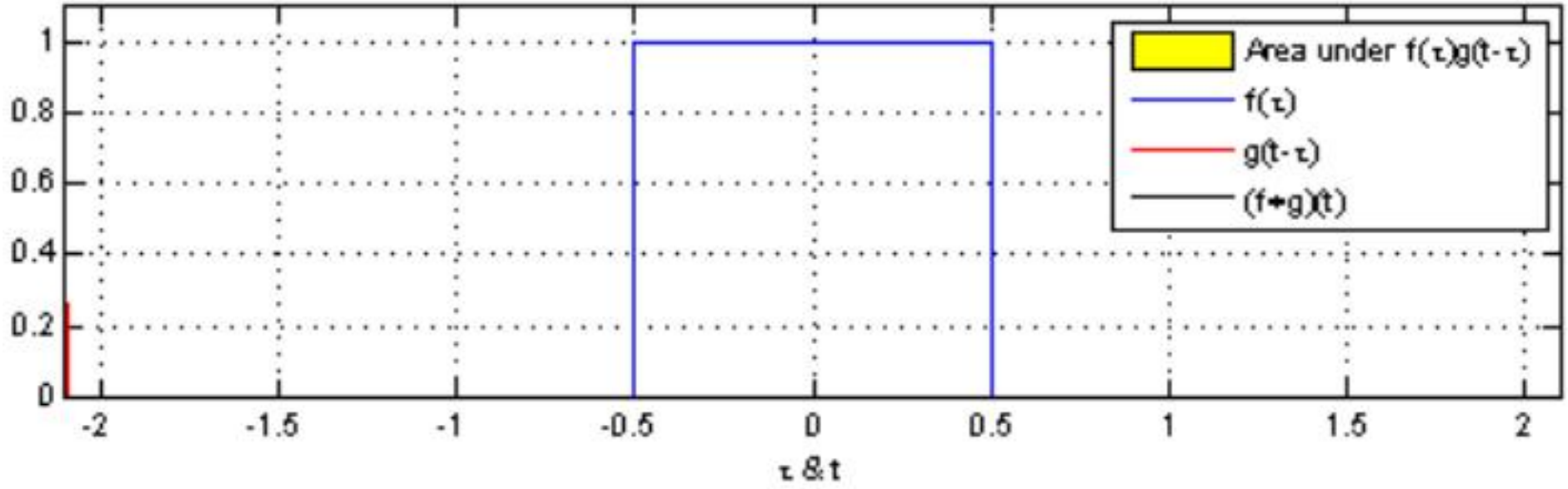
Convolution

Introduction

Convolution

In mathematics convolution is a mathematical operation on two functions (f and g) to produce a third function that expresses how the shape of one is modified by the other.



Source: Wikipedia

Introduction

CONVOLUTION

There are several possible notations to indicate the convolution of two (multi-dimensional) signals to produce an output signal. The most common are:⊖

$$c = a \otimes b = a * b$$

We shall use the first form, $c = a \otimes b$, with the following formal definitions.

Introduction

In 2D continuous space:

$$c(x,y) = a(x,y) \otimes b(x,y) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} a(\chi,\zeta) b(x-\chi, y-\zeta) d\chi d\zeta$$

In 2D discrete space:

$$c[m,n] = a[m,n] \otimes b[m,n] = \sum_{j=-\infty}^{+\infty} \sum_{k=-\infty}^{+\infty} a[j,k] b[m-j, n-k]$$

Introduction

What We See

Considering only one channel

```
08 02 22 97 38 15 00 40 00 75 04 05 07 78 52 12 50 77 91 08
49 49 99 40 17 81 18 57 60 87 17 40 98 43 69 48 04 56 62 00
81 49 31 73 55 79 14 29 93 71 40 67 53 88 30 03 49 13 36 65
52 70 95 23 04 60 11 42 69 24 68 56 01 32 56 71 37 02 36 91
22 31 16 71 51 67 63 89 41 92 36 54 22 40 40 28 66 33 13 80
24 47 32 60 99 03 45 02 44 75 33 53 78 36 84 20 35 17 12 50
32 98 81 28 64 23 67 10 26 38 40 67 59 54 70 66 18 38 64 70
67 26 20 68 02 62 12 20 95 63 94 39 63 08 40 91 66 49 94 21
24 55 58 05 66 73 99 26 97 17 78 78 96 83 14 88 34 89 63 72
21 36 23 09 75 00 76 44 20 45 35 14 00 61 33 97 34 31 33 95
78 17 53 28 22 75 31 67 15 94 03 80 04 62 16 14 09 53 56 92
16 39 05 42 96 35 31 47 55 58 88 24 00 17 54 24 36 29 85 57
86 56 00 48 35 71 89 07 05 44 44 37 44 60 21 58 51 54 17 58
19 80 81 68 05 94 47 69 28 73 92 13 86 52 17 77 04 89 55 40
04 52 08 83 97 35 99 16 07 97 57 32 16 26 26 79 33 27 98 66
88 36 68 87 57 62 20 72 03 46 33 67 46 55 12 32 63 93 53 69
04 42 16 73 38 25 39 11 24 94 72 18 08 46 29 32 40 62 76 36
20 69 36 41 72 30 23 88 34 62 99 69 82 67 59 85 74 04 36 16
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01 70 54 71 83 51 54 69 16 92 33 48 61 43 52 01 89 19 67 48
```
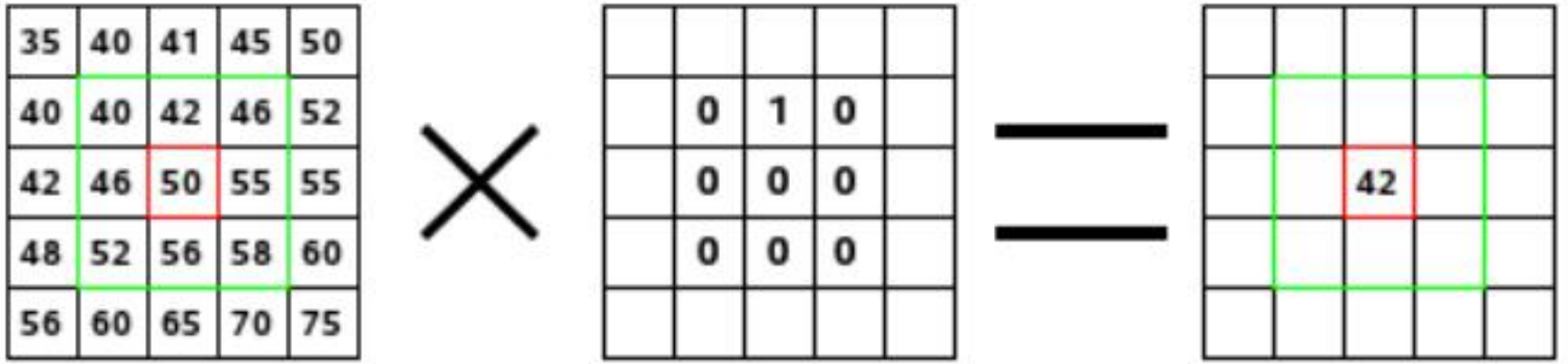

What Computers See

Introduction



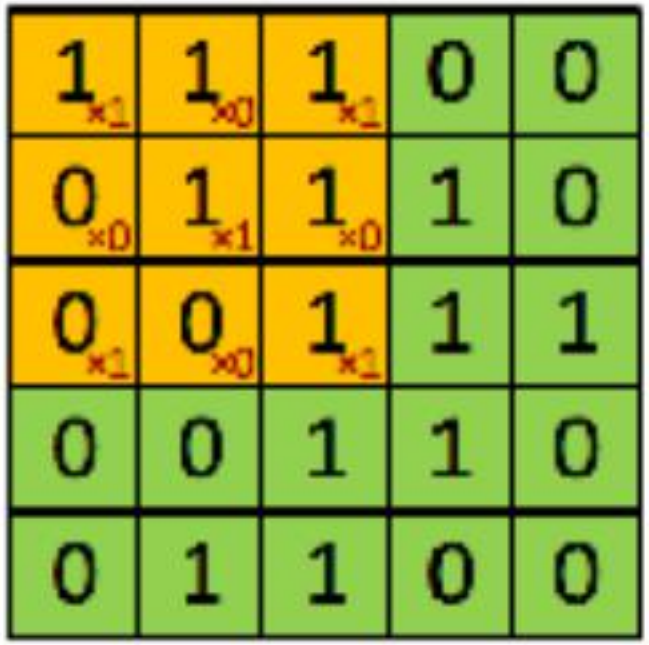
Introduction

0	0	0	0	0
0	0	-1	0	0
0	-1	5	-1	0
0	0	-1	0	0
0	0	0	0	0

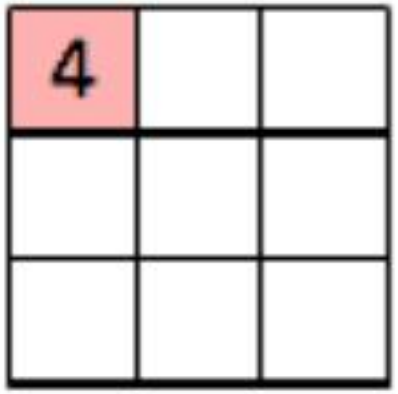
Introduction

	0	1	0	
	1	-4	1	
	0	1	0	

Introduction

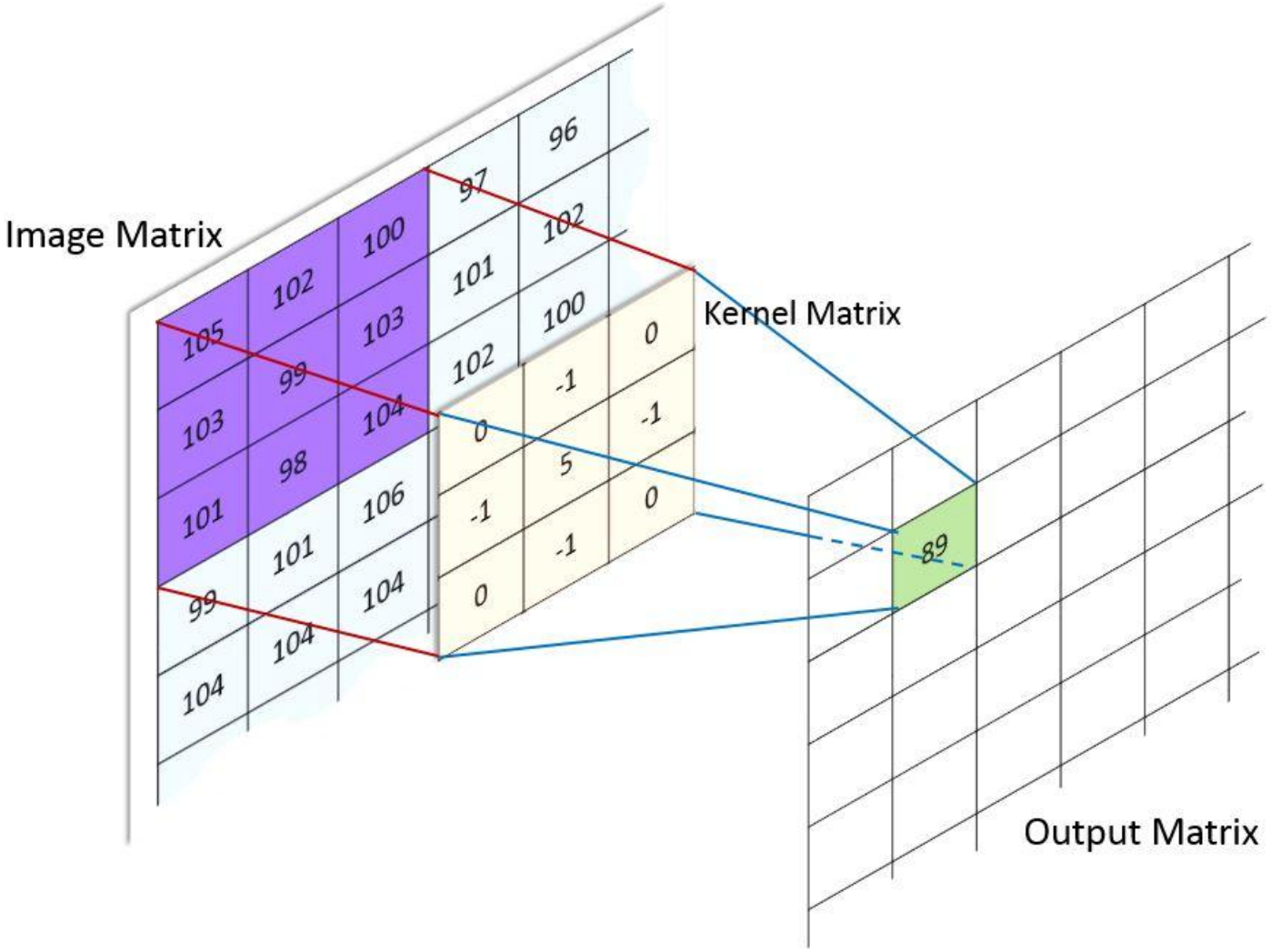


Image



Convolved Feature

Introduction



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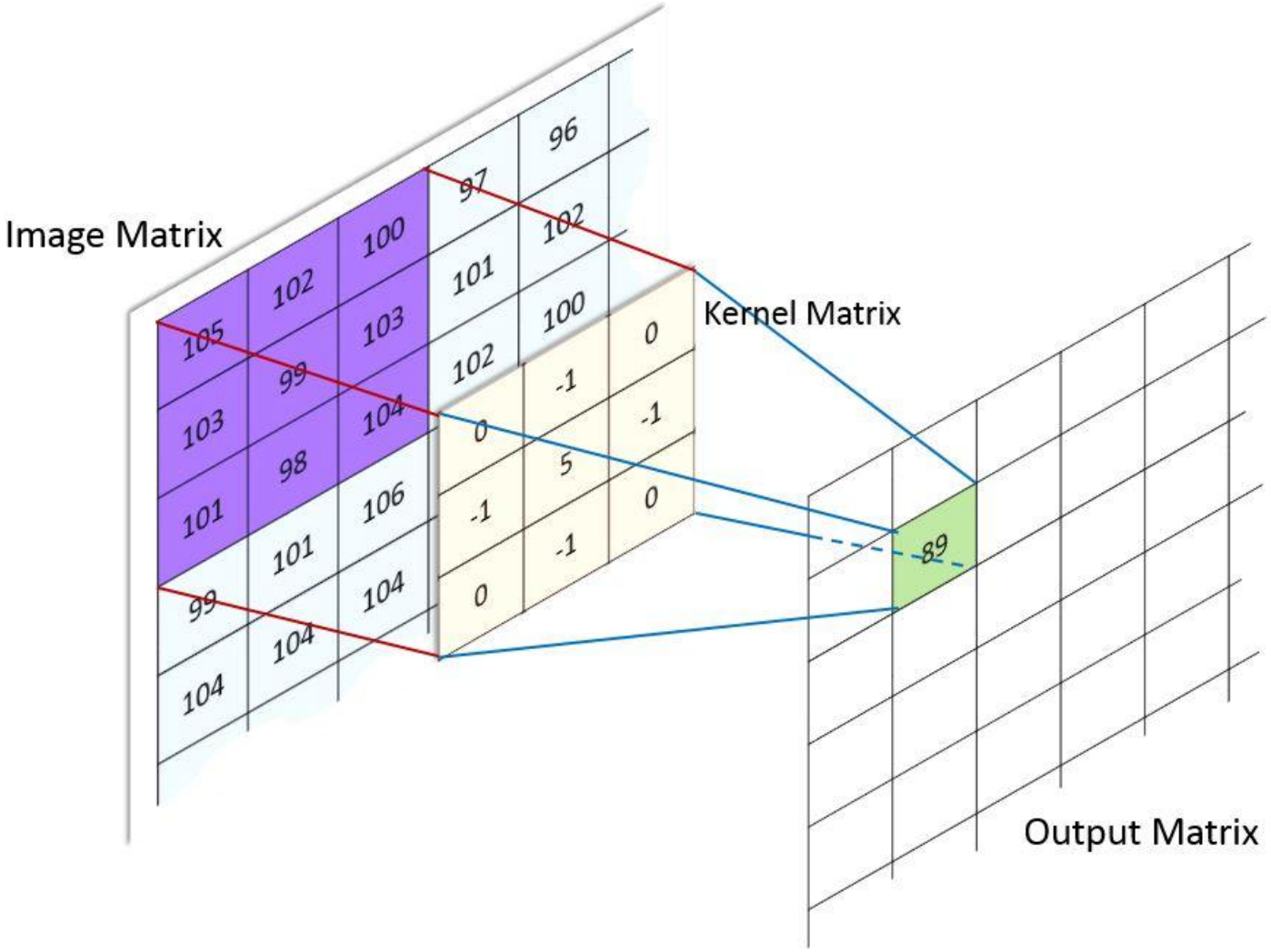
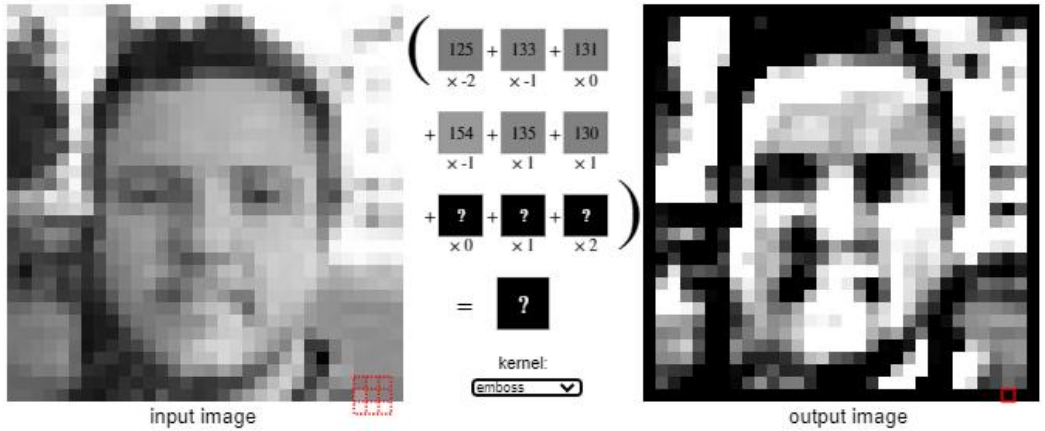
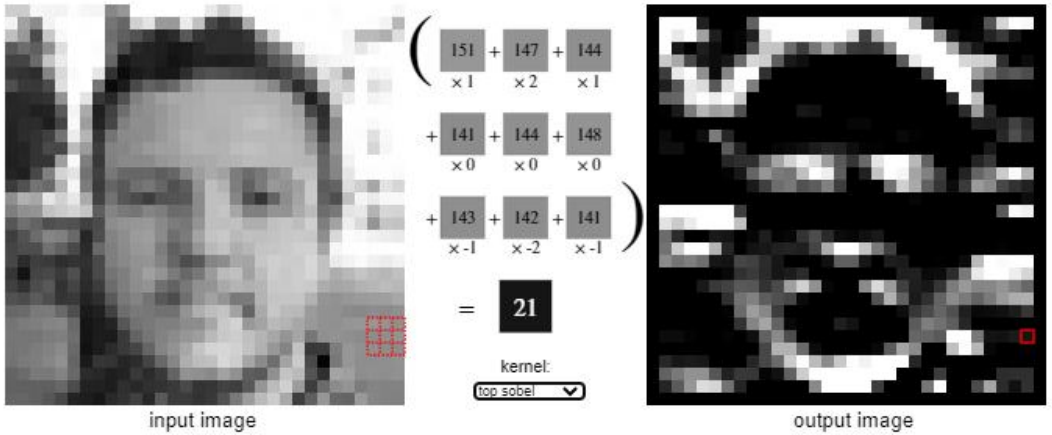
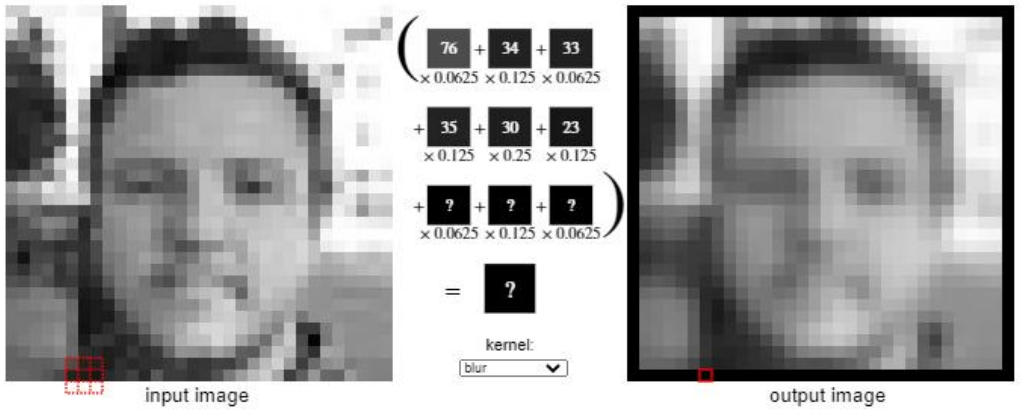
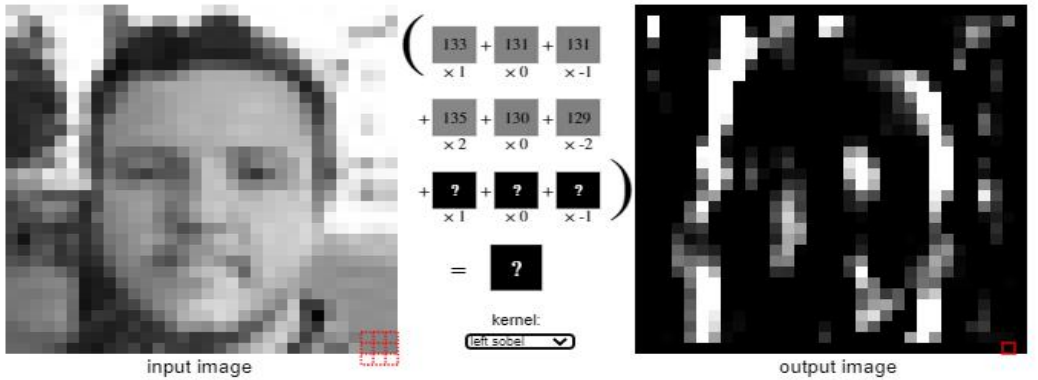


Kernel Effects









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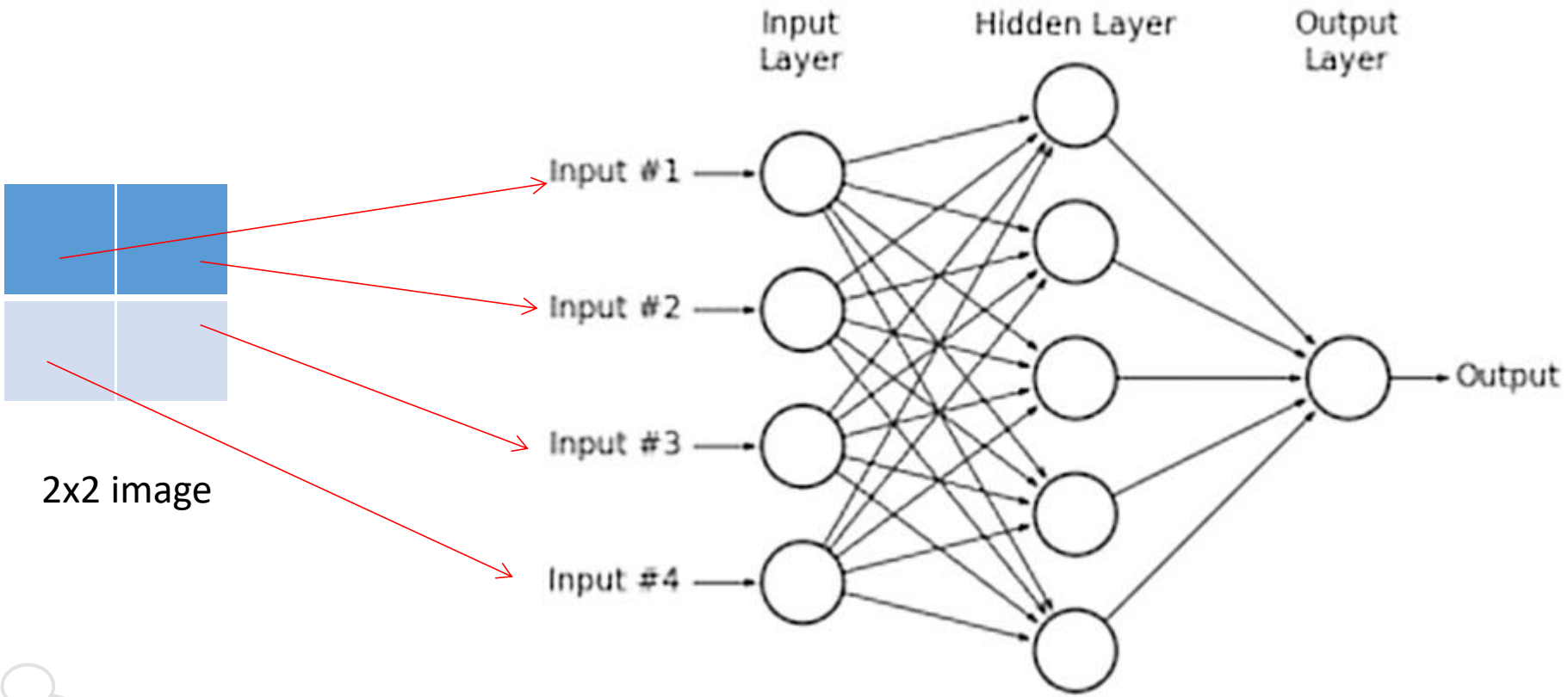

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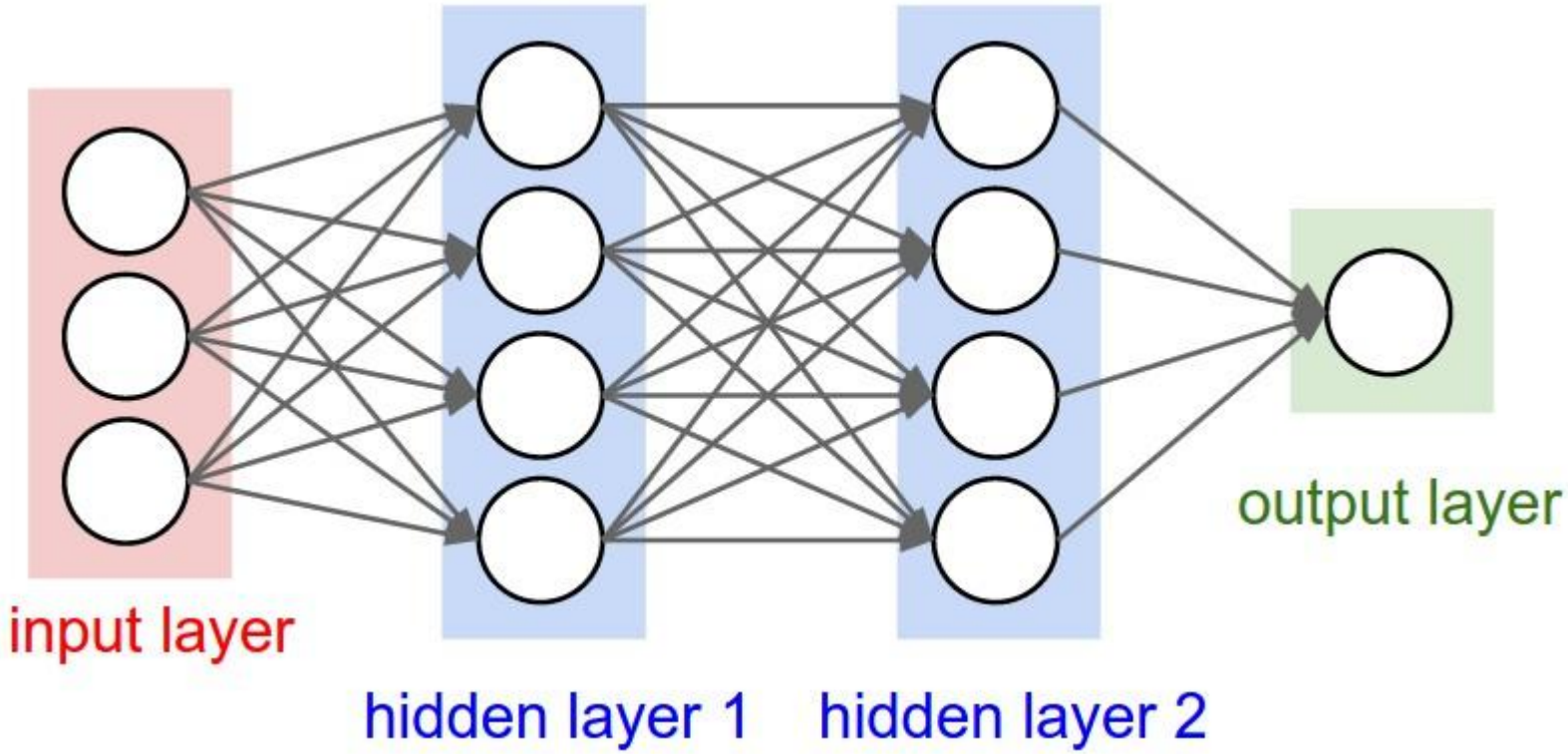
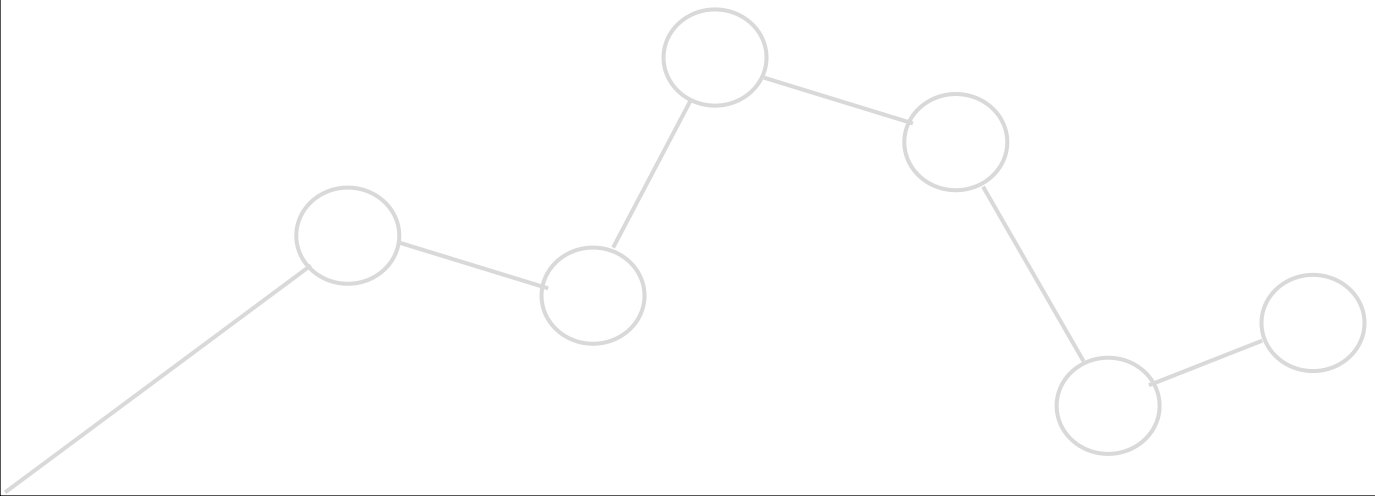


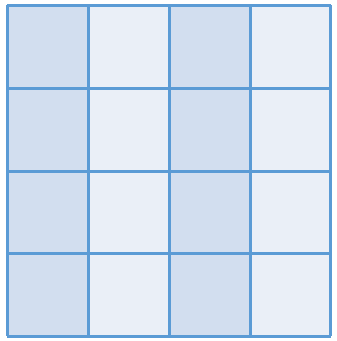
Exercise

- Download the script *Deep_Intro_Convolution* and visualize the effect of differents kernels on the image cat.jpg

Deep Learning

- An introduction to Convolutional Neural Networks





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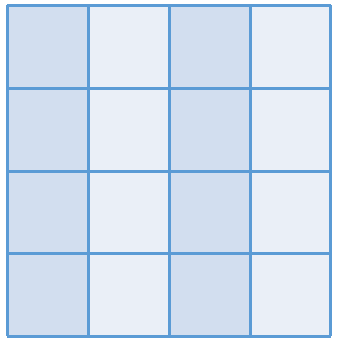
One channel



4x4
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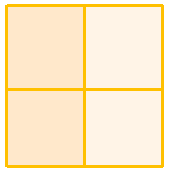

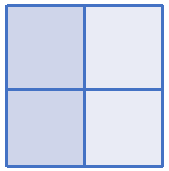

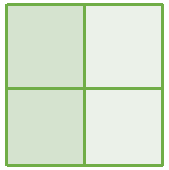

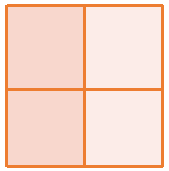

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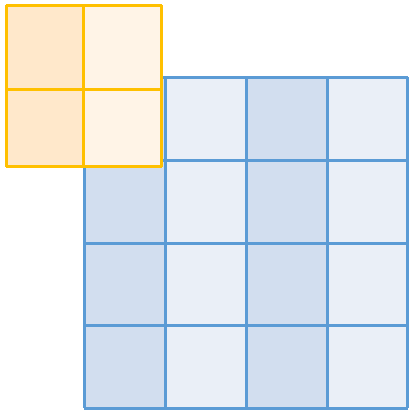

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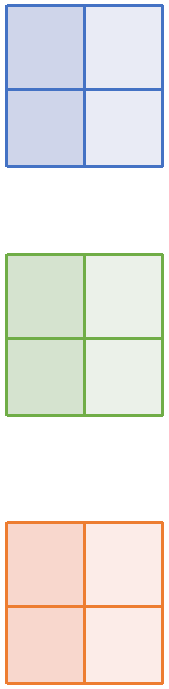

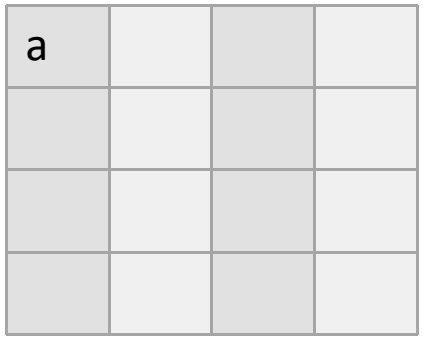

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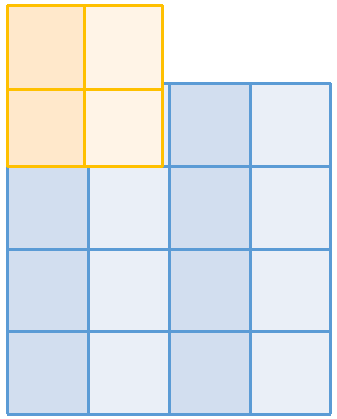

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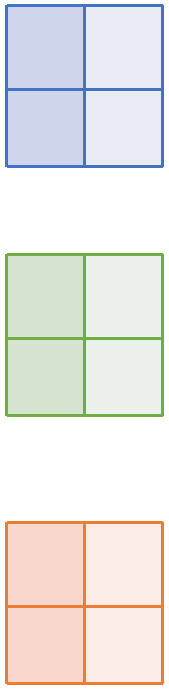
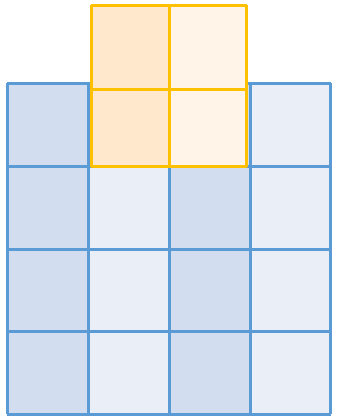


a	b		

Convolution Stage



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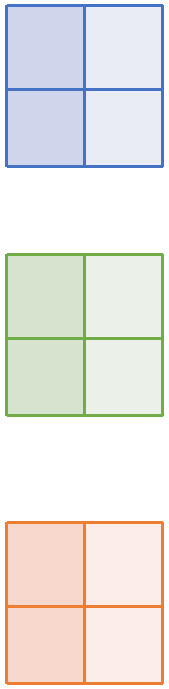
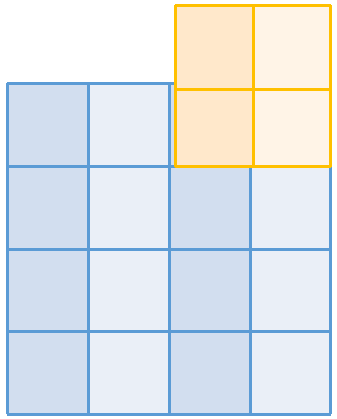


a	b	c	

Convolution Stage



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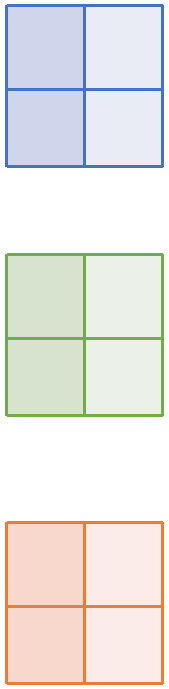
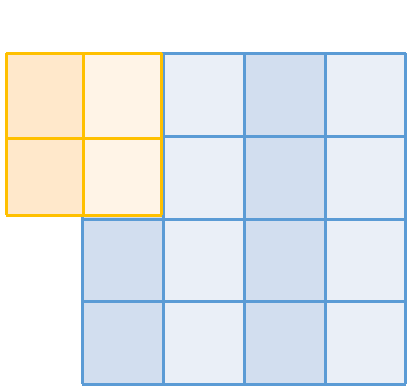


a	b	c	d

Convolution Stage



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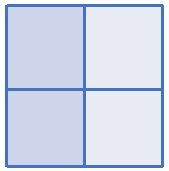
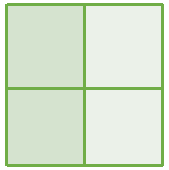
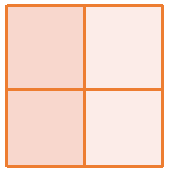
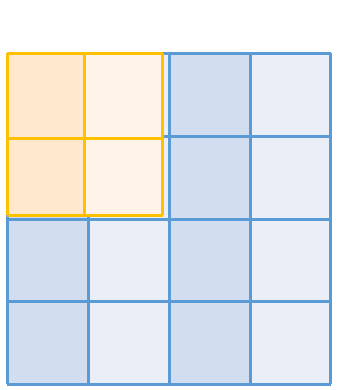






a	b	c	d
e			

Convolution Stage



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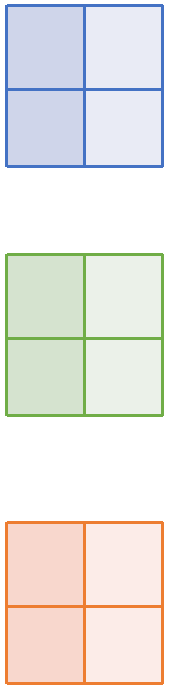
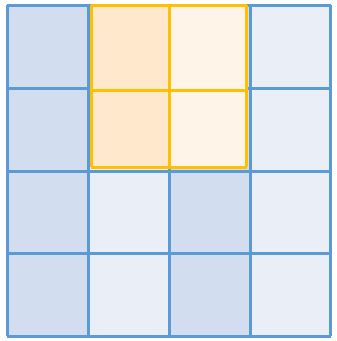


a	b	c	d
e	f		

Convolution Stage



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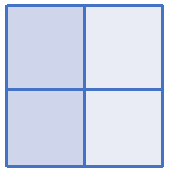
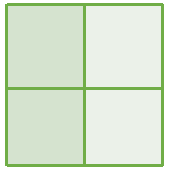
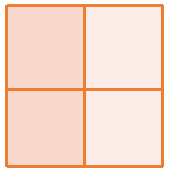
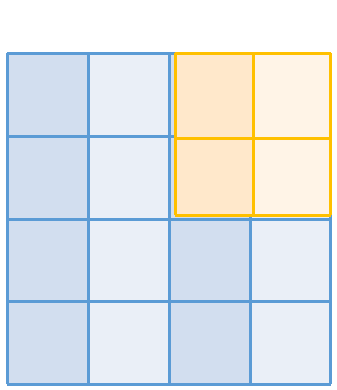






a	b	c	d
e	f	g	

Convolution Stage



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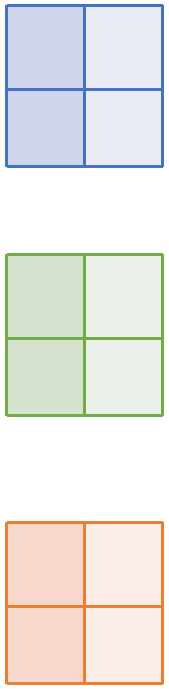
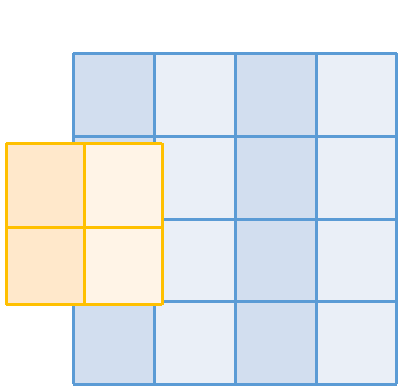


a	b	c	d
e	f	g	h

Convolution Stage



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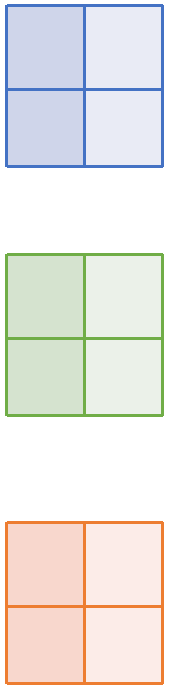
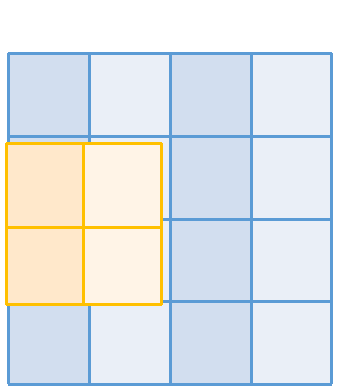


a	b	c	d
e	f	g	h
i			

Convolution Stage



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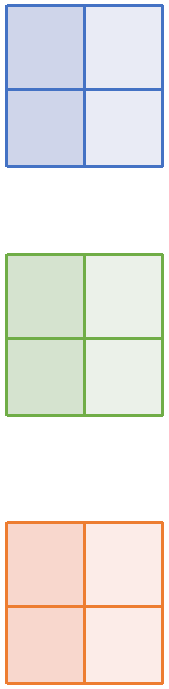
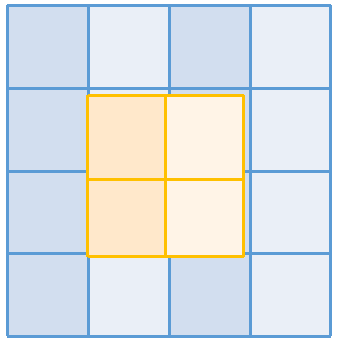
One channel



a	b	c	d
e	f	g	h
i	j		

Convolution Stage



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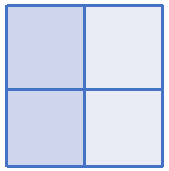
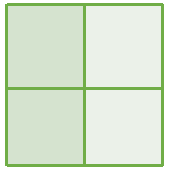
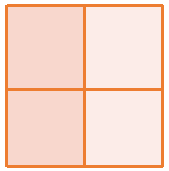
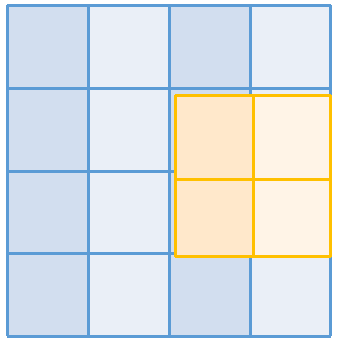






a	b	c	d
e	f	g	h
i	j	k	

Convolution Stage



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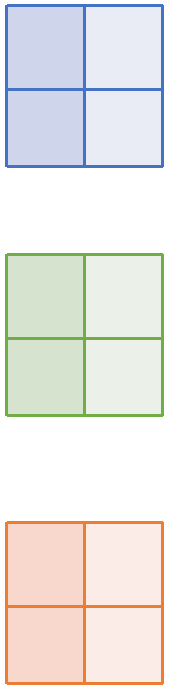
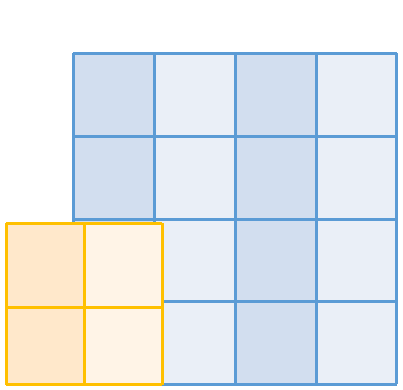
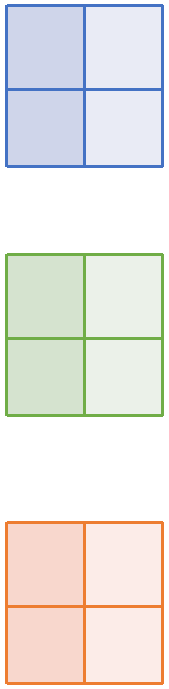


a	b	c	d
e	f	g	h
i	j	k	l

Convolution Stage

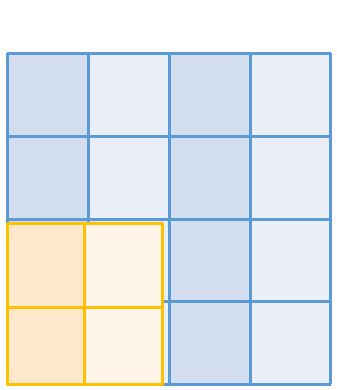


4x4
One channel

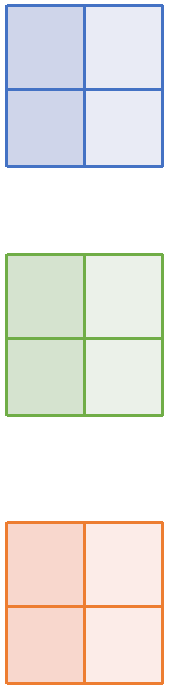


a	b	c	d
e	f	g	h
i	j	k	l
m			

Convolution Stage

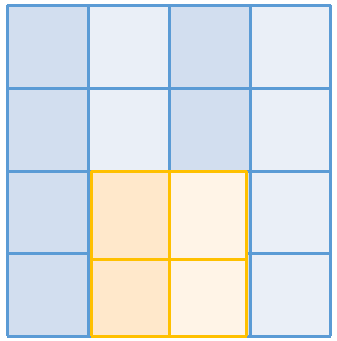


4x4
One channel

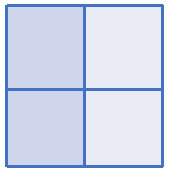


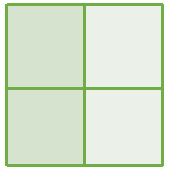
a	b	c	d
e	f	g	h
i	j	k	l
m	n		

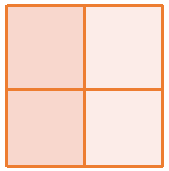
Convolution Stage



4x4
One channel

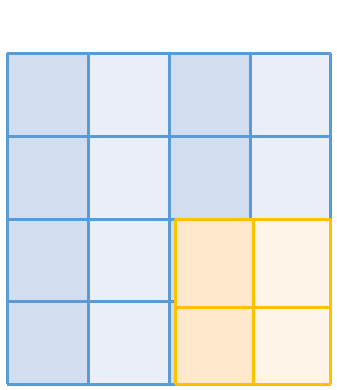




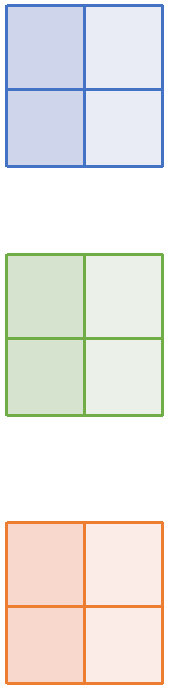


a	b	c	d
e	f	g	h
i	j	k	l
m	n	l	

Convolution Stage

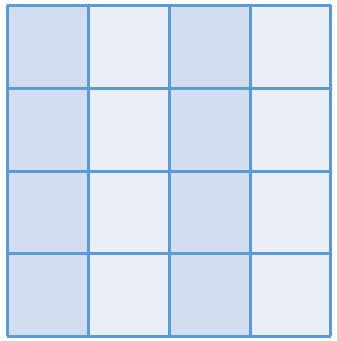


4x4
One channel

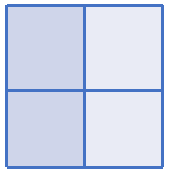


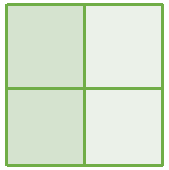
a	b	c	d
e	f	g	h
i	j	k	l
m	n	l	o

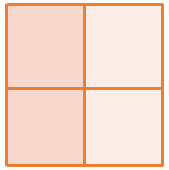
Convolution Stage



4x4
One channel

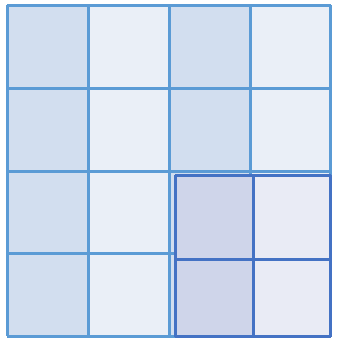




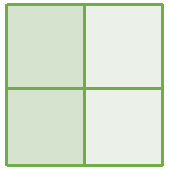


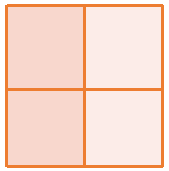
a	b	c	d
e	f	g	h
i	j	k	l
m	n	l	o

Convolution Stage



4x4
One channel

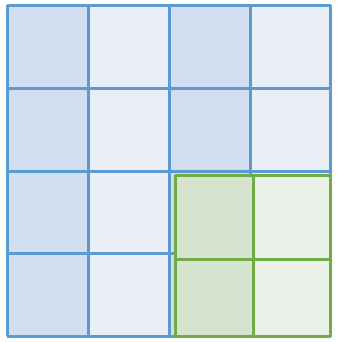




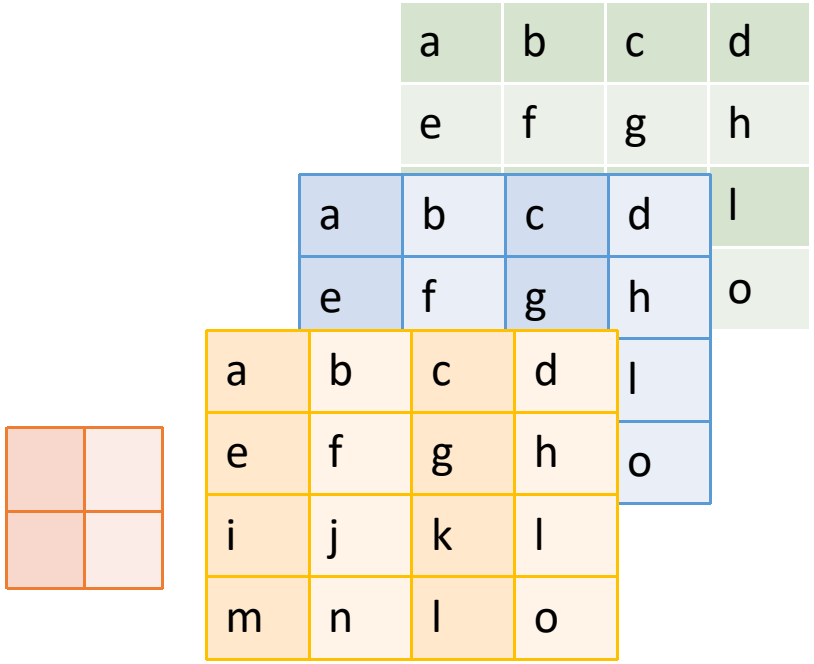
a	b	c	d
e	f	g	h
i	j	k	l
m	n	l	o

a	b	c	d
e	f	g	h
			l
			o

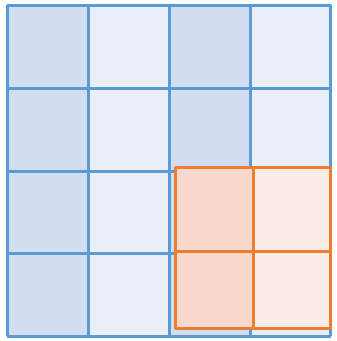
Convolution Stage



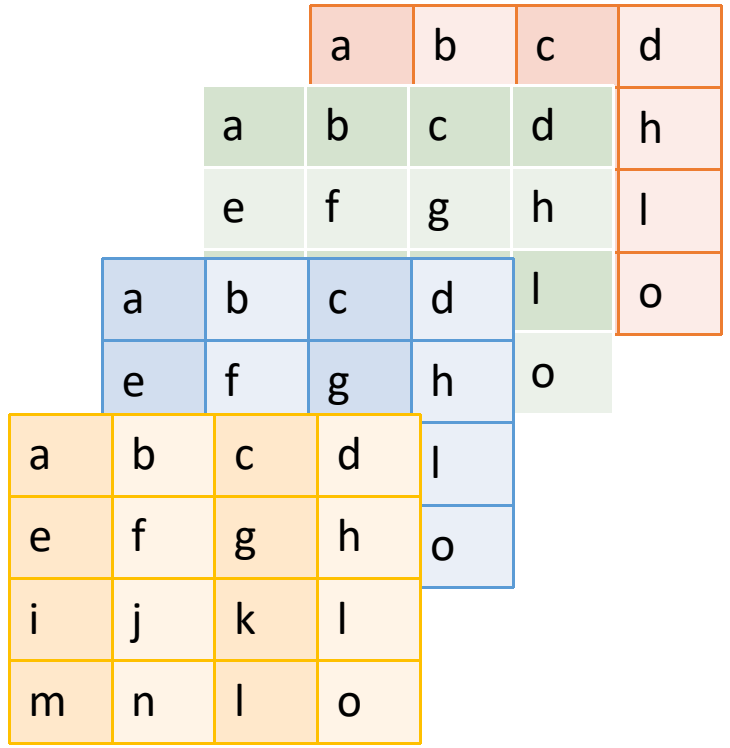
4x4
One channel



Convolution Stage

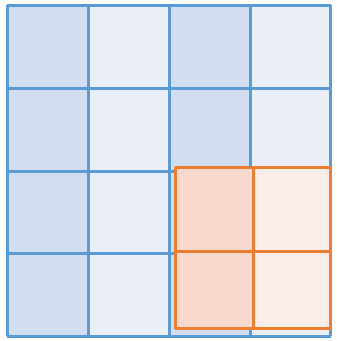


4x4
One channel

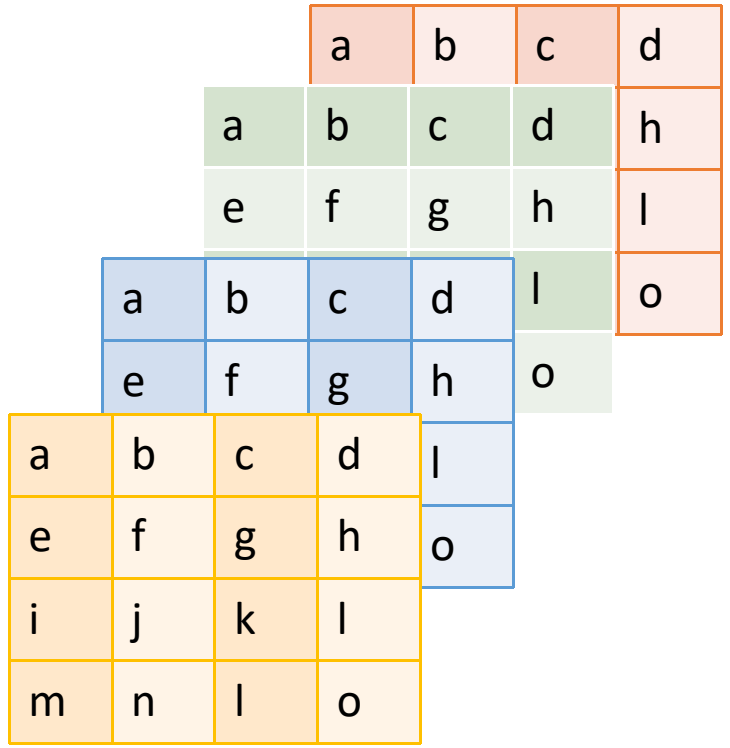


4X4x4

Convolution Stage

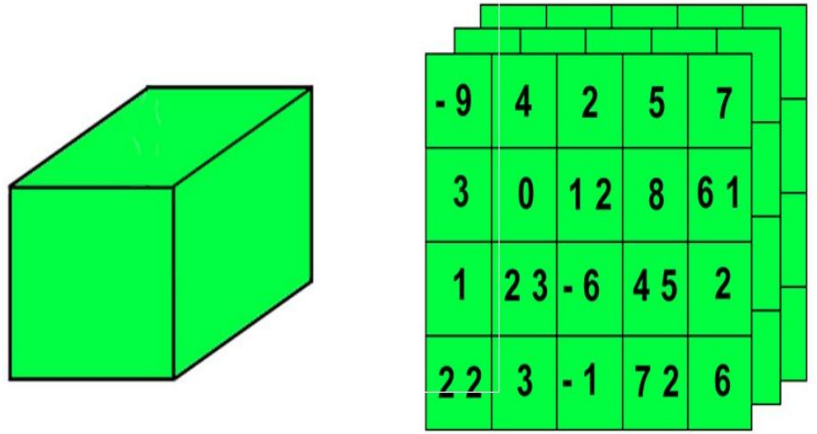


4x4
One channel

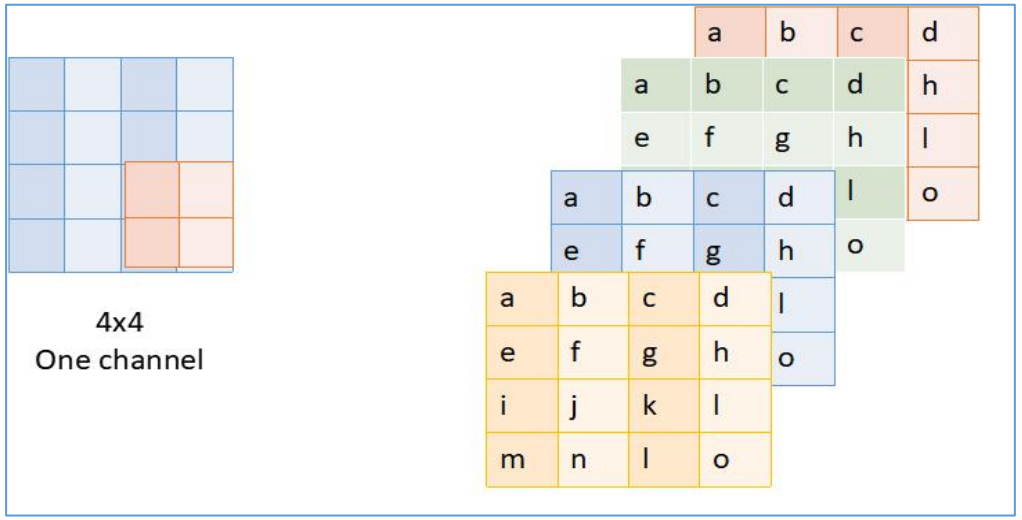


4X4x4

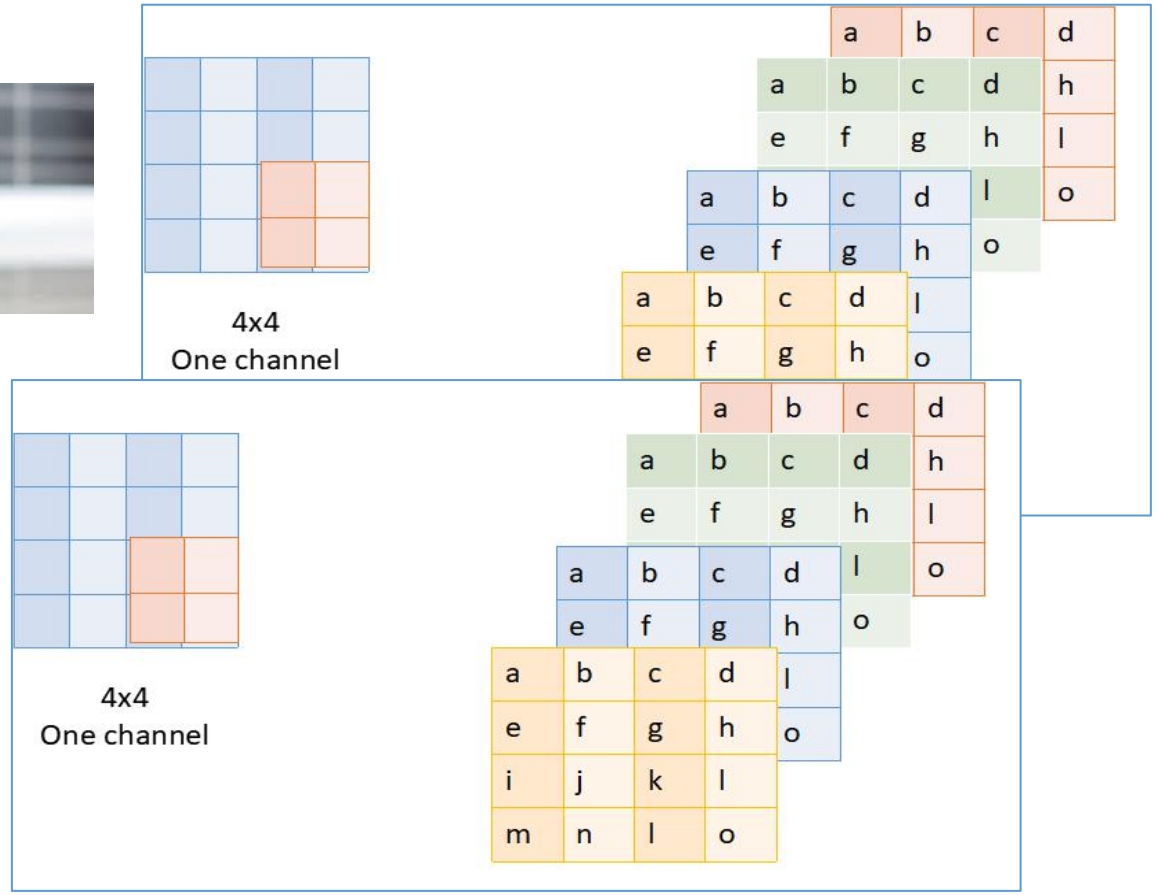
3D TENSOR/
CUBE



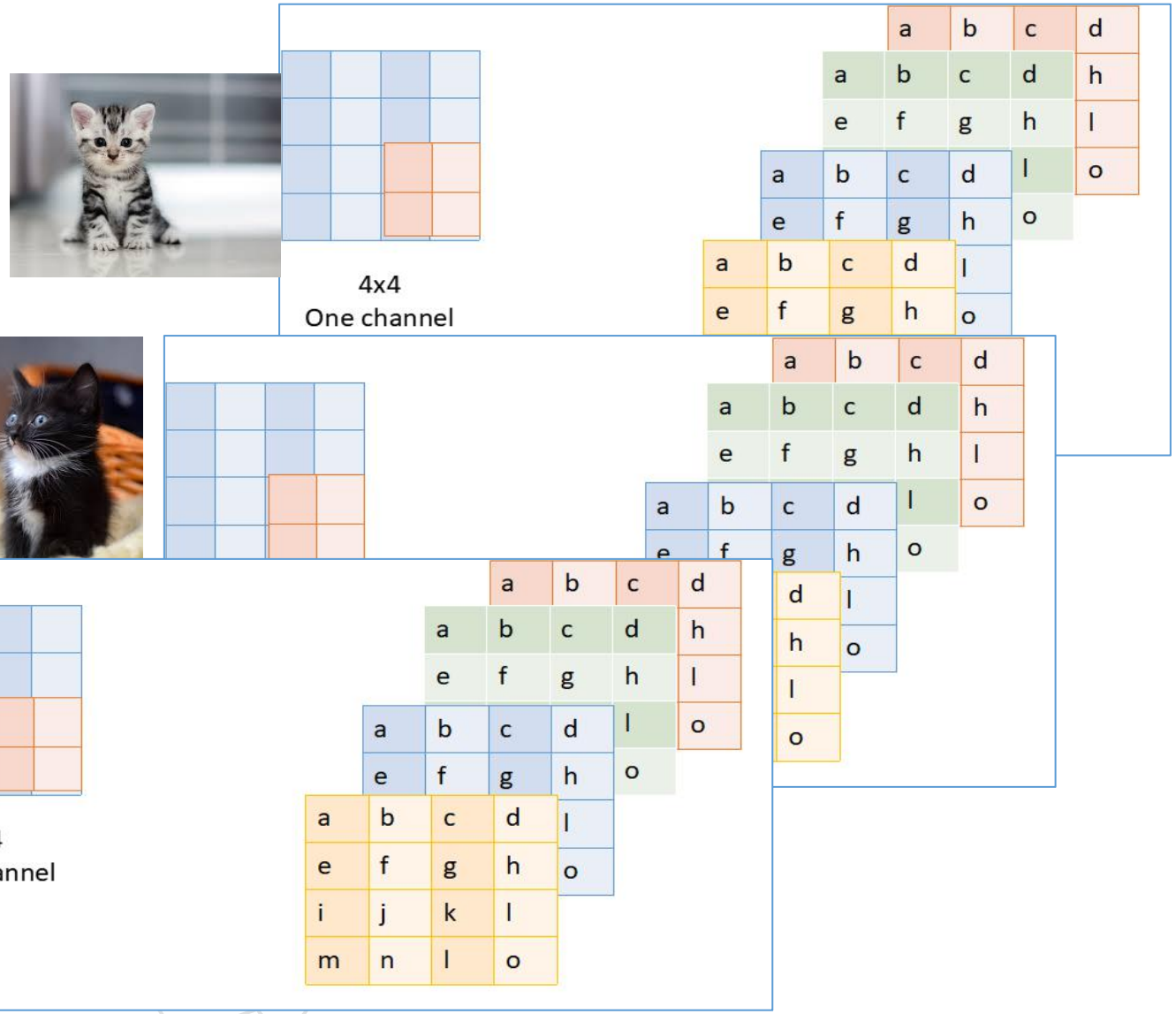
Convolution Stage



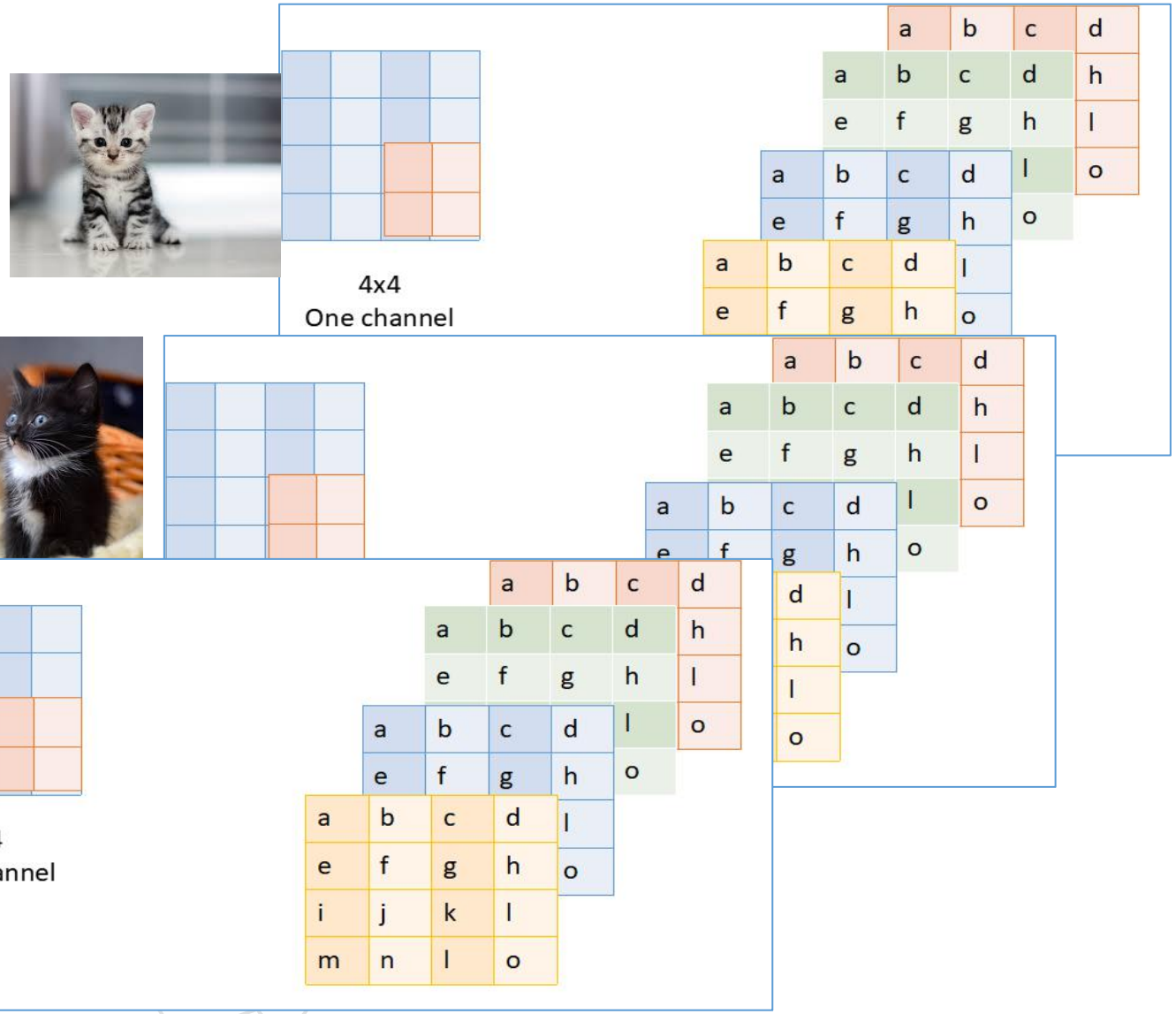
Convolution Stage

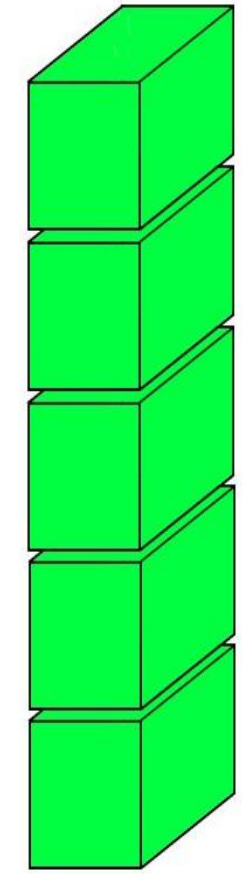


Convolution Stage



Convolution Stage

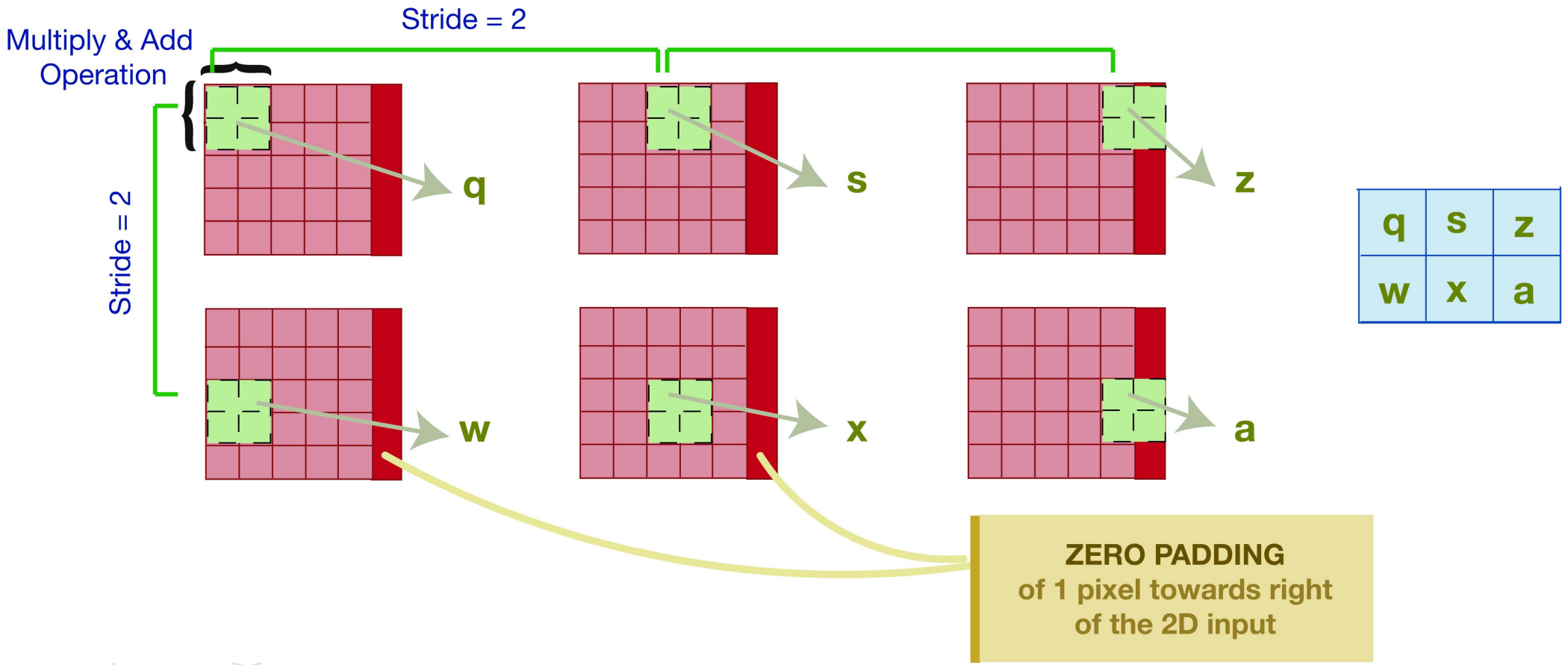




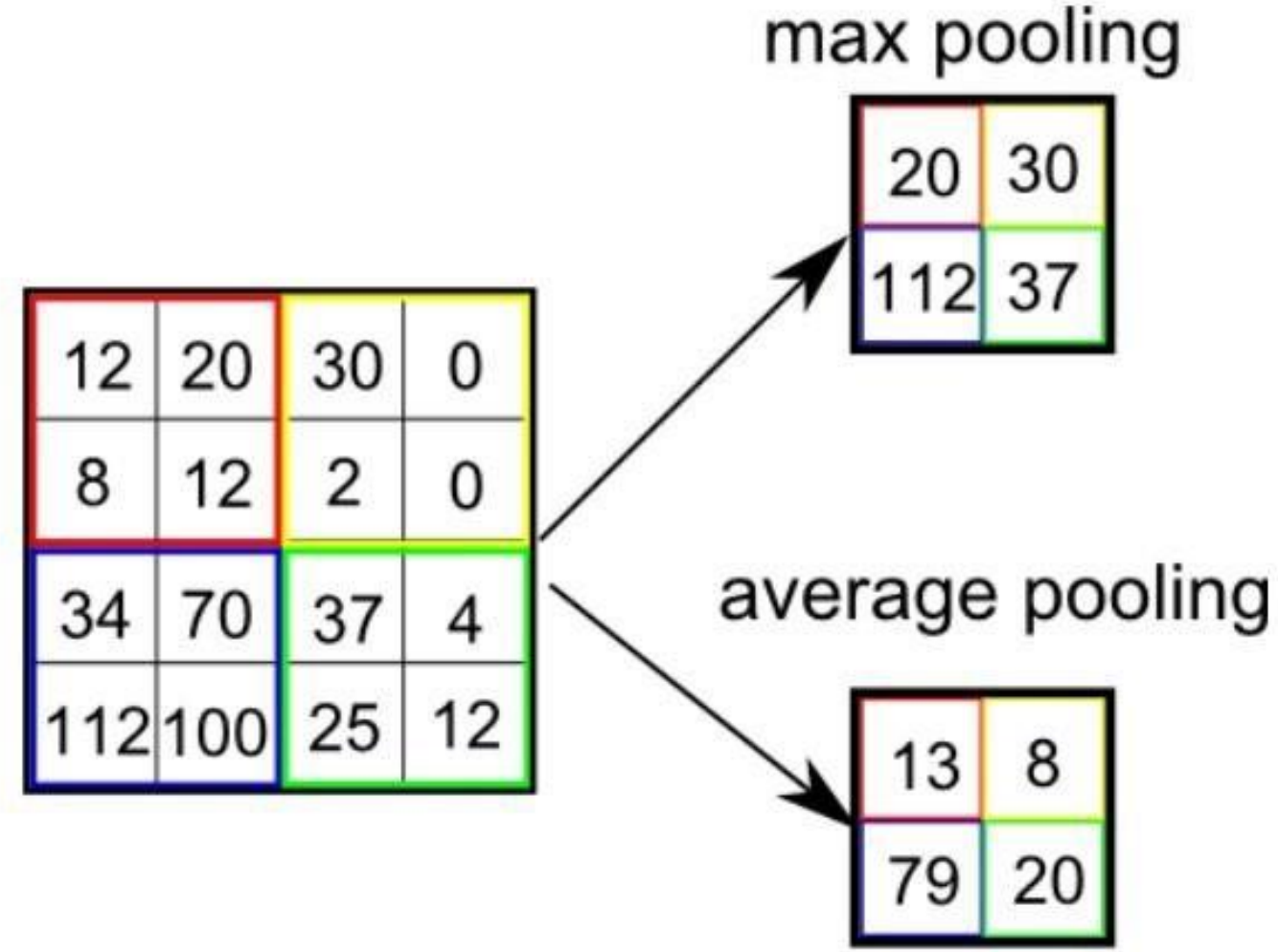
4D TENSOR

VECTOR OF CUBES

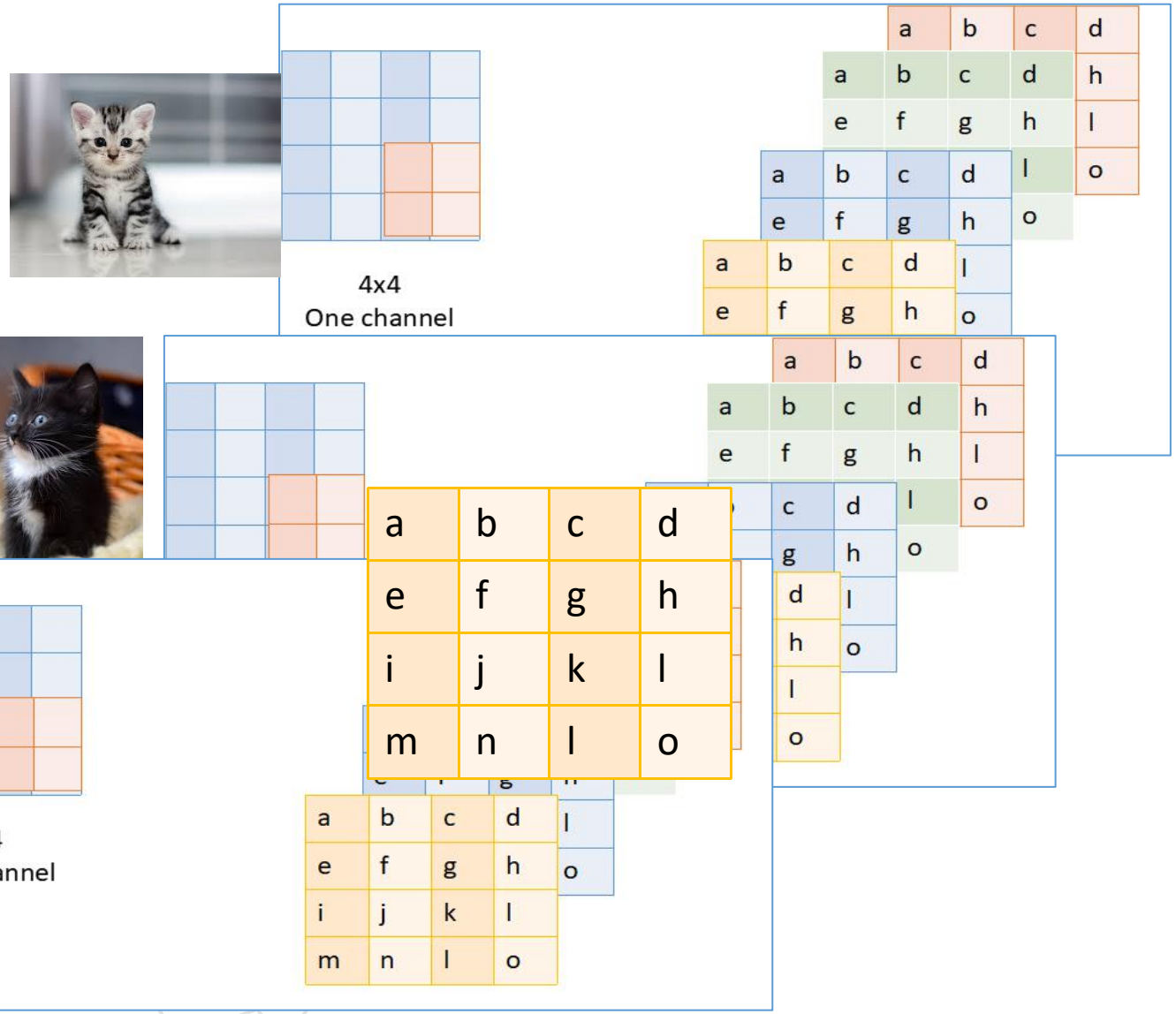
Stride and Padding



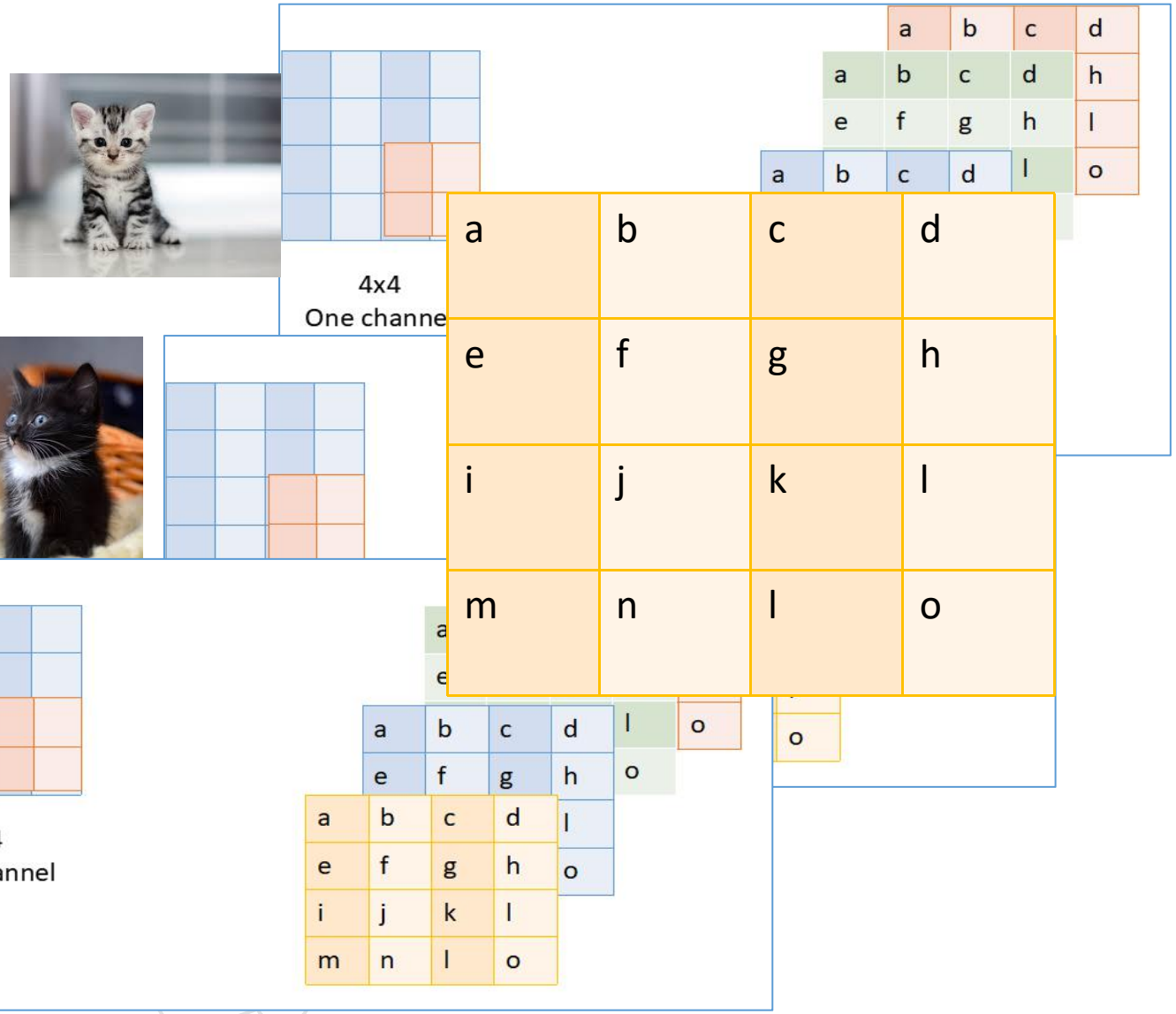
Pooling Stage



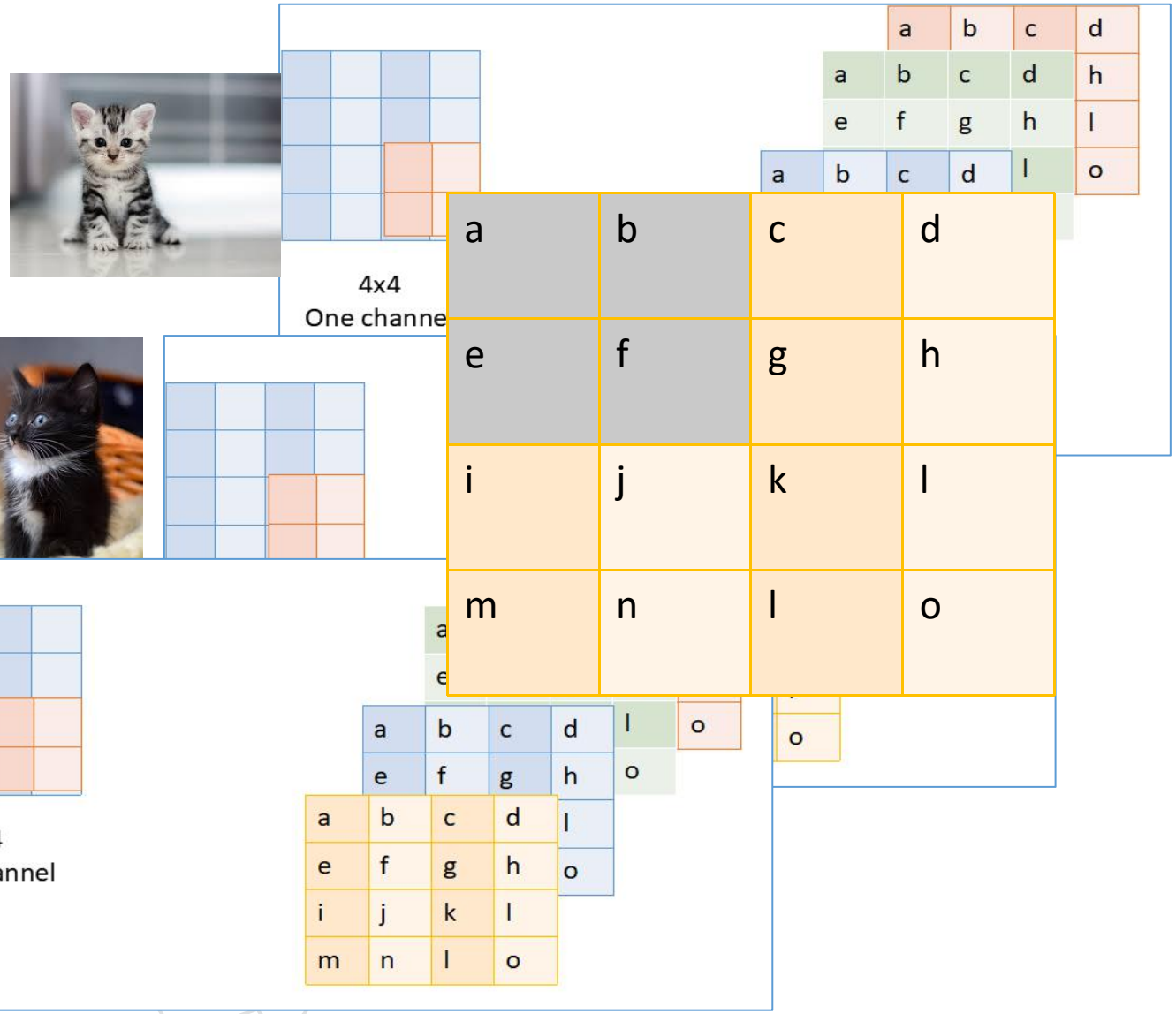
Pooling Stage

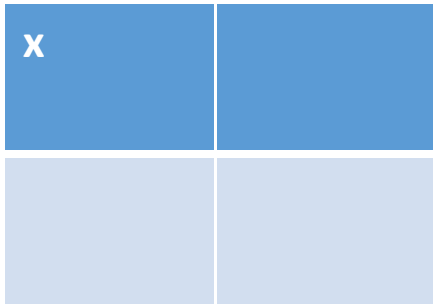


Pooling Stage



Pooling Stage





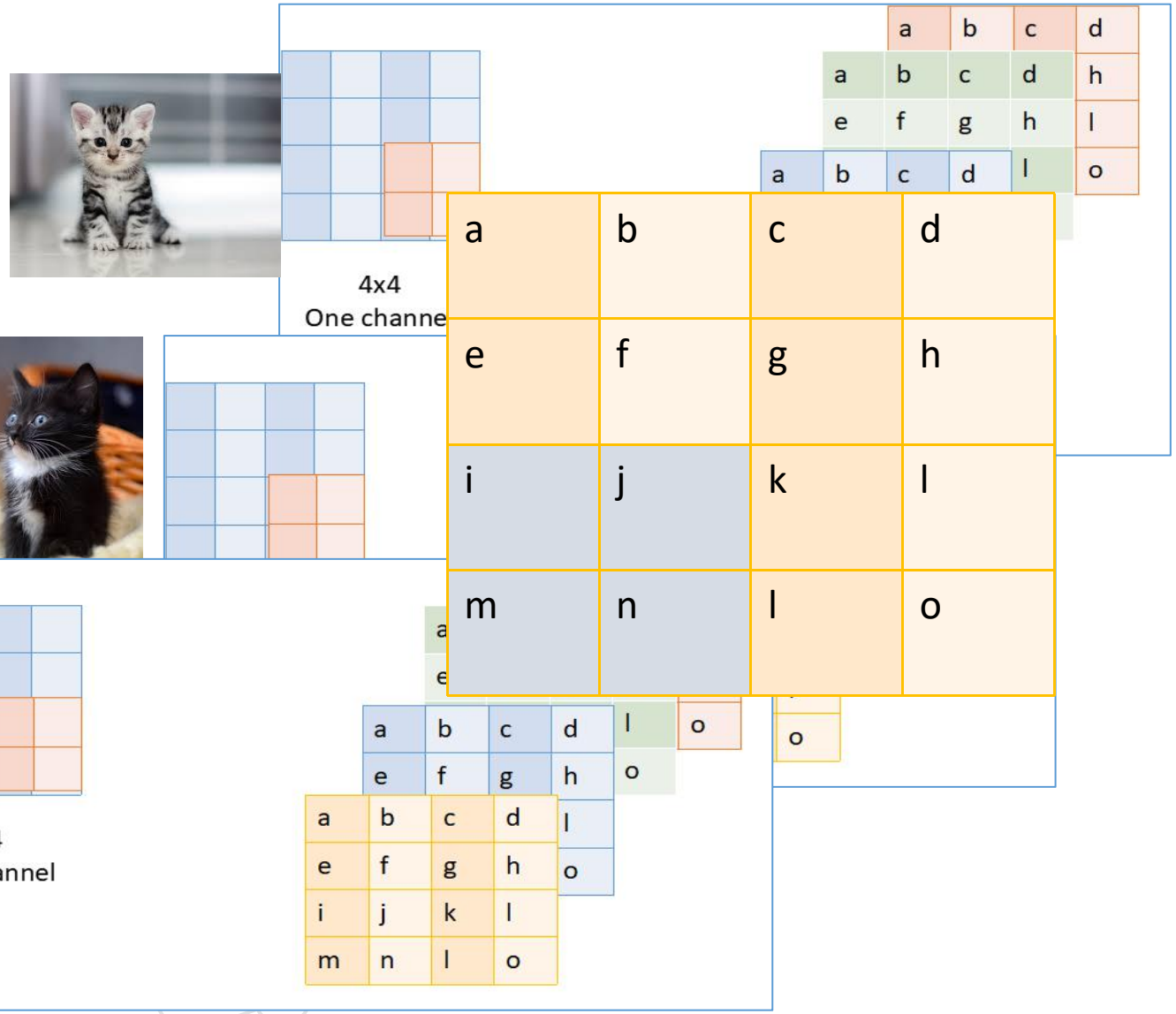
Pooling Stage

4x4
One channel

a	b	c	d
e	f	g	h
i	j	k	l
m	n	l	o

x	y

Pooling Stage



x	y
z	

Pooling Stage

4x4
One channel

a	b	c	d
e	f	g	h
i	j	k	l
m	n	l	o

x	y
z	w

Pooling Stage

Pooling Stage

4x4
One channel

4x4
One channel

Pooling Stage

4x4
One channel

4x4
One channel

Pooling Stage

4x4
One channel

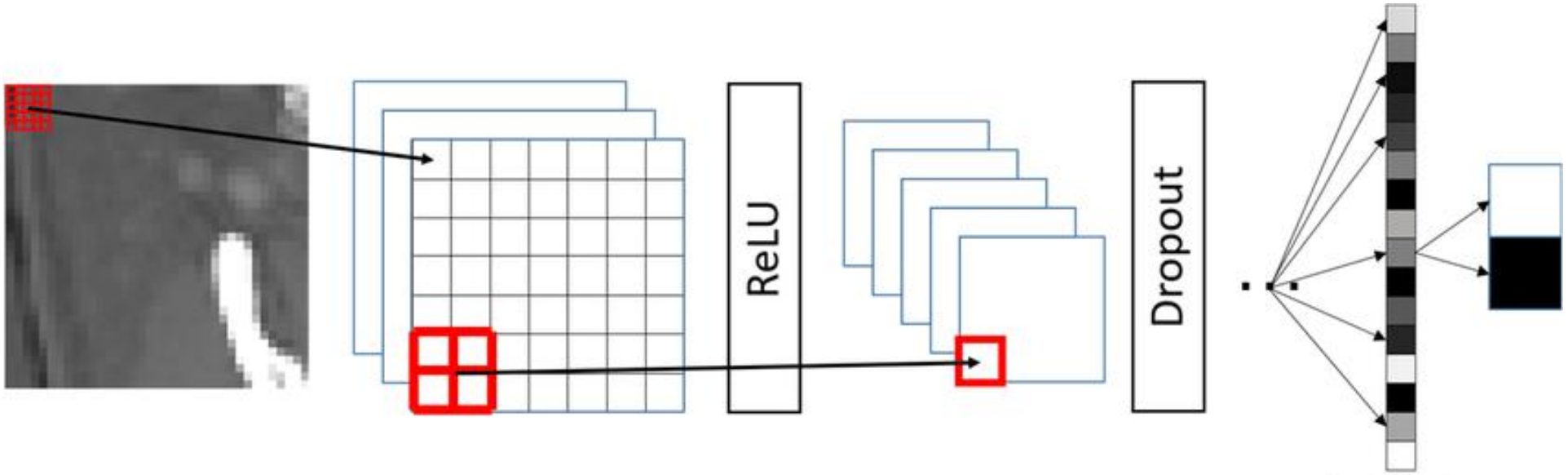
4x4
One channel

Pooling Stage

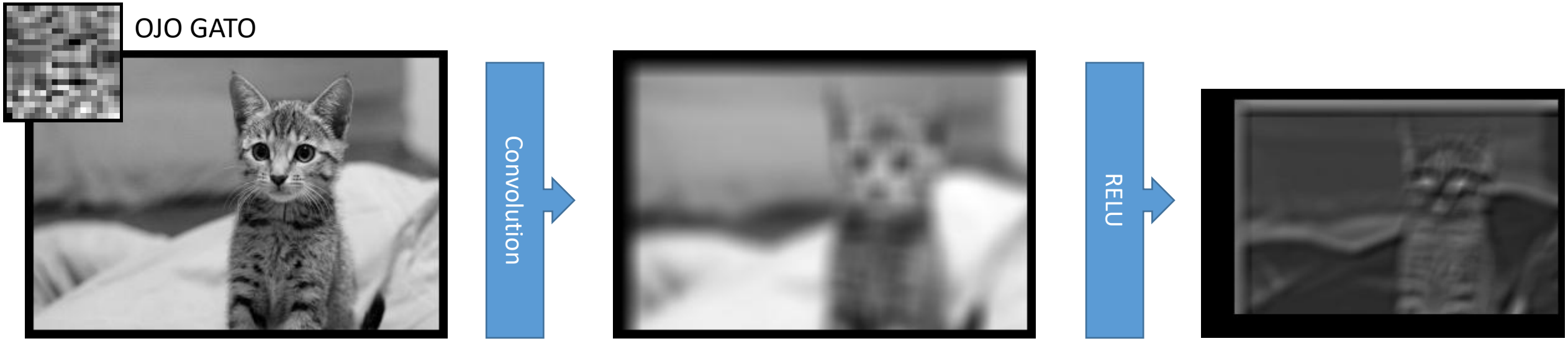
4x4
One channel

4x4
One channel

Summary Stages



Convolution and Relu



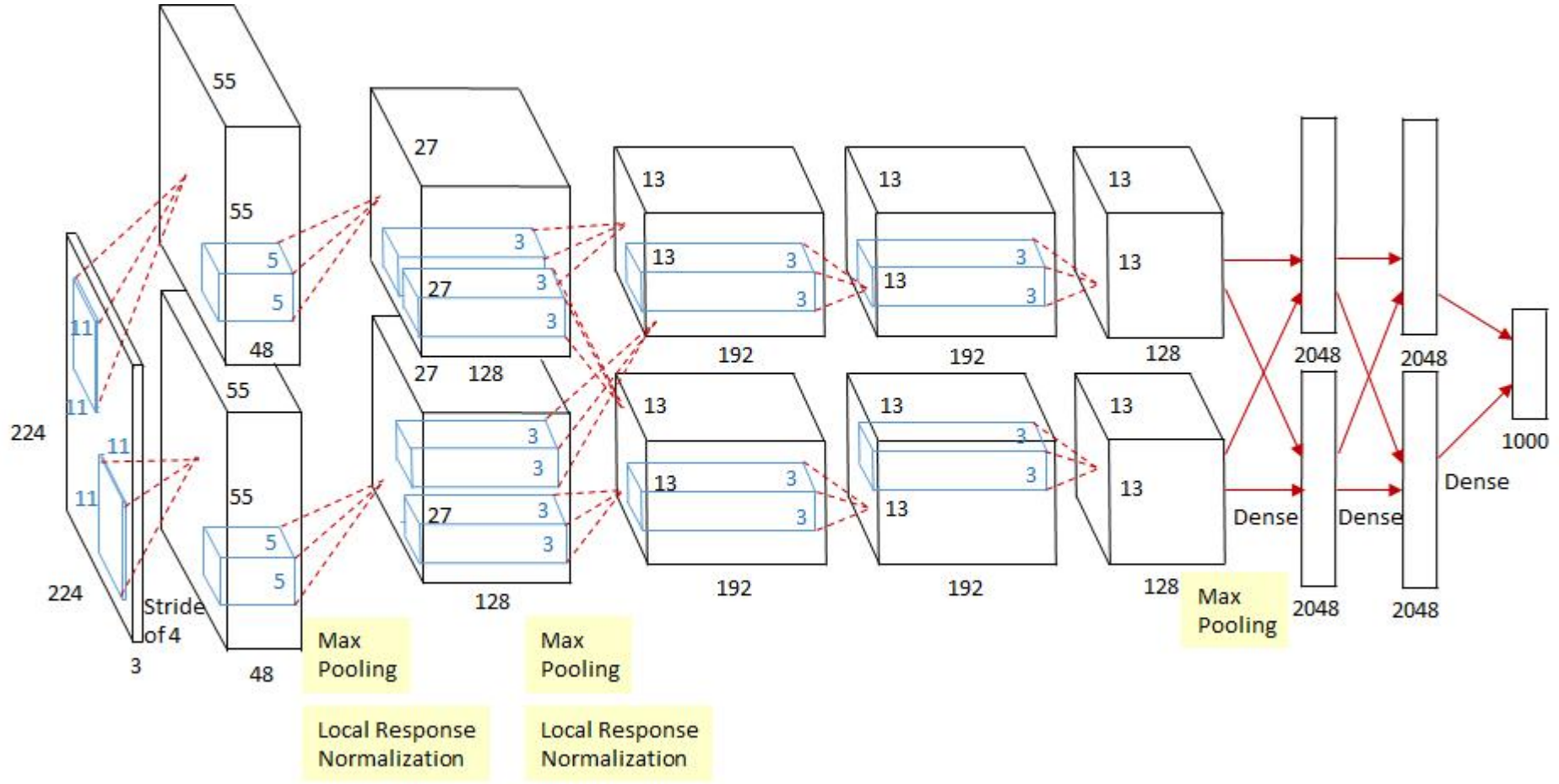
Exercise 1

- Download the script *Deep_Convolution_Layer_Relu*
- Review the effects of ReLU function after a convolution is applied.
- Note that this operation highligths several properties of the image

Exercise 2

- Download the script *DeepLearning_ConvolutionNetwork*
- Review the process to create a convolution network using the dataset included in file miml_dataset.zip

AlexNet Architecture



Exercise 3

- Convolution Netwo Application
- Pose Estimation