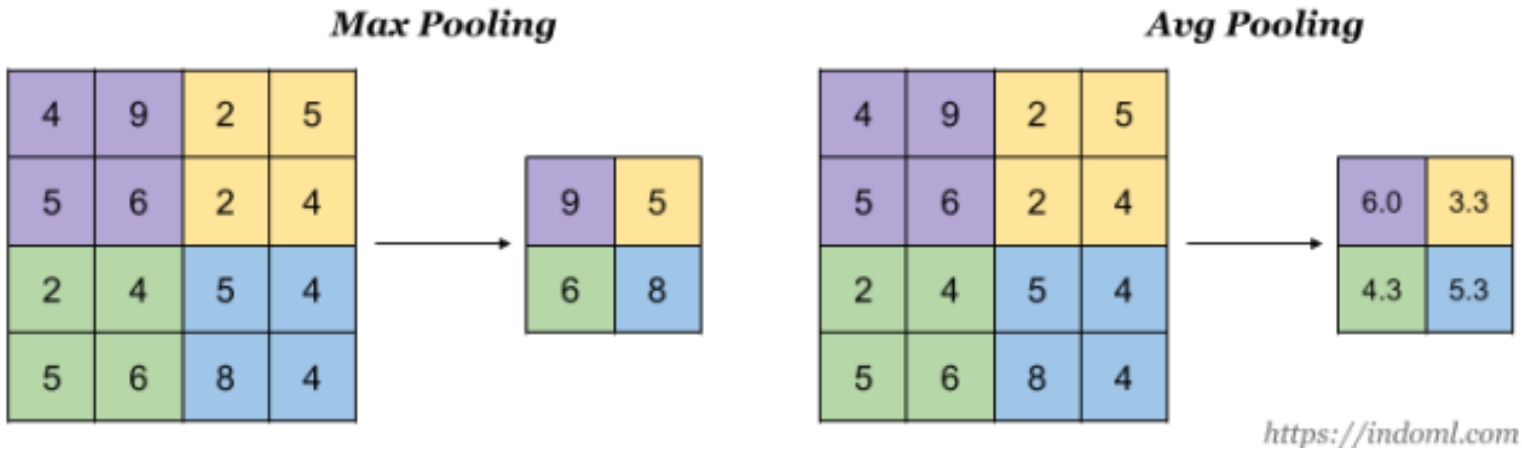


Padding



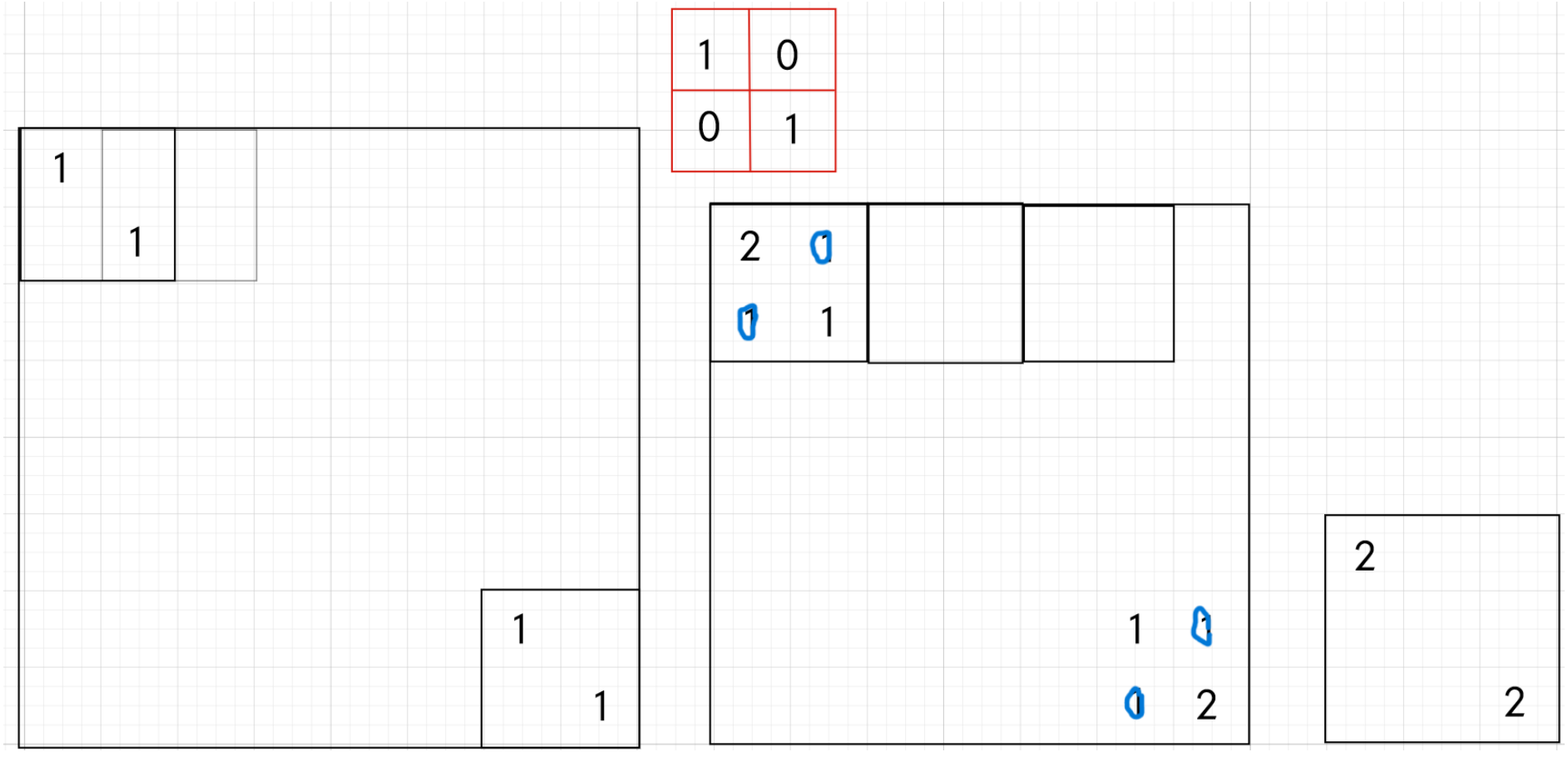
https://indoml.com/2018/03/07/student-notes-convolutional-neural-networks-cnn-introduction/

Pooling

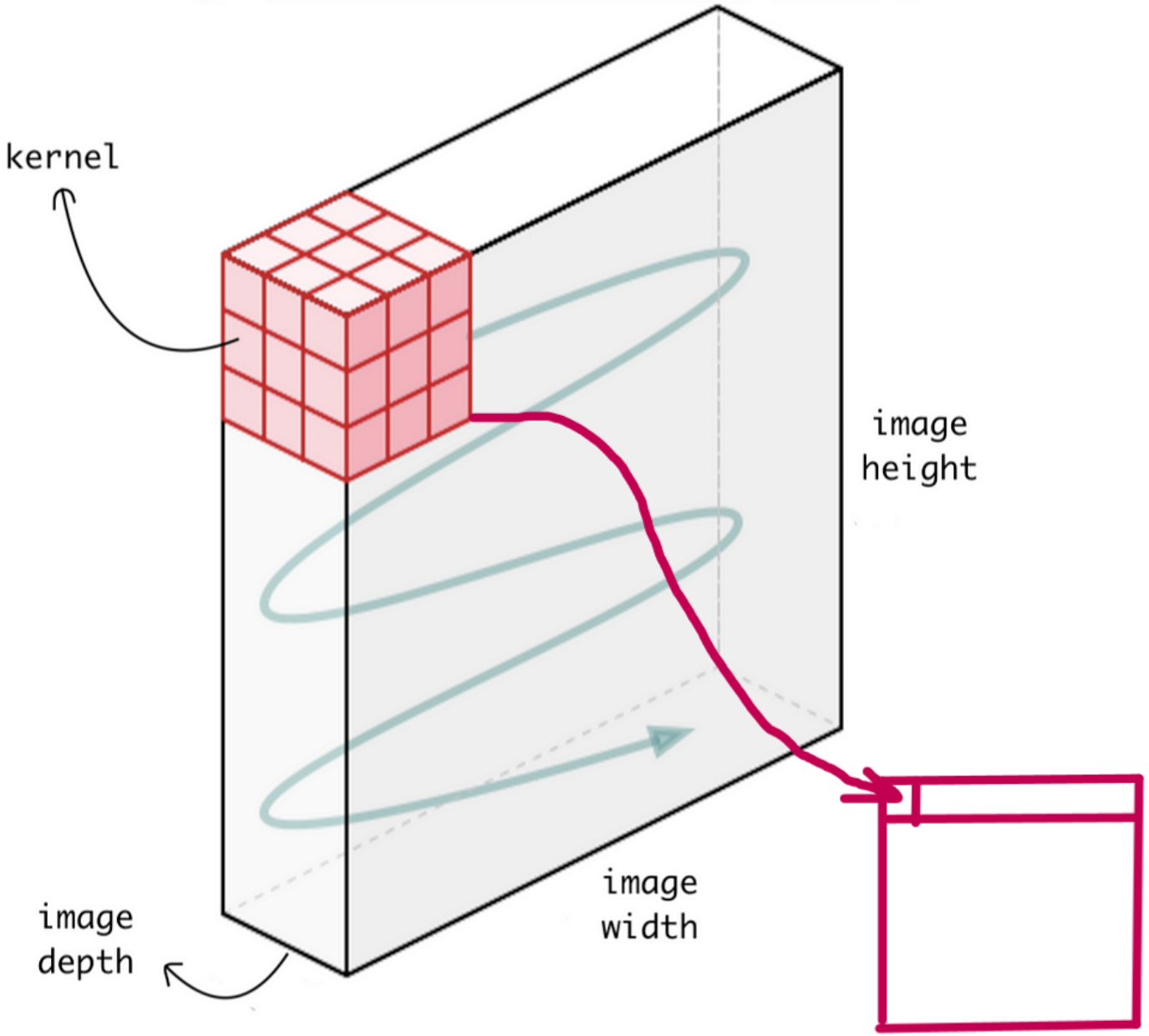


https://indoml.com/2018/03/07/student-notes-convolutional-neural-networks-cnn-introduction/

Shift Invariant (with max-pooling)

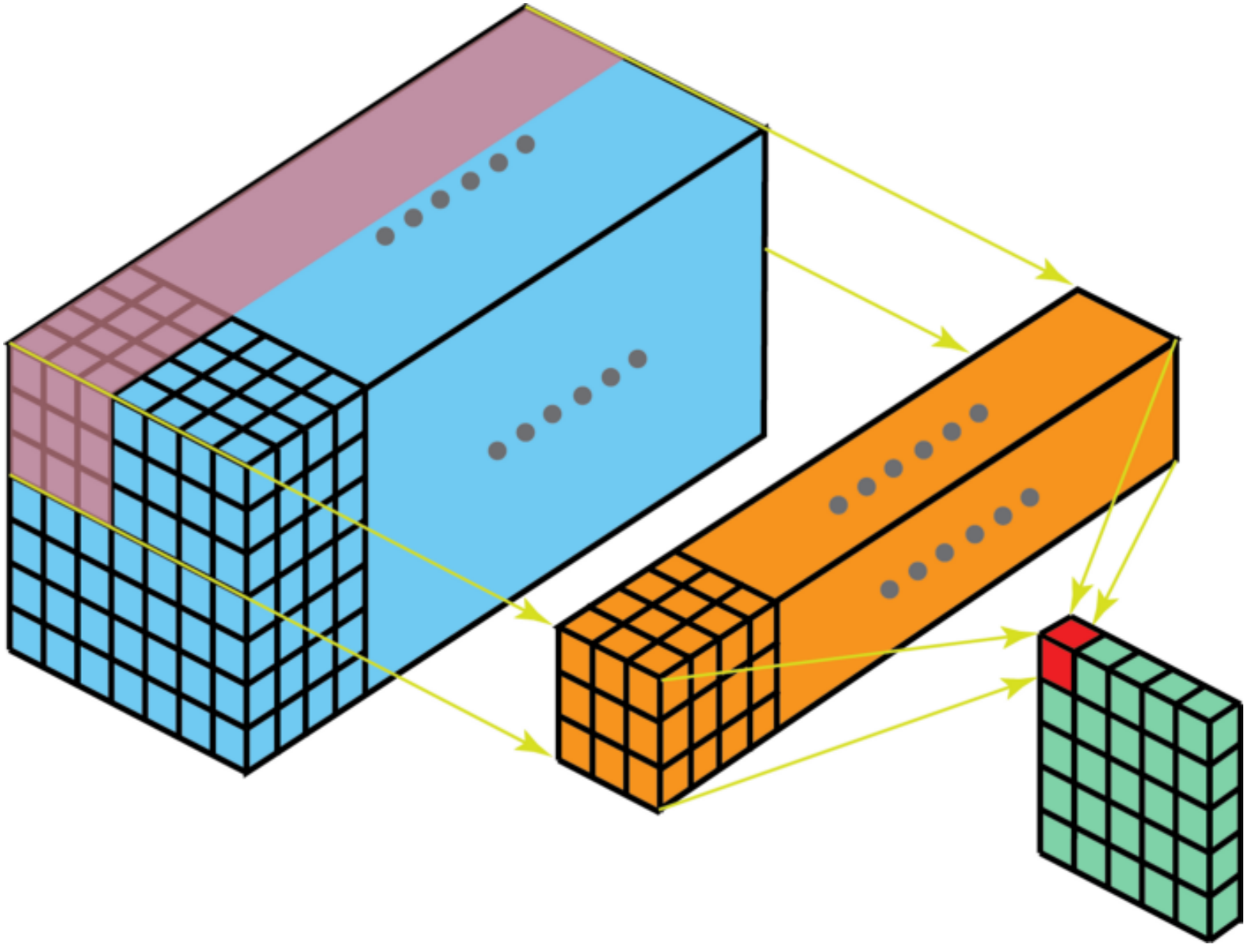


Learnable Filters



http://www.sefidian.com/2019/02/24/

Learnable Filters



https://ai.stackexchange.com/questions/18663/how-to-calculate-the-number-of-parameters-of-a-convolutional-layer

LeNet 1998

PROC. OF THE IEEE, NOVEMBER 1998

Gradient-Based Learning Applied to Document Recognition

Yann LeCun, Léon Bottou, Yoshua Bengio, and Patrick Haffner

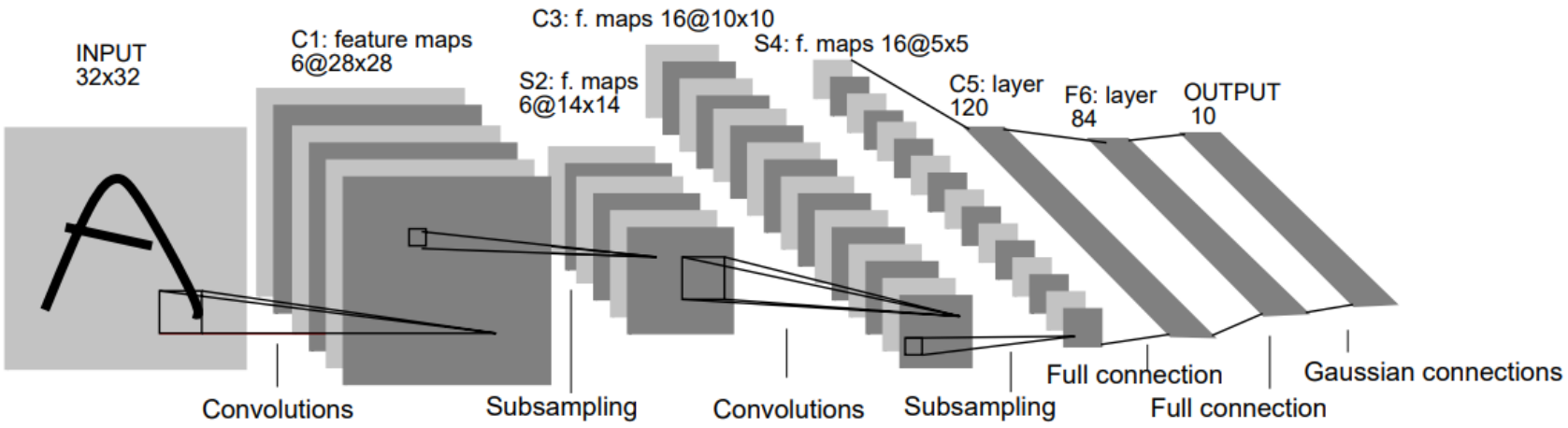


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

http://vision.stanford.edu/cs598_spring07/papers/Lecun98.pdf

R·I·T

Computer Science @ RIT

LeNet 1998

- Trained on MNIST
- End-to-end
- Augmentation was used
- About 60,000 parameters
- Test error 0.8