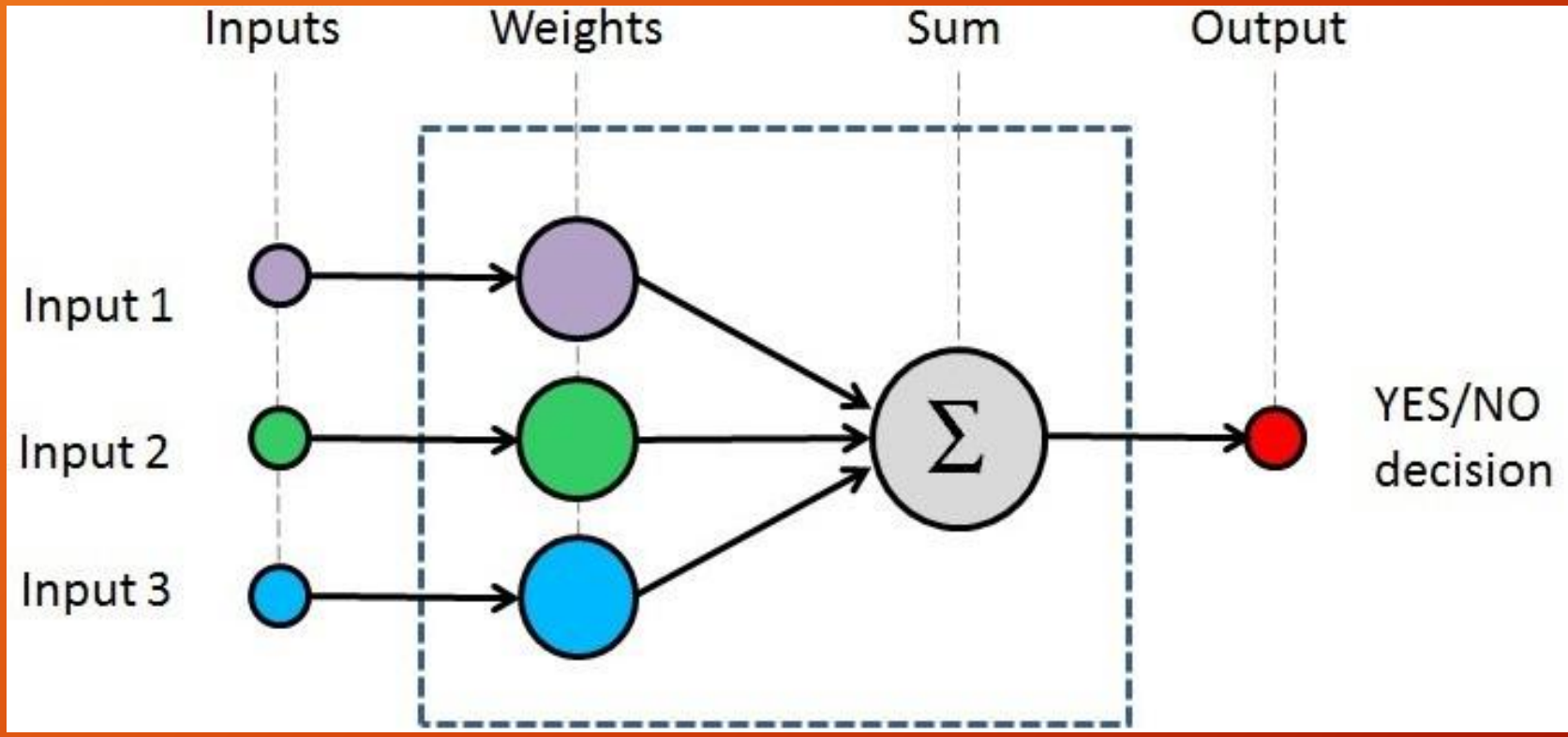
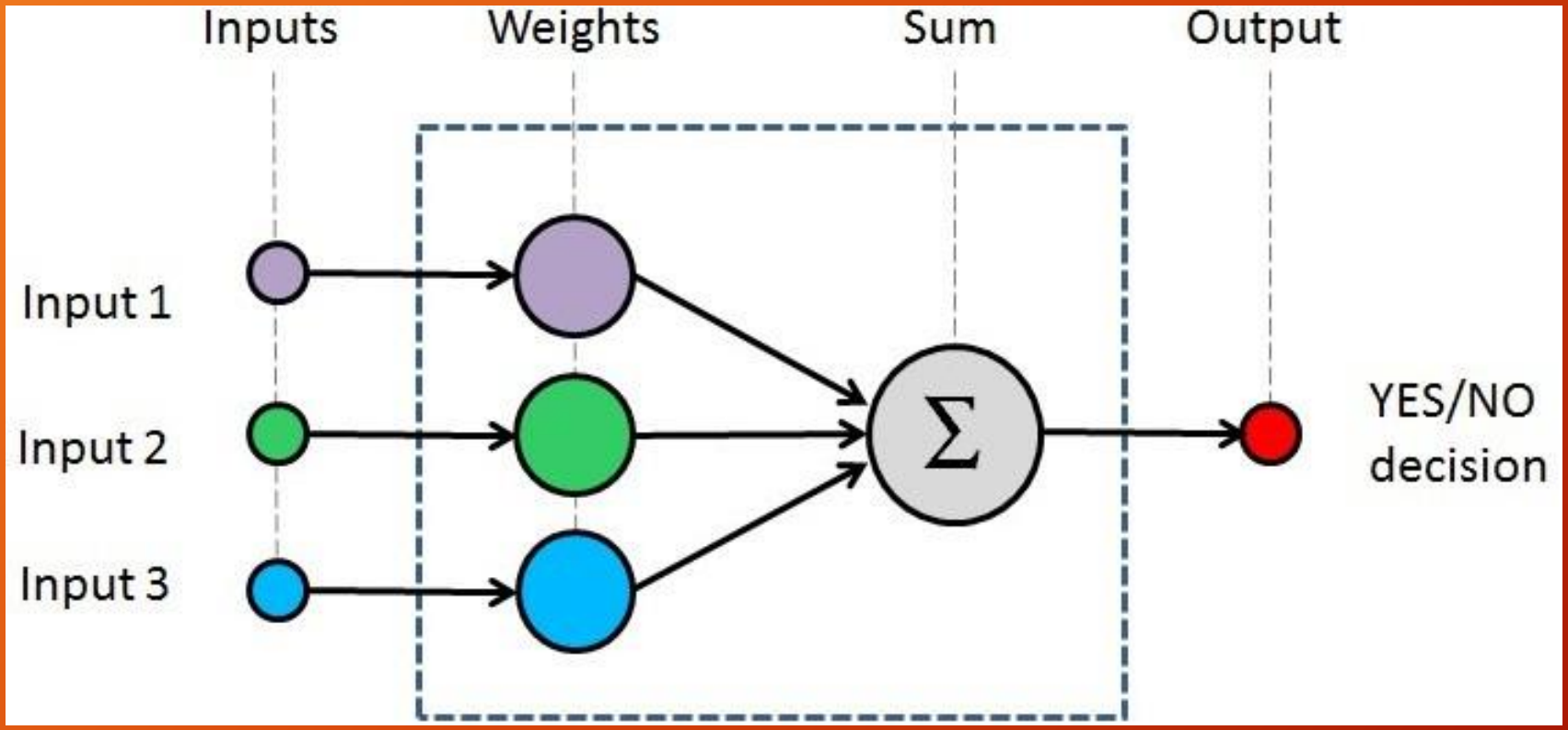
Convolutions

What is convolution?



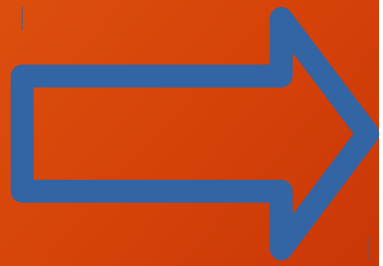
$$X \cdot W = \sum_{i=1}^{n} x_i \times w_i = w^T x$$

What is convolution?

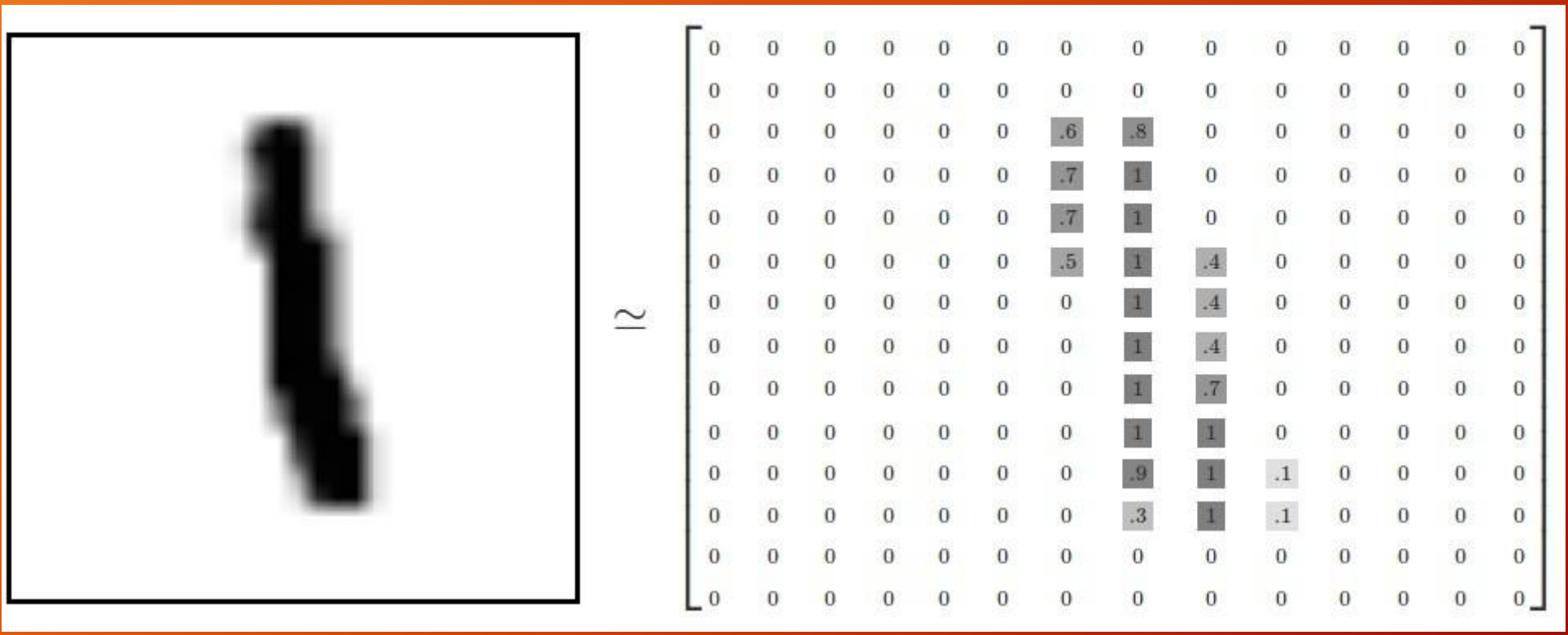



```
Out = 0
for index in number_of_inputs:
        Out = Out + (input[index] x weight[index])
```

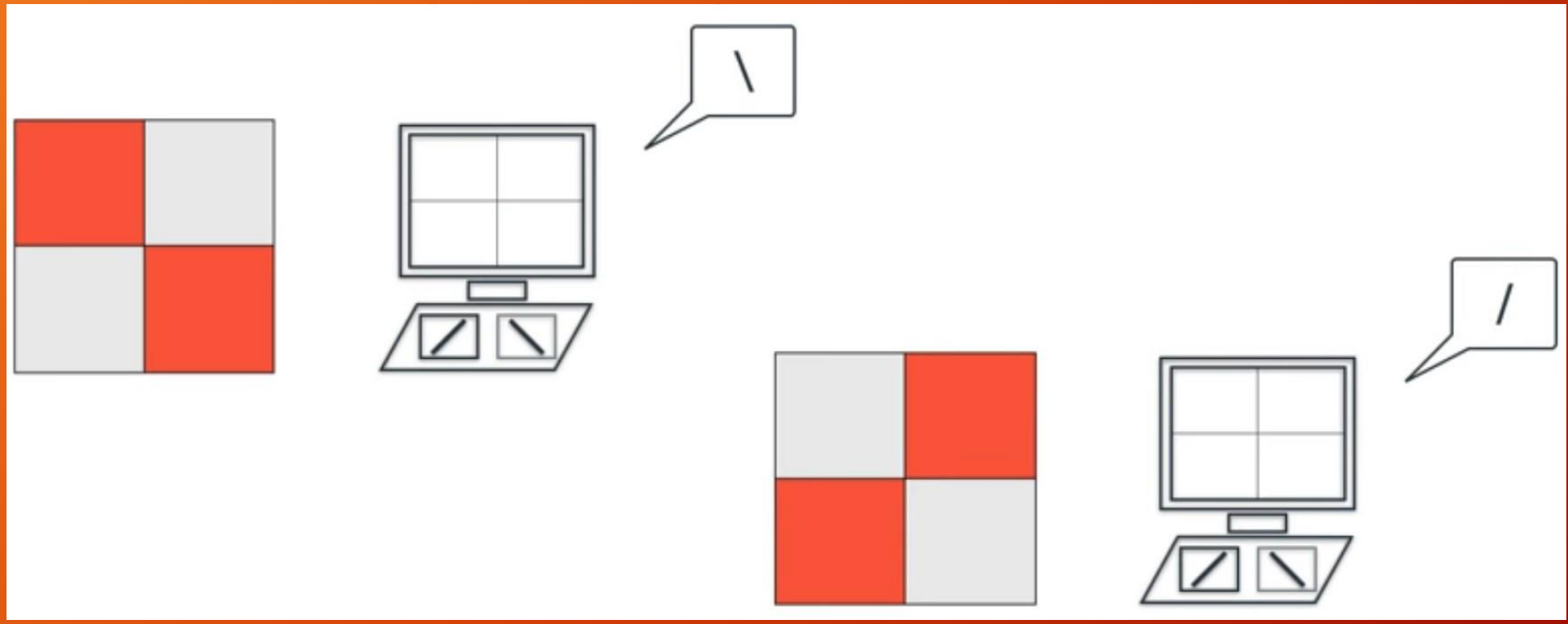
What is convolution?



What is convolution?

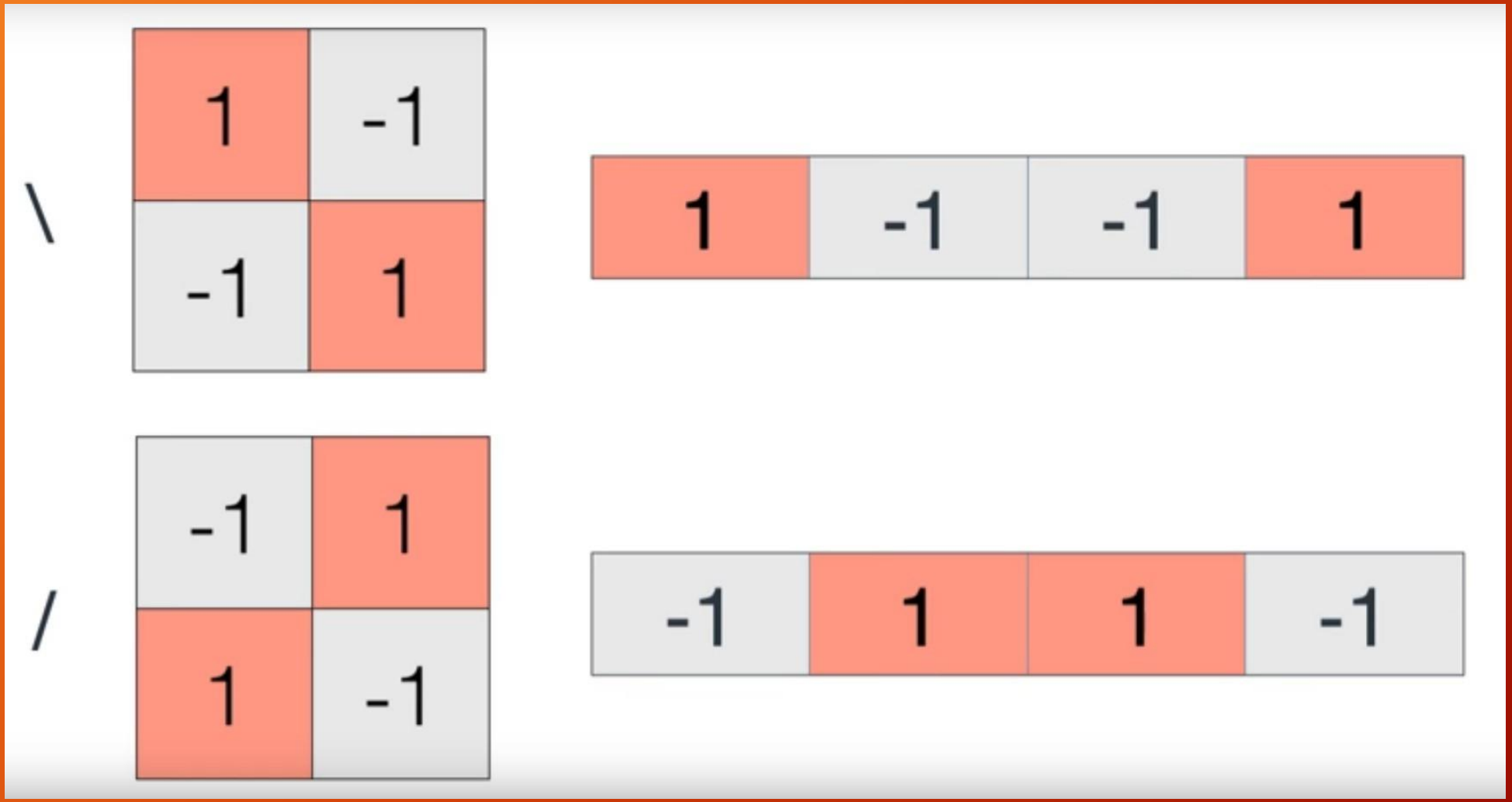


What is convolution?
Detecting slash or backslash..



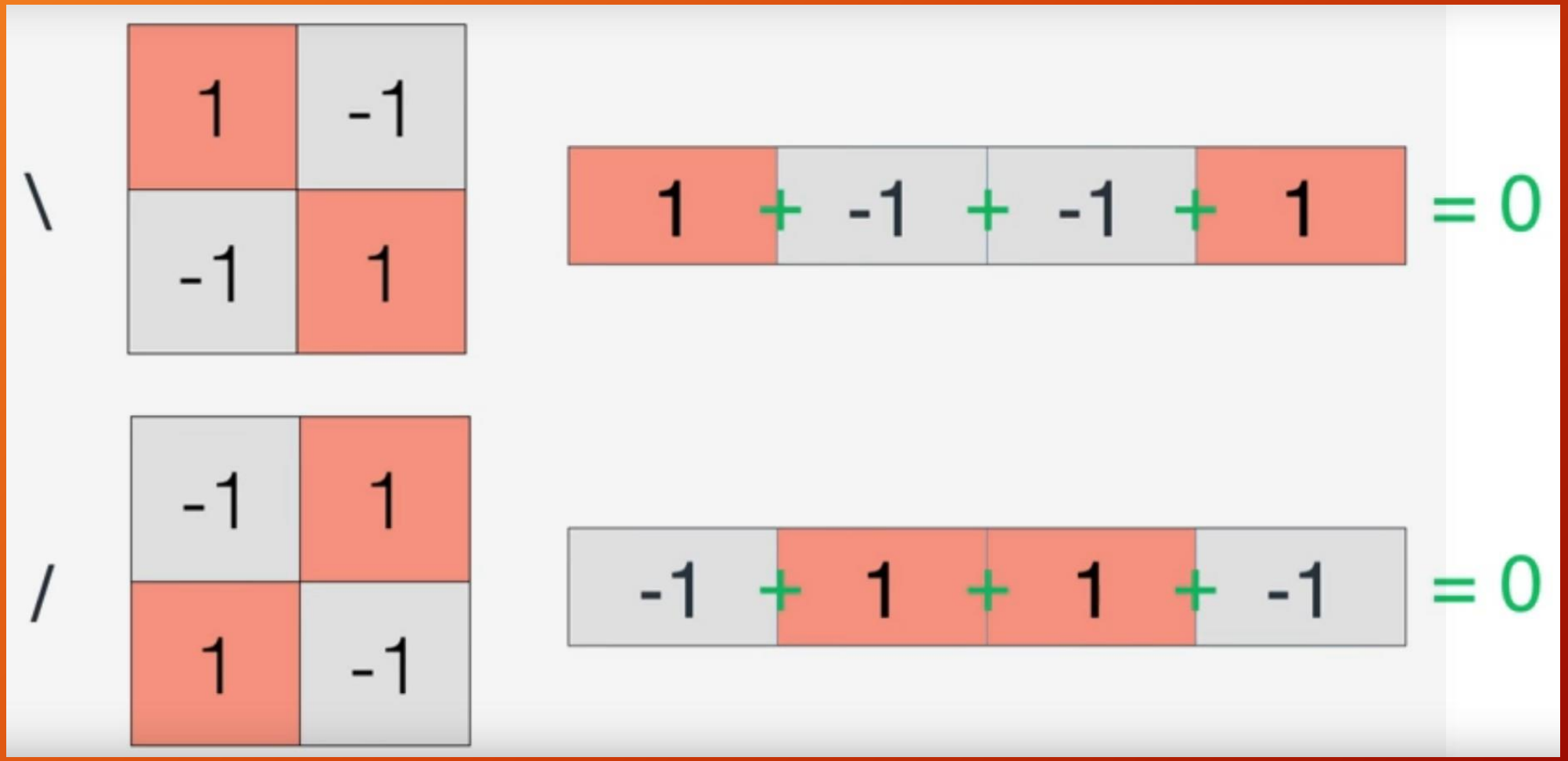
SOURCE: Luis Serrano, Udacity, https://www.youtube.com/watch?v=2-Ol7ZB0MmU

What is convolution?



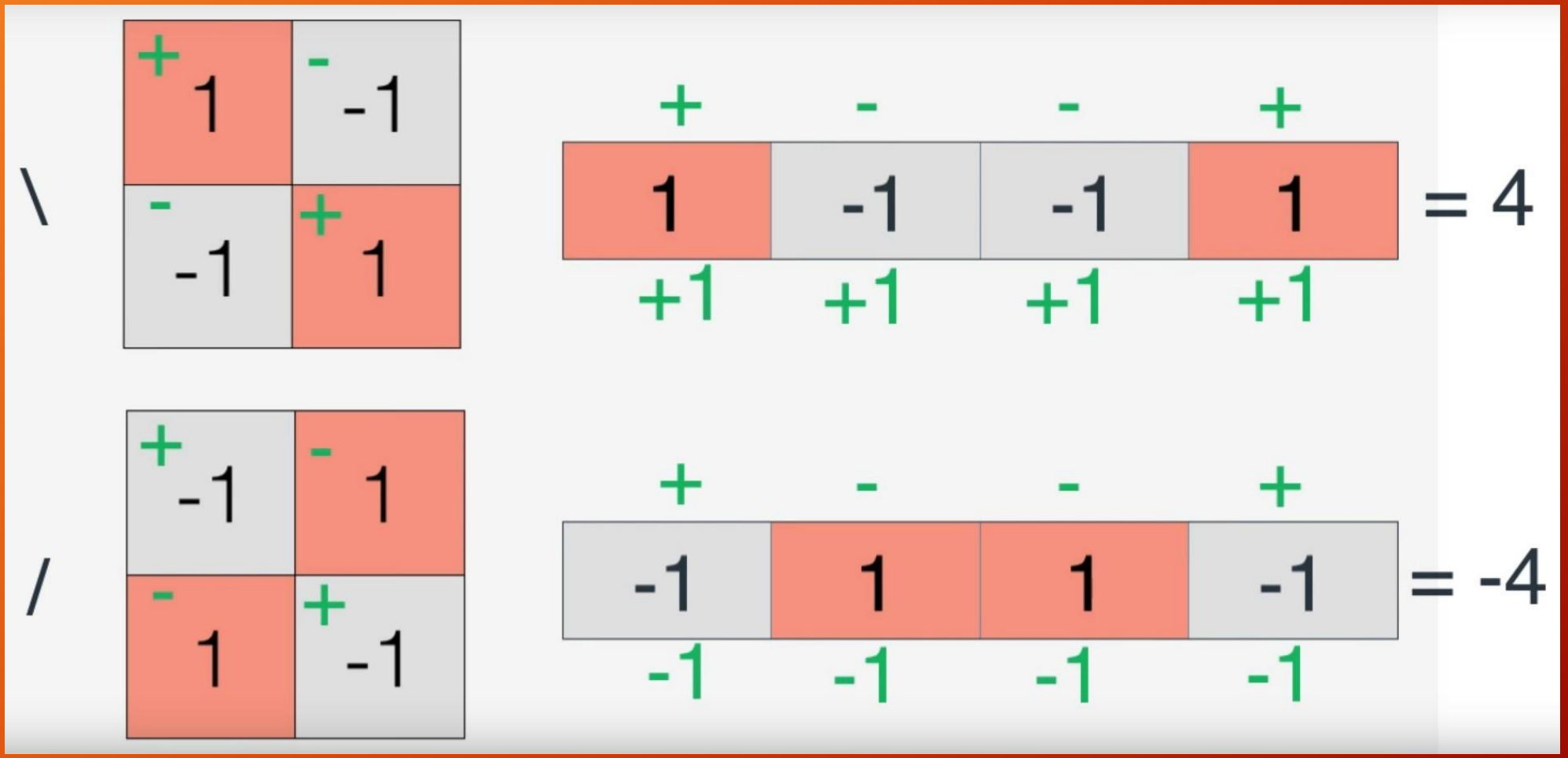
SOURCE: Luis Serrano, Udacity, https://www.youtube.com/watch?v=2-Ol7ZB0MmU

What is convolution?



SOURCE: Luis Serrano, Udacity, https://www.youtube.com/watch?v=2-Ol7ZB0MmU

What is convolution?

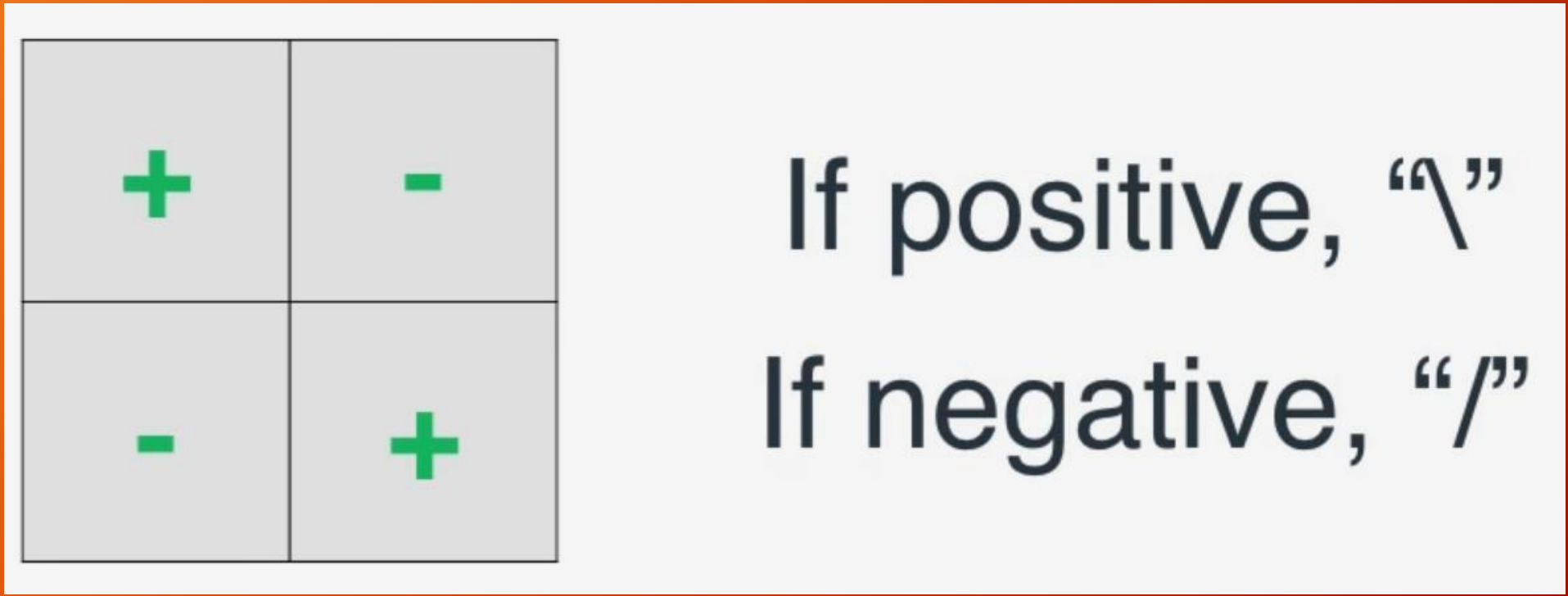


SOURCE: Luis Serrano, Udacity, https://www.youtube.com/watch?v=2-OI7ZB0MmU

What is convolution?

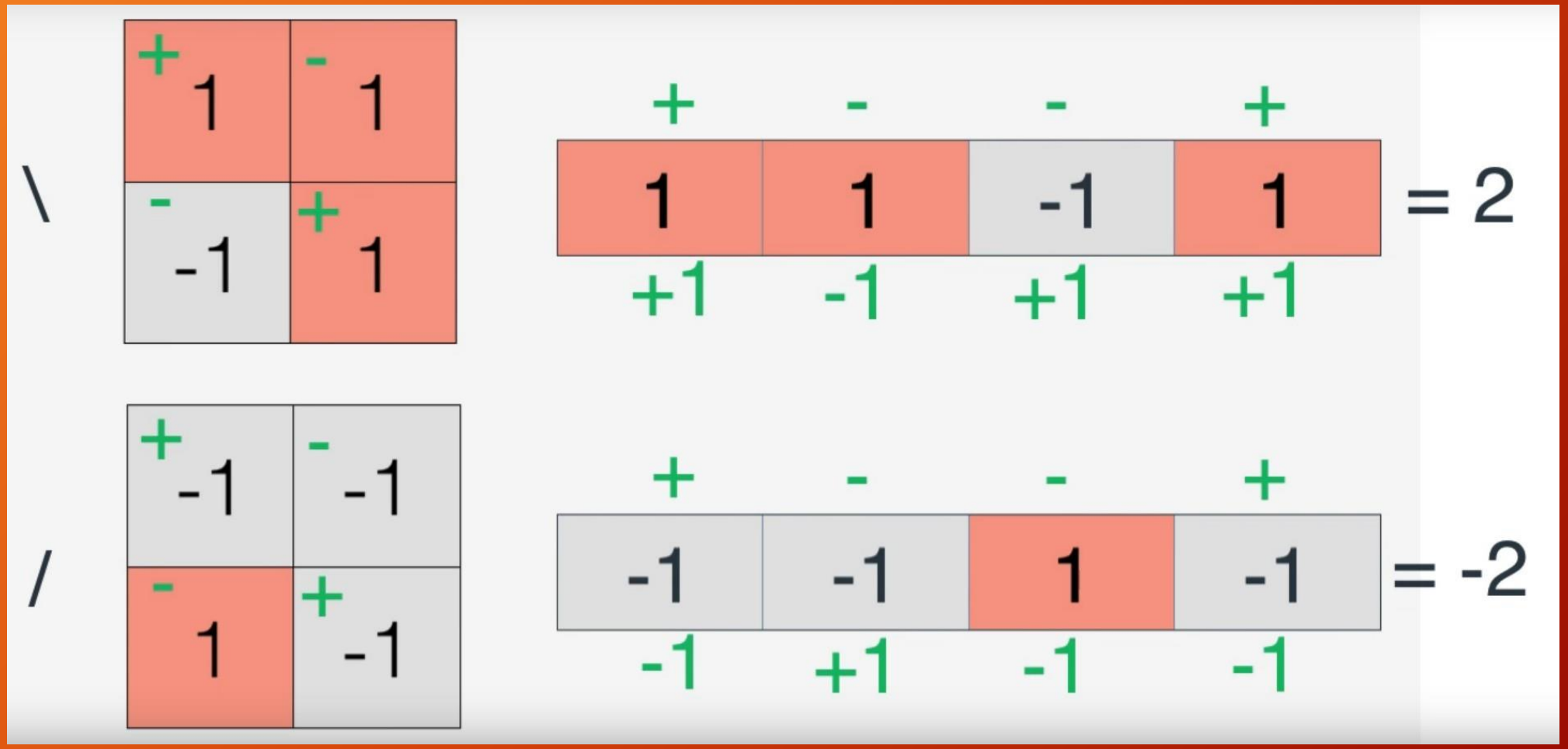
Convolutional Kernel

Image Classifier



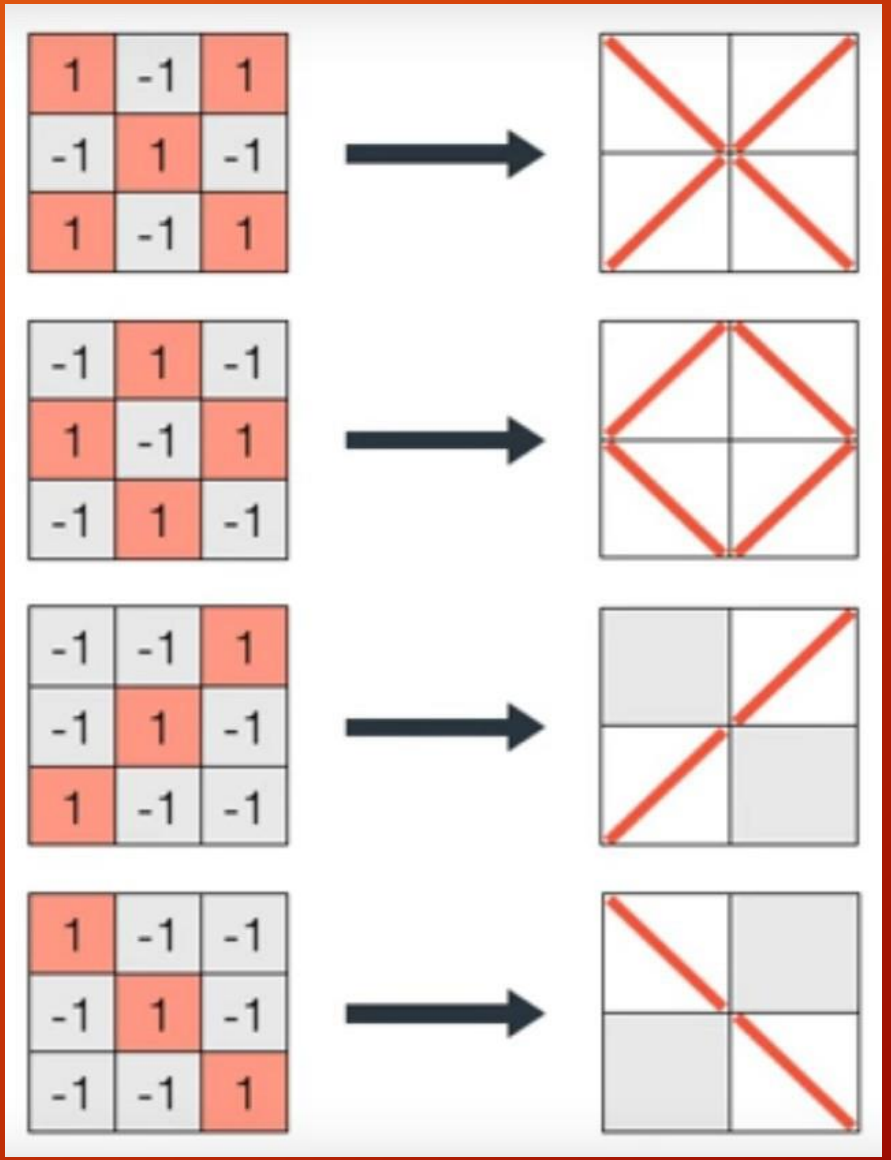
SOURCE: Luis Serrano, Udacity, https://www.youtube.com/watch?v=2-Ol7ZB0MmU

What is convolution?



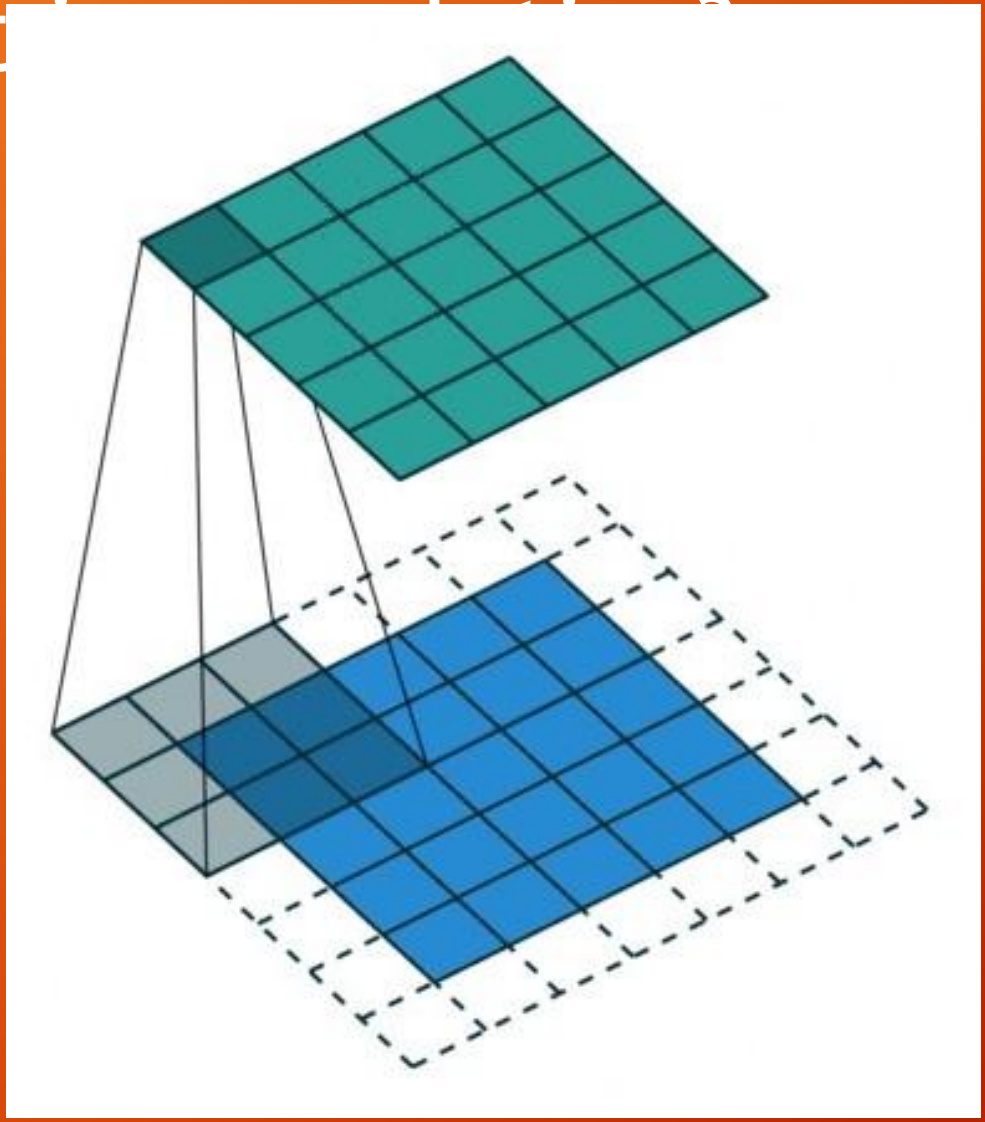
SOURCE: Luis Serrano, Udacity, https://www.youtube.com/watch?v=2-Ol7ZB0MmU

What is convolution?



SOURCE: Luis Serrano, Udacity, https://www.youtube.com/watch?v=2-Ol7ZB0MmU

What



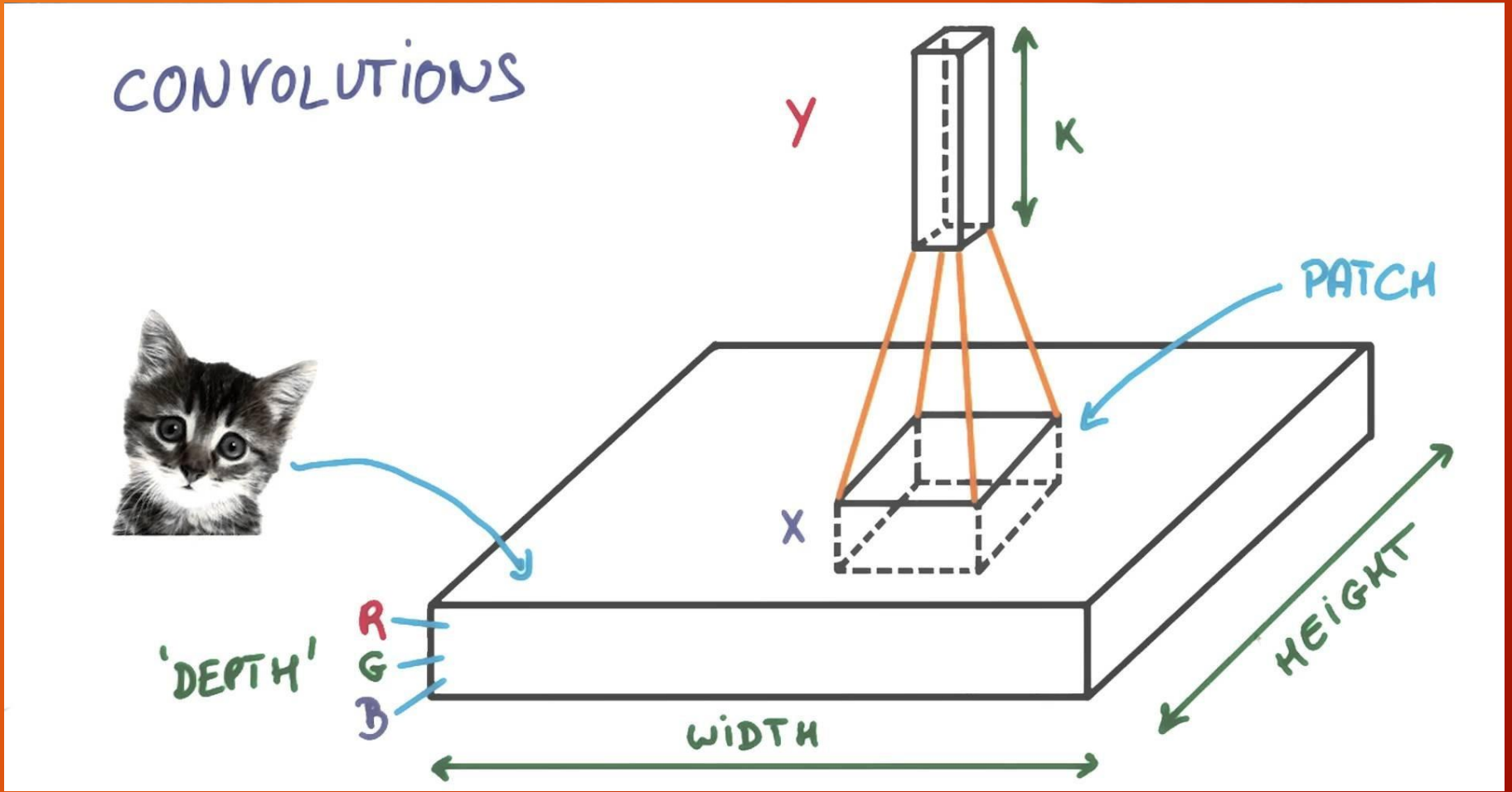
Feature Map

Kernel or Filter

Image

Source: Vincent Dumoulin, https://github.com/vdumoulin/conv_arithmetic

What is convolution?

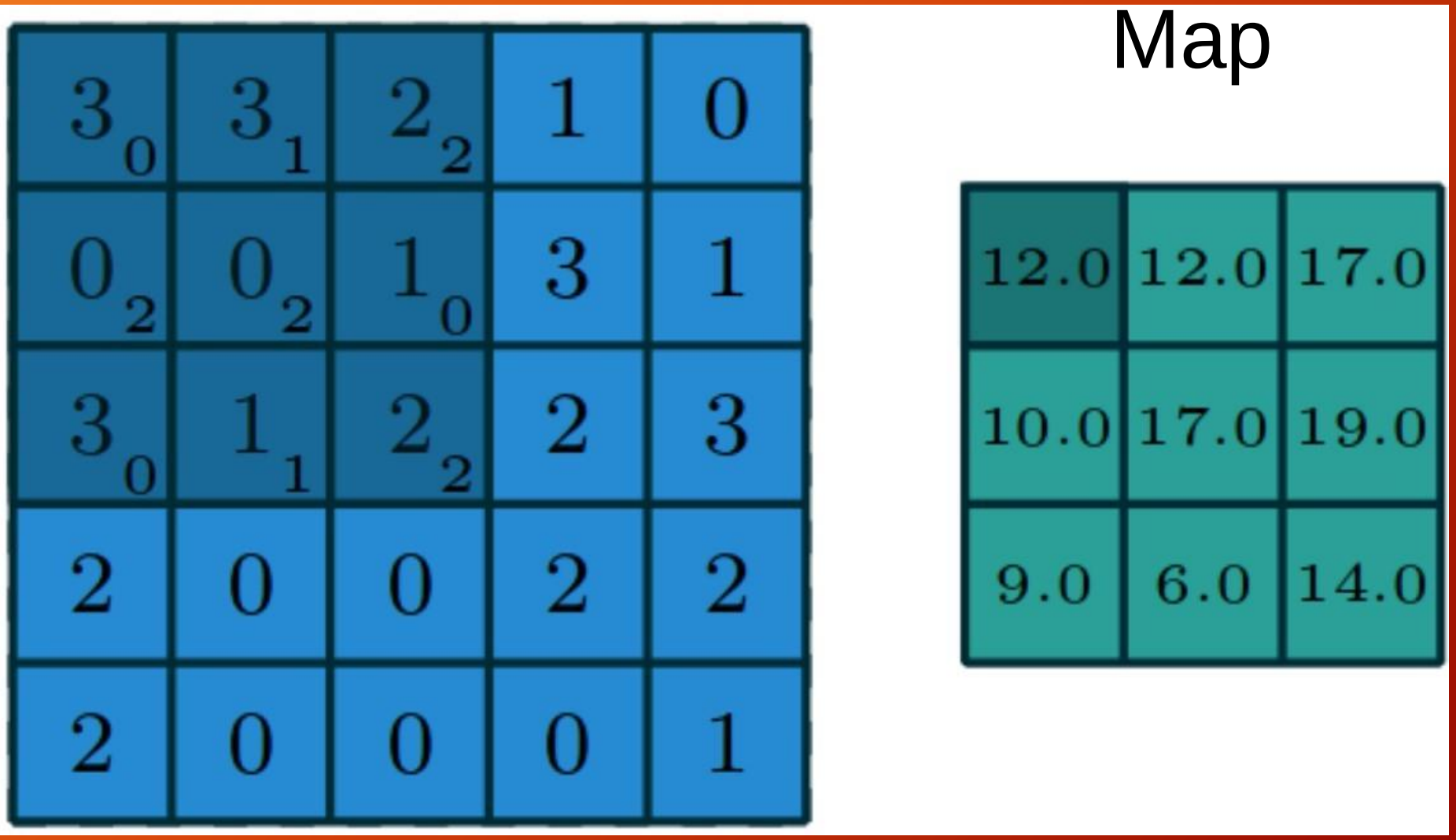


Source: Vincent Vanhoucke, Udacity, https://www.youtube.com/watch?v=jajksuQW4mc

What is convolution?

Image

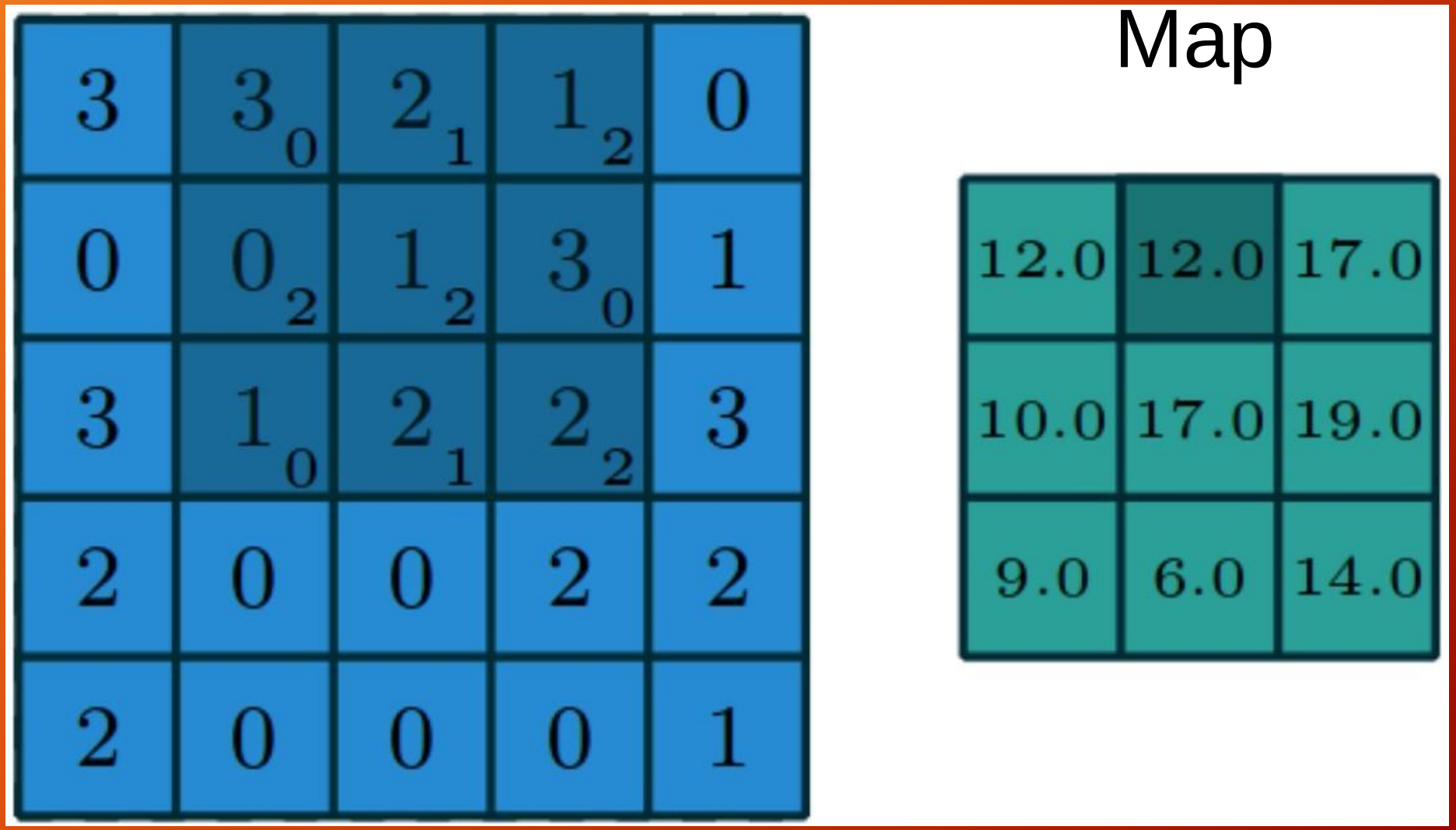
Feature Map



Source: Vincent Dumoulin and Francesco Visin, https://arxiv.org/pdf/1603.07285.pdf

Image

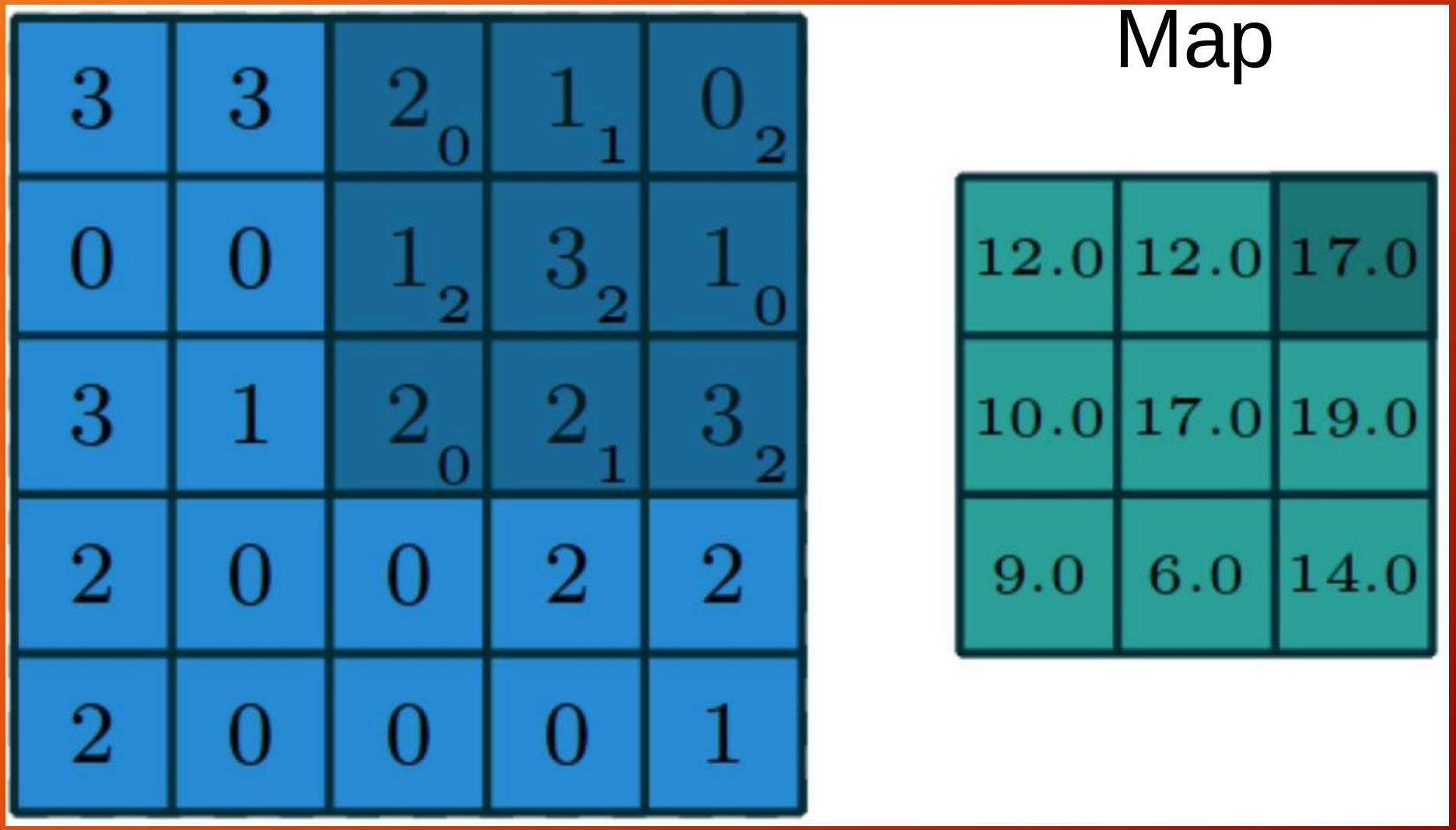
Feature Map



Source: Vincent Dumoulin and Francesco Visin, https://arxiv.org/pdf/1603.07285.pdf

Image

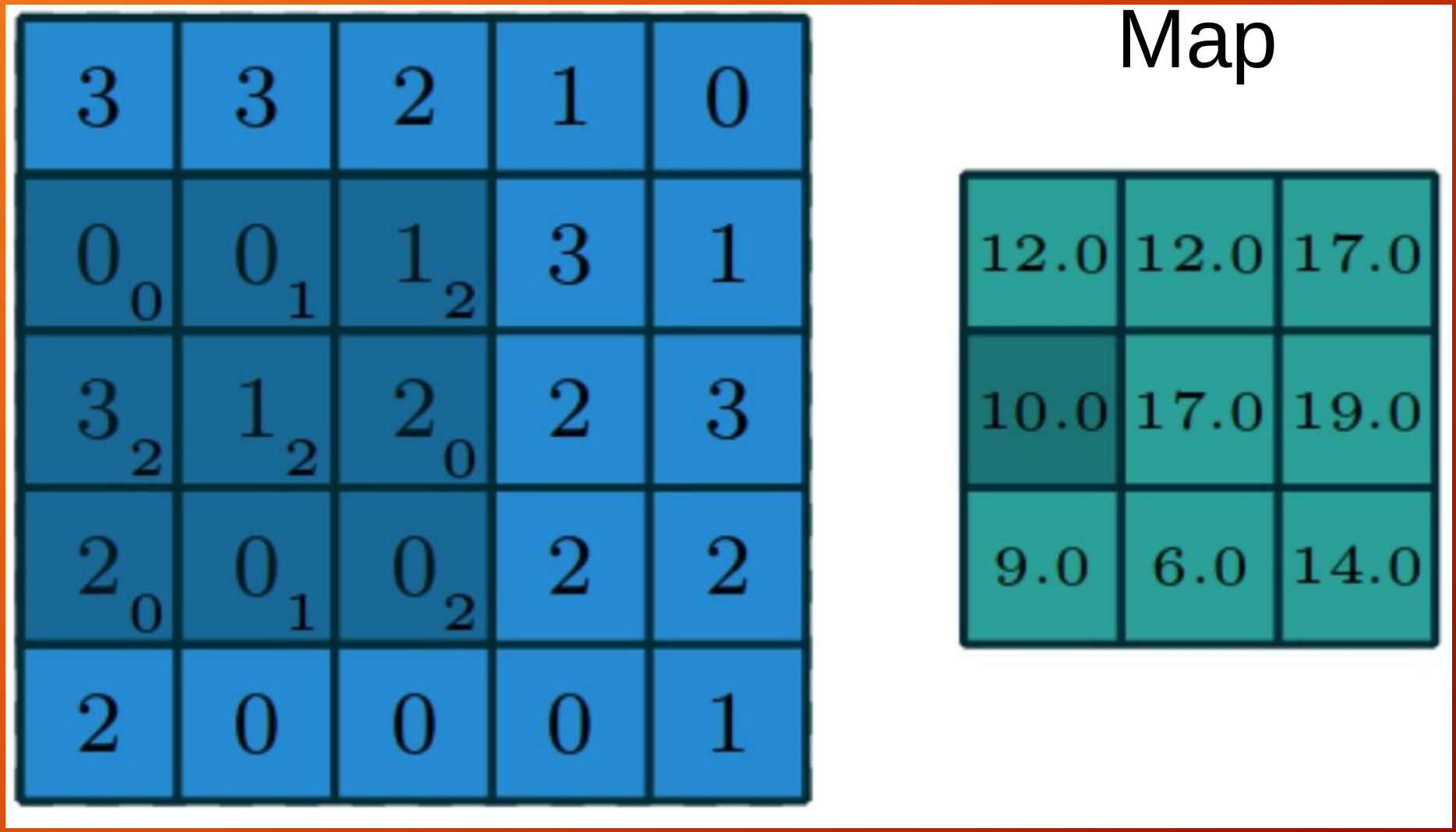
Feature Map



Source: Vincent Dumoulin and Francesco Visin, https://arxiv.org/pdf/1603.07285.pdf

Image

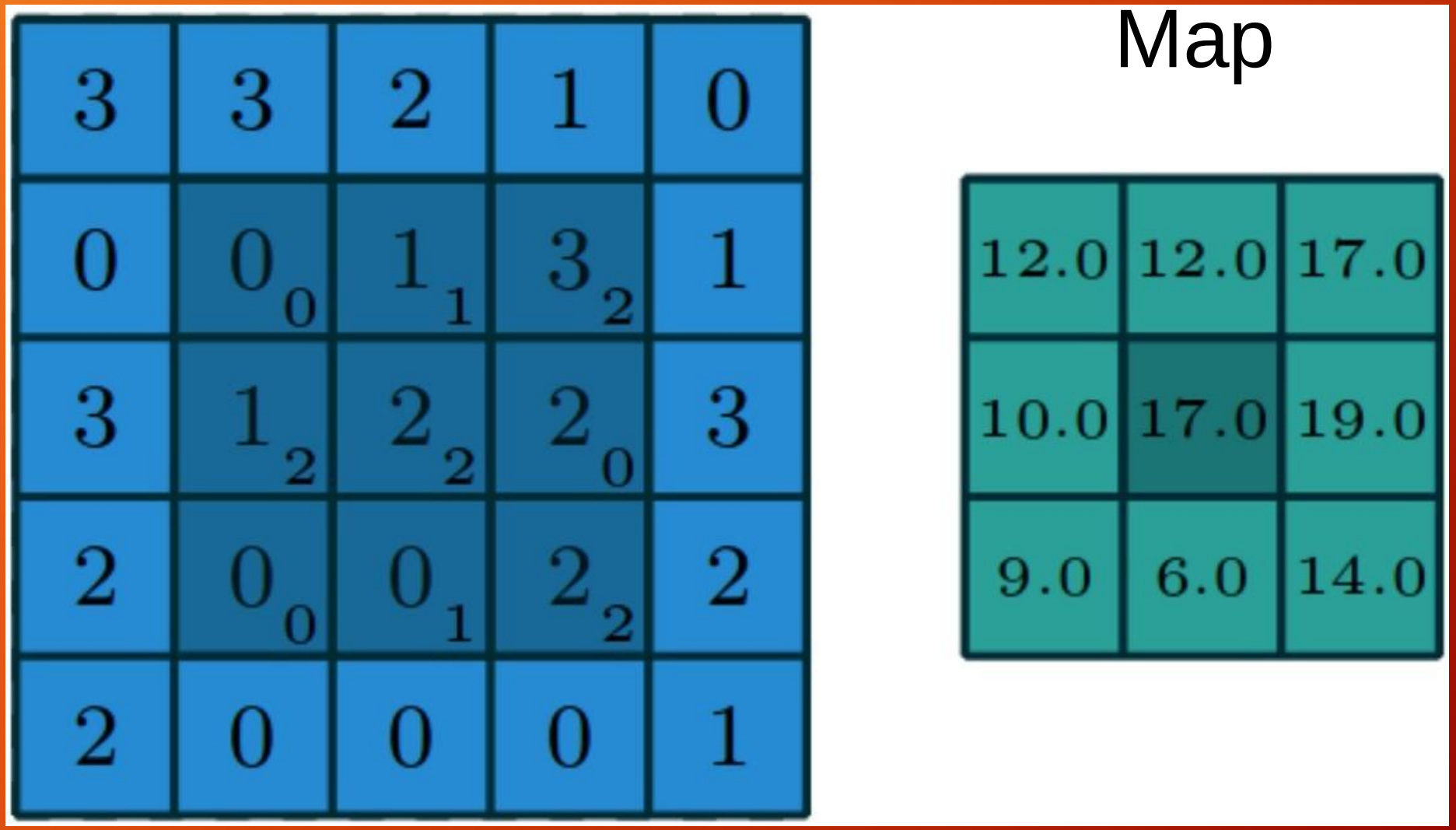
Feature Map



Source: Vincent Dumoulin and Francesco Visin, https://arxiv.org/pdf/1603.07285.pdf

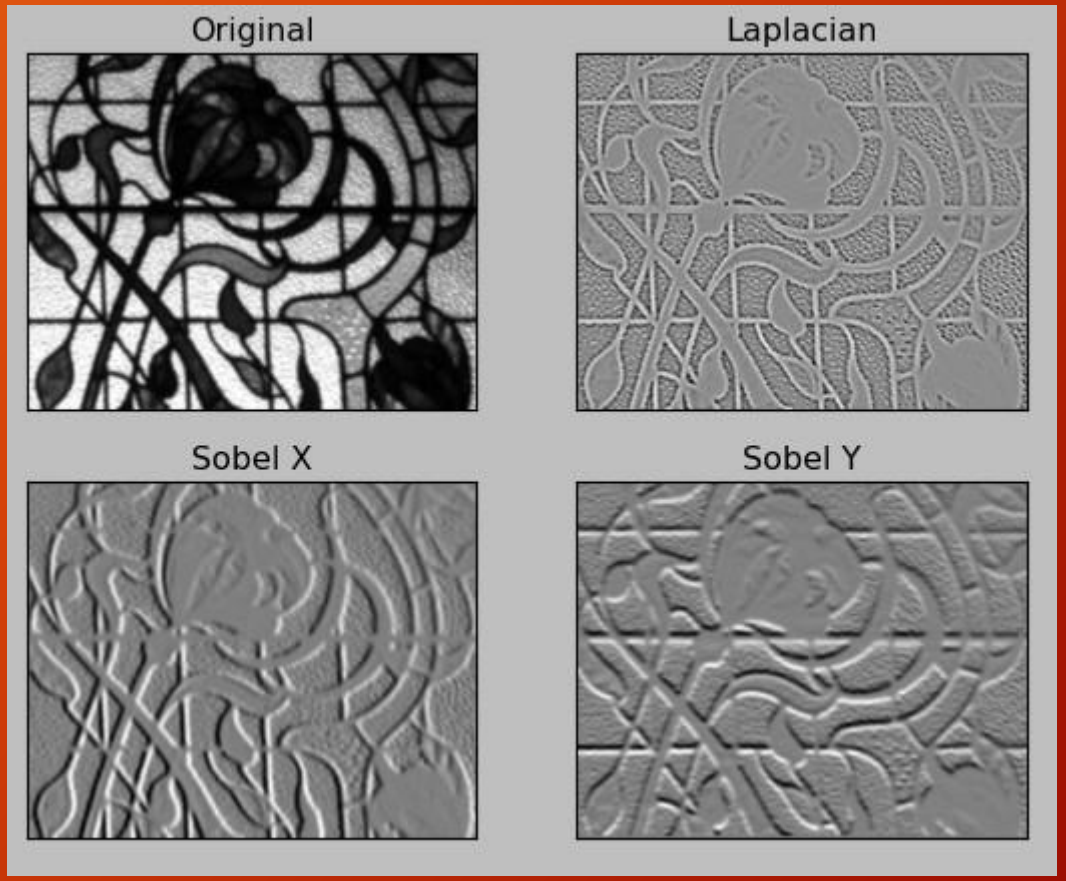
Image

Feature Map



Source: Vincent Dumoulin and Francesco Visin, https://arxiv.org/pdf/1603.07285.pdf

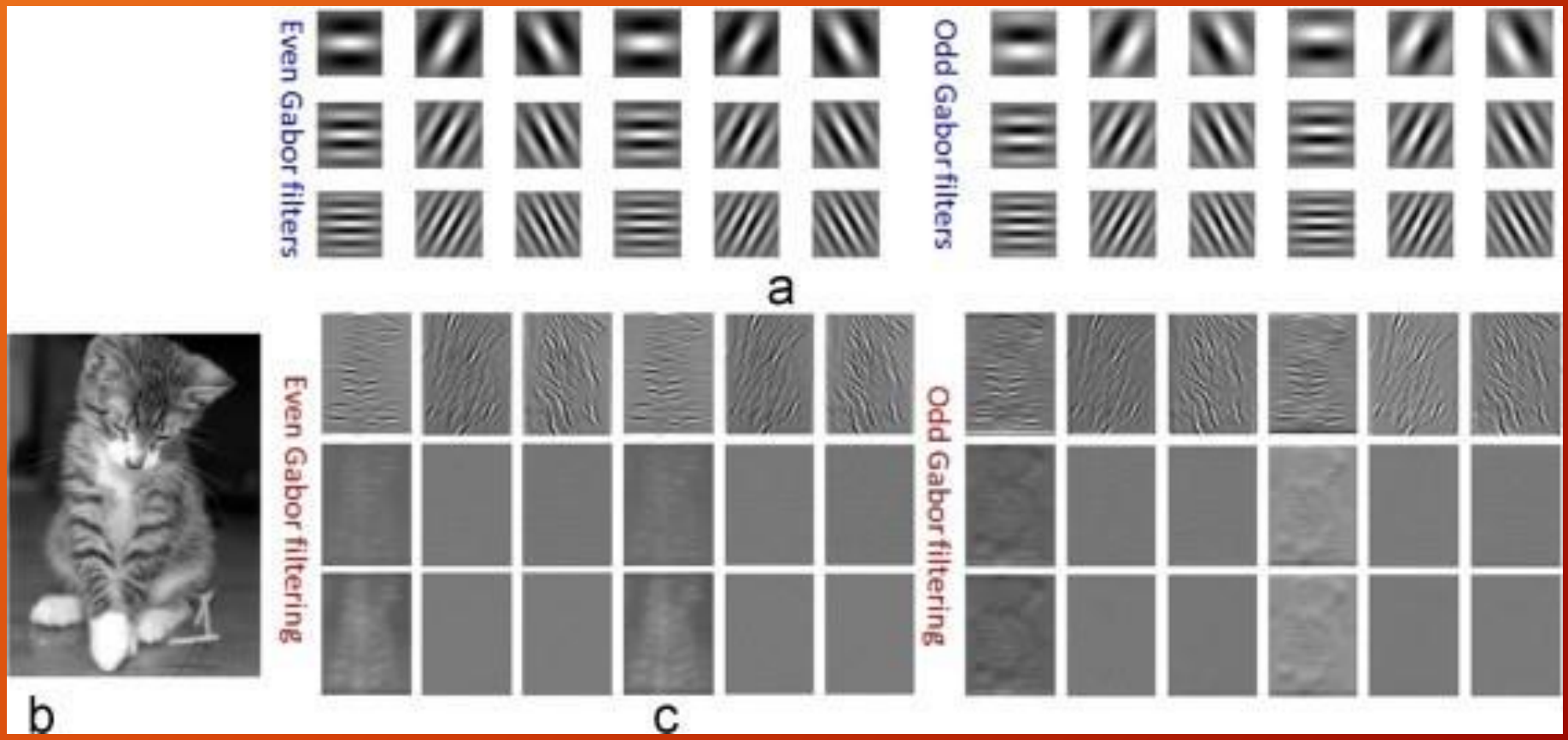
Operation	Kernel	Image result
Identity	$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$	
Edge detection	$\begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}$	
	$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$	
	$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$	
Sharpen	$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$	
Box blur (normalized)	$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	
Gaussian blur 3 × 3 (approximation)	$\frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$	
Gaussian blur 5 × 5 (approximation)	$\frac{1}{256}\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}$	



Watch the video: http://setosa.io/ev/image-kernels/

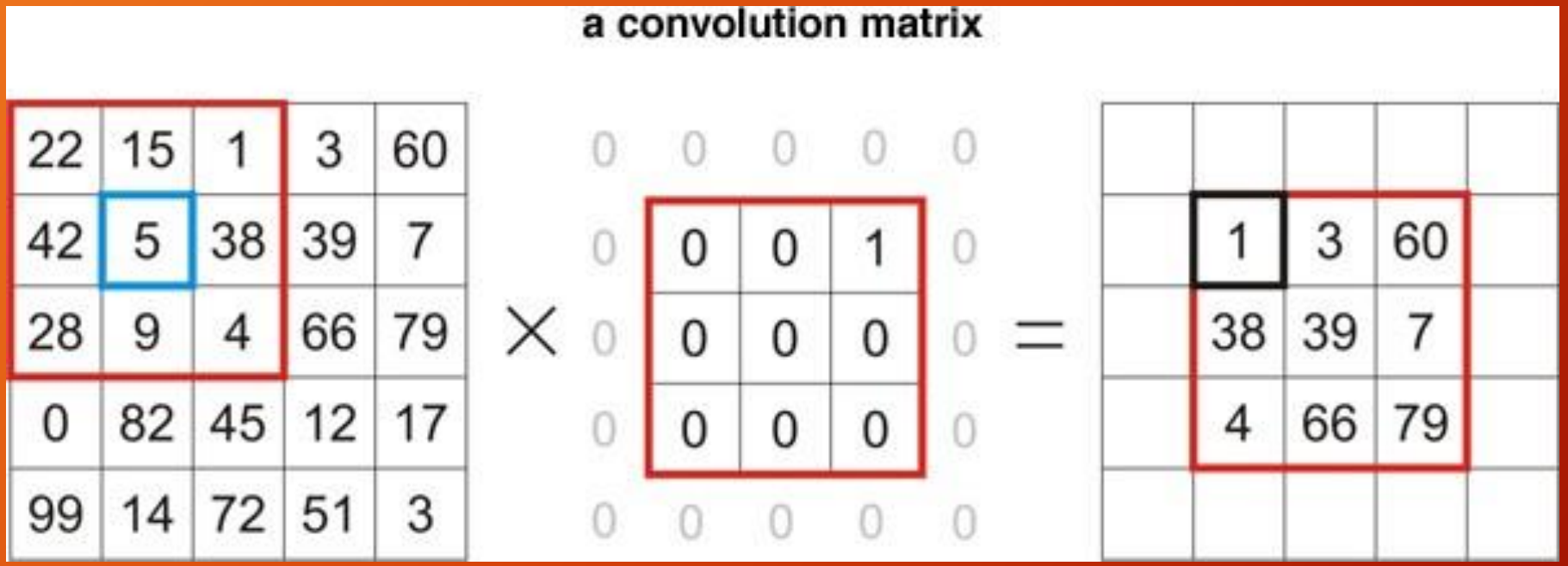
What is convolution?

Gabor Filter



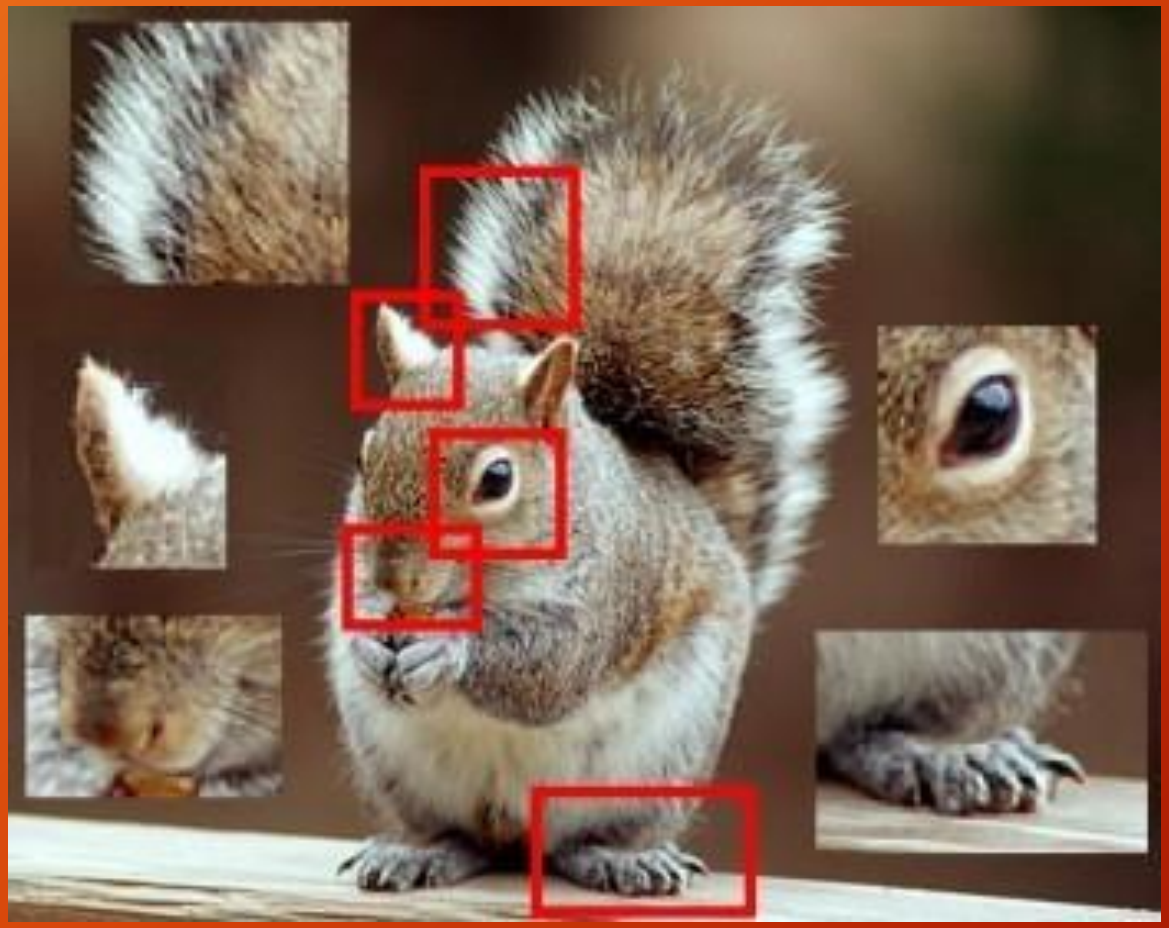
Source: http://www.sciencedirect.com/science/article/pii/S0031320315001570

What is convolution?



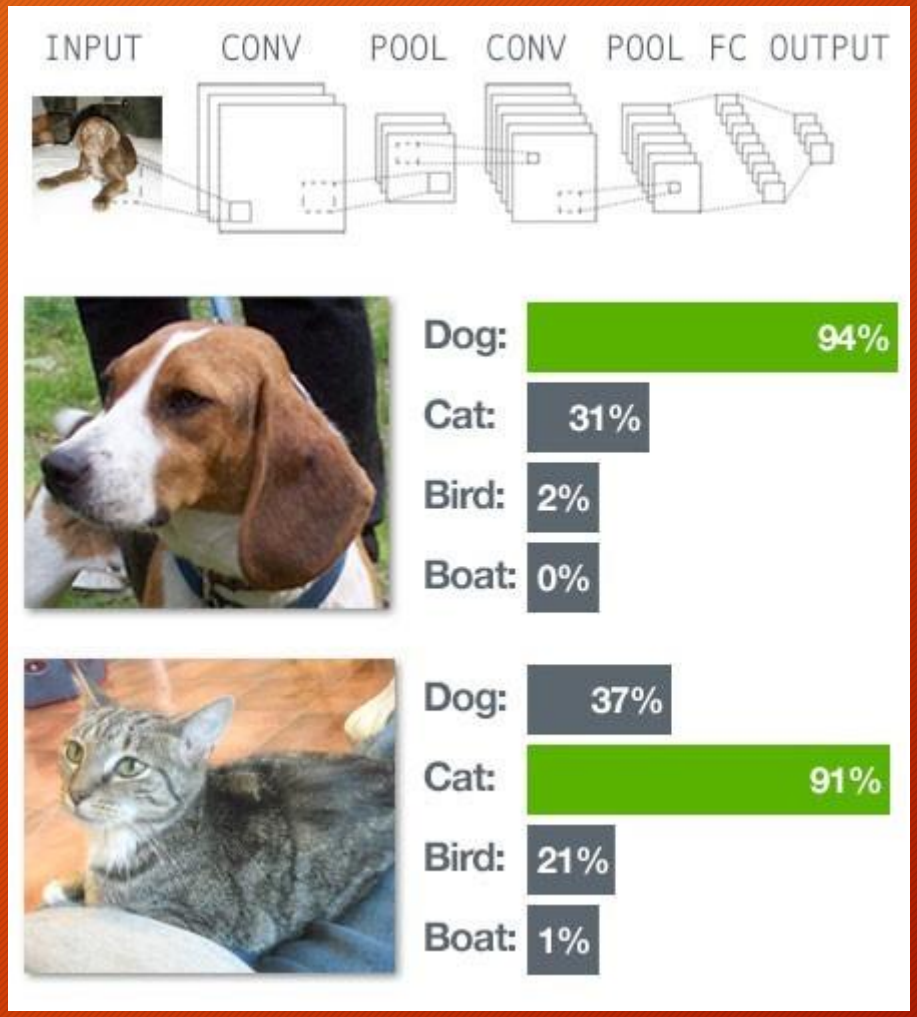
“Take the top right corner of the image?”

What is convolution?

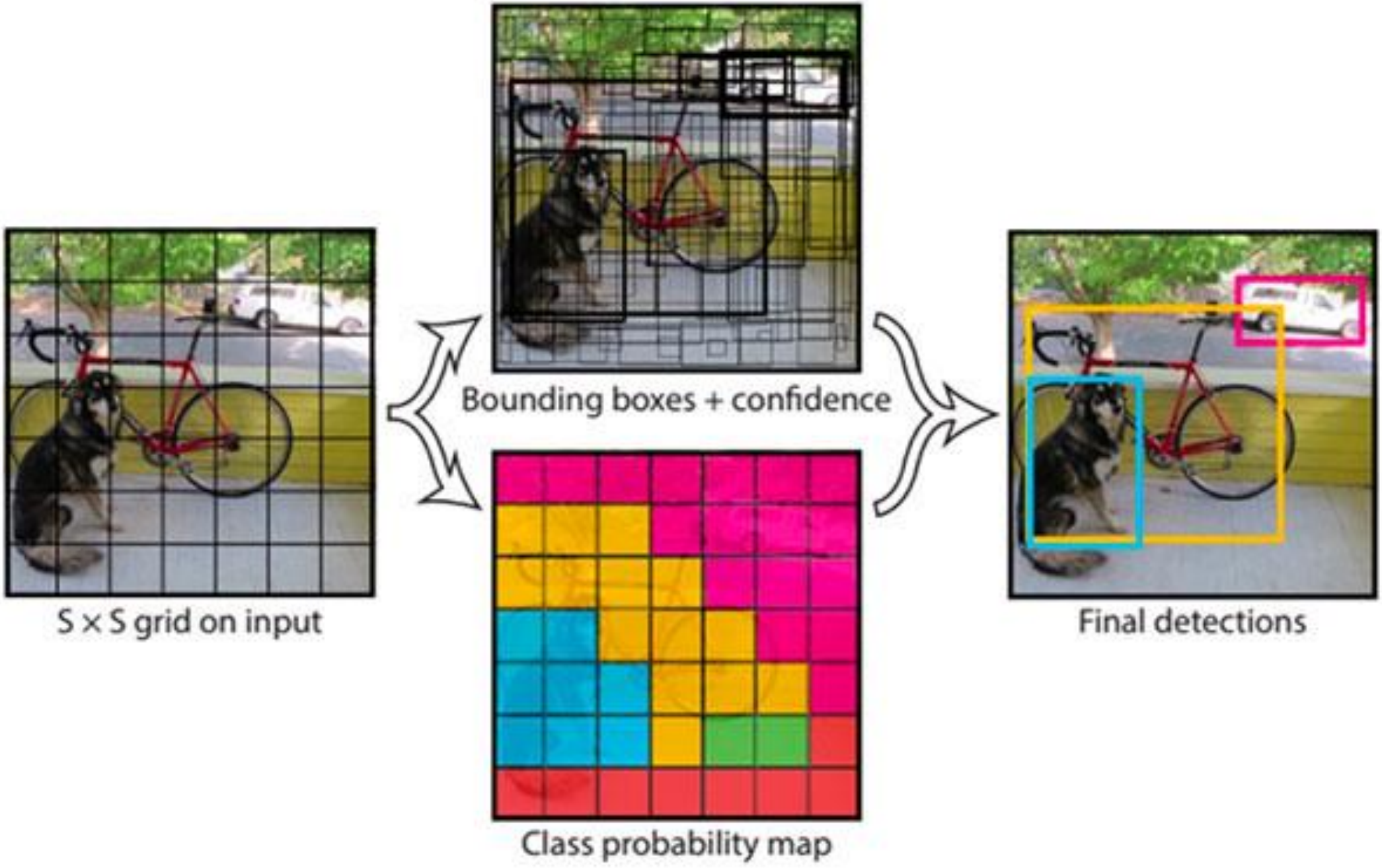


Convolution creates FEATURE DETECTORS.

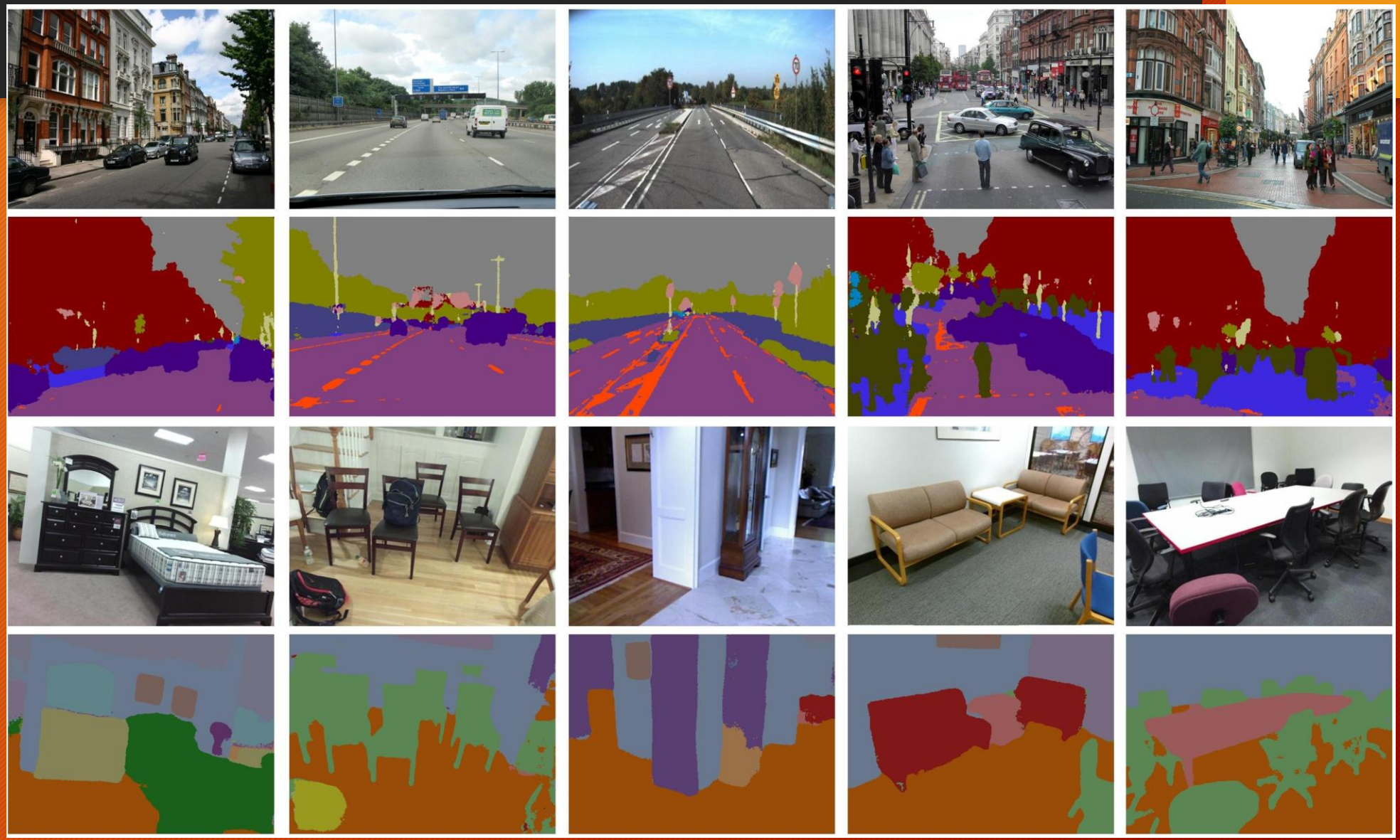
Convolutional Networks



YOLO

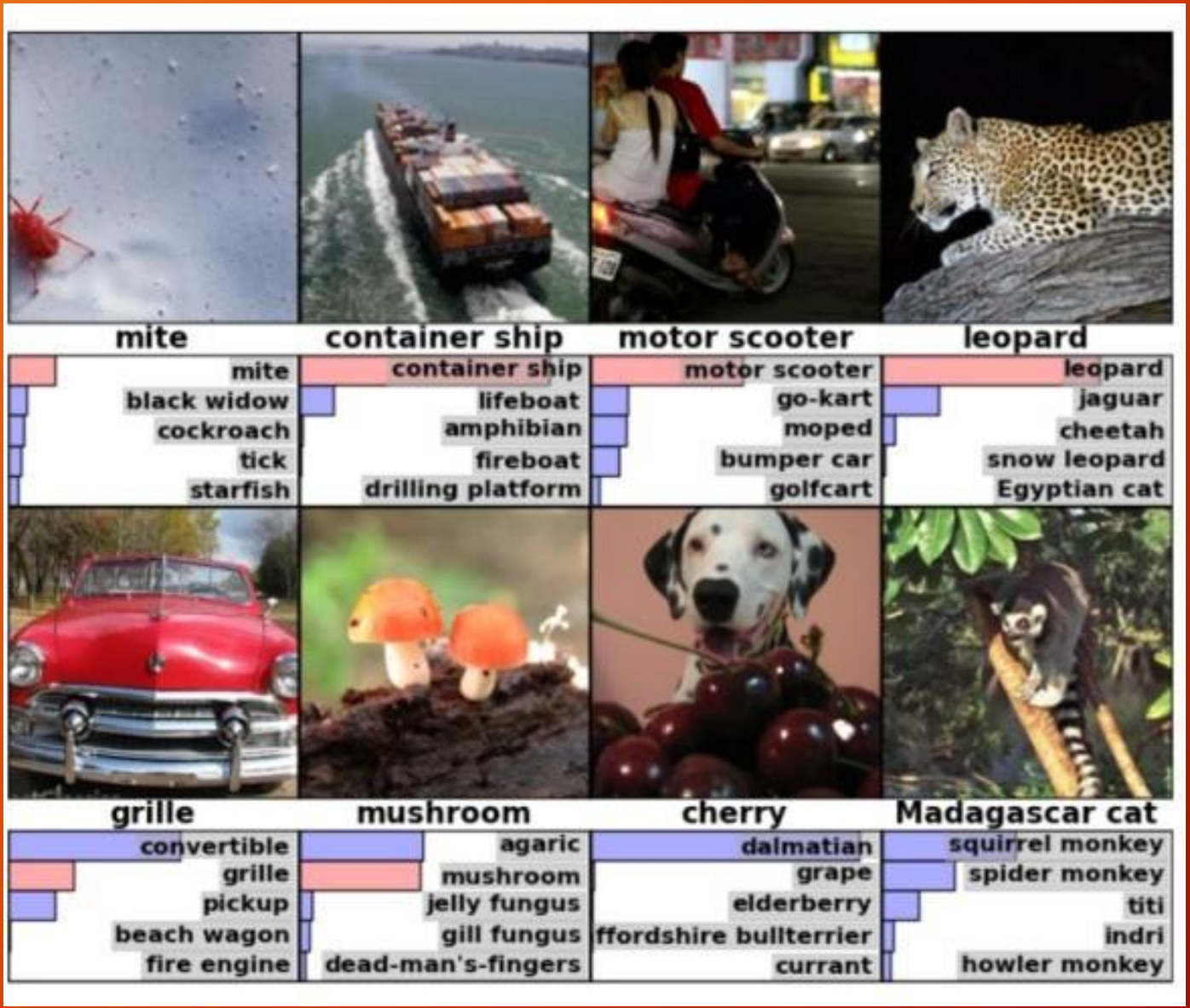

Bounding boxes + confidence
S × S grid on input
Class probability map
Final detections

SegNet



University of Cambridge, https://www.youtube.com/watch?v=CxanE_W46ts

ImageNet



Source: https://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks