

Deep Learning

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Convolutional Neural Network

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Convolutional Neural N



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Convolutional Neural N

Examples from the test set
(with the network's guesses)



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cheetah



bullet train

bullet train

Convolutional Neural N

● convolutional neural network
Search term

● artificial neural network
Search term

Worldwide ▾

Past 5 years ▾

All categories ▾

Web Search ▾

Interest over time ⓘ



Convolutional Neural N



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Convolutional Neural N

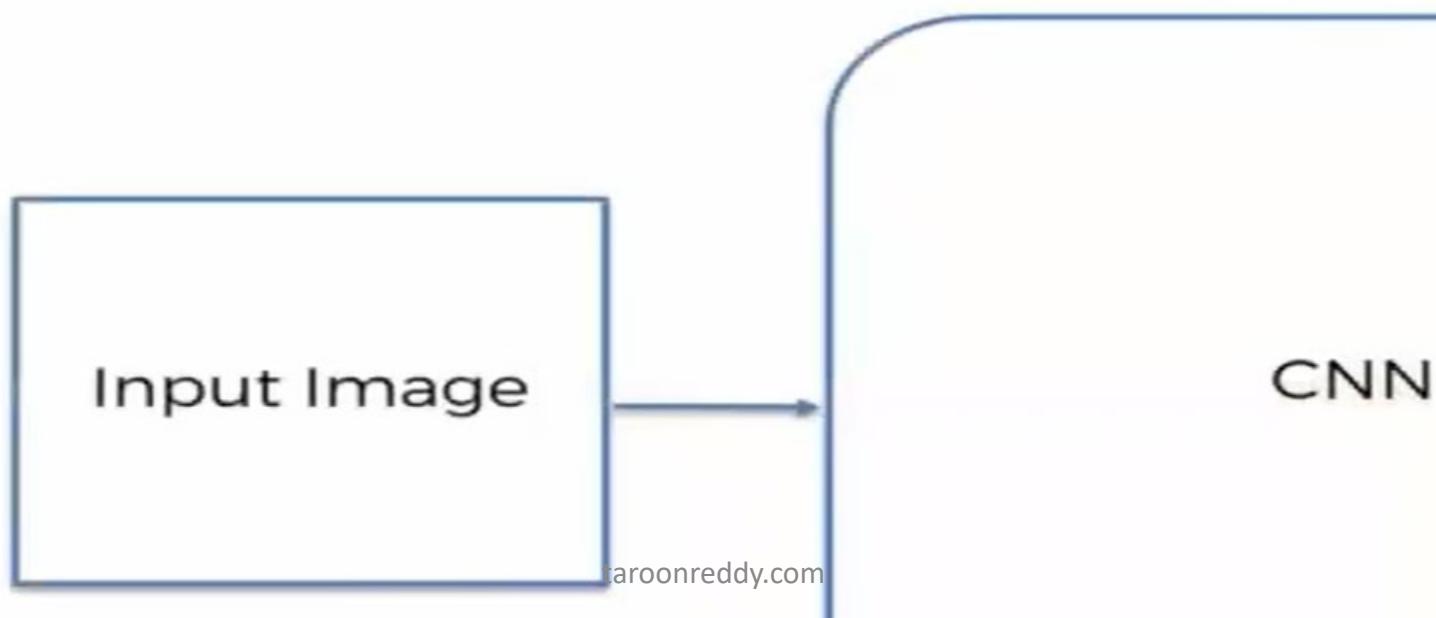
Google

Facebook

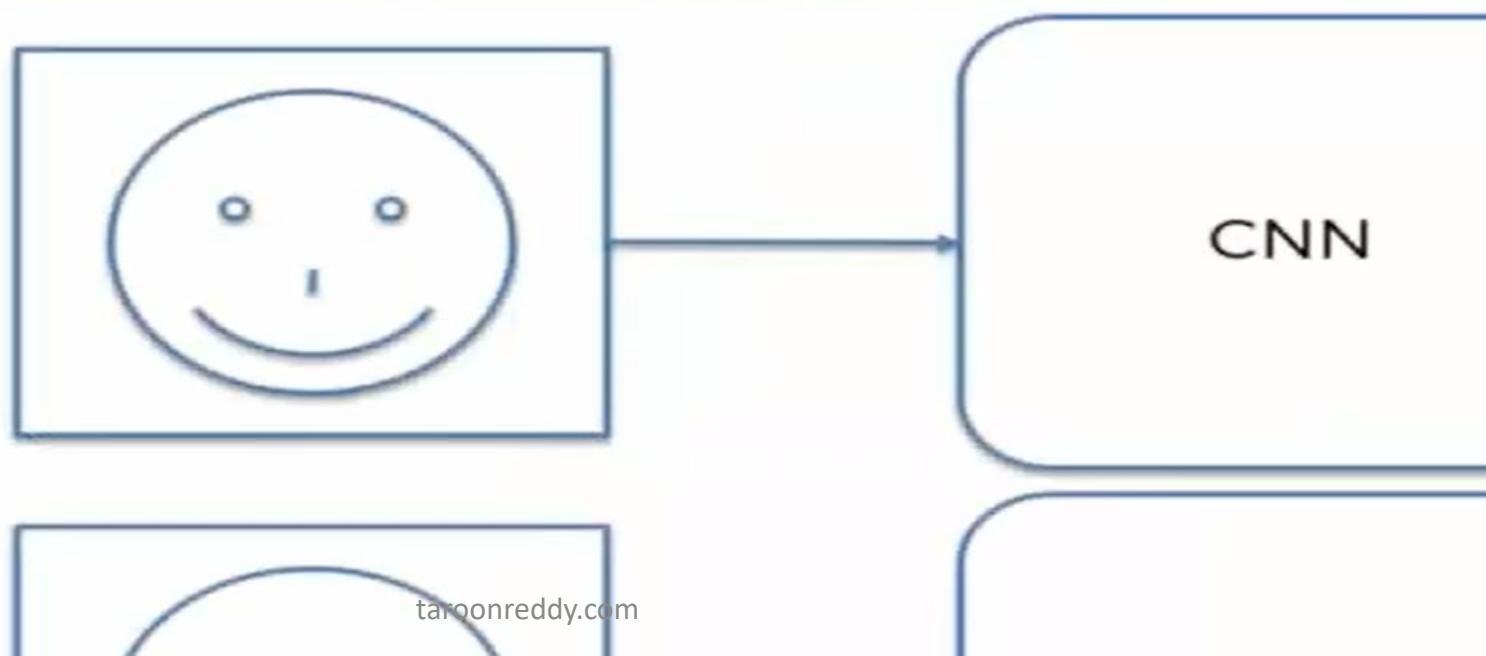


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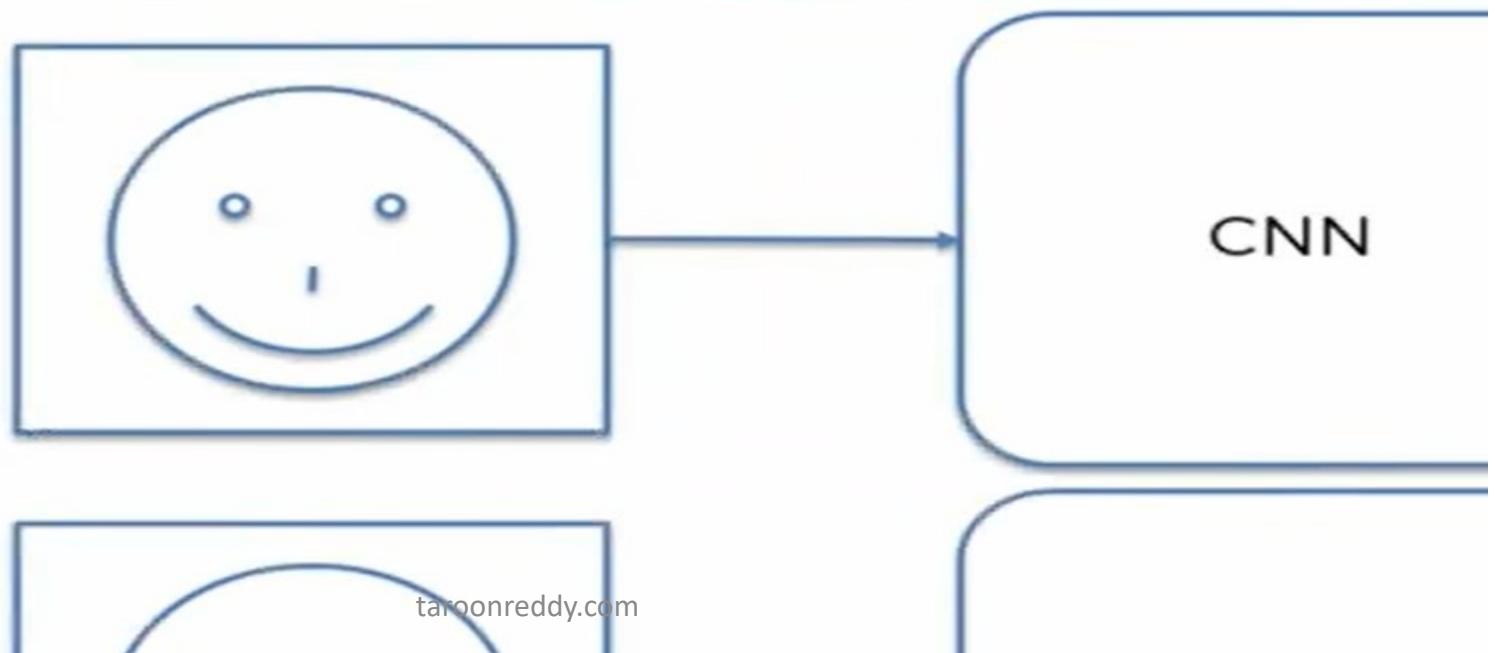
Convolutional Neural N



Convolutional Neural N



Convolutional Neural N



Convolutional Neural N

B / W Image 2x2px

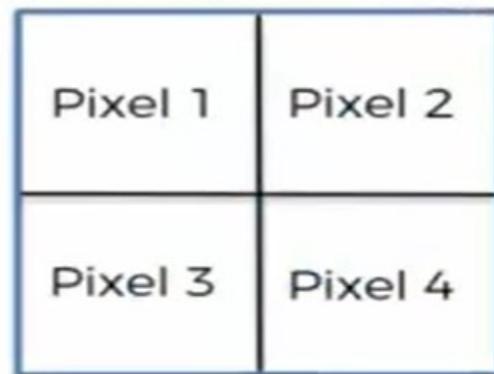
Pixel 1	Pixel 2
Pixel 3	Pixel 4

Colored Image 2x2px

Pixel 1	Pixel 2
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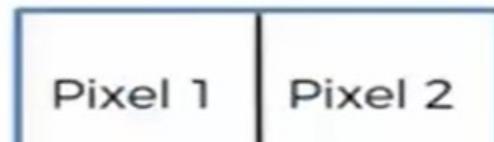
Convolutional Neural N

B / W Image 2x2px



2d array

Colored Image 2x2px



Convolutional Neural N

B / W Image 2x2px

Pixel 1	Pixel 2
Pixel 3	Pixel 4

2d array

Colored Image 2x2px

Pixel 1	Pixel 2
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Red channel

Convolutional Neural N

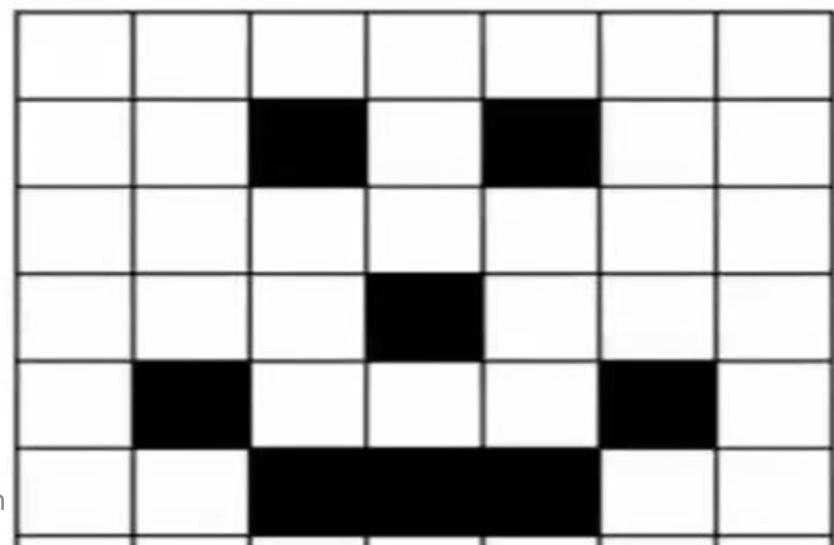


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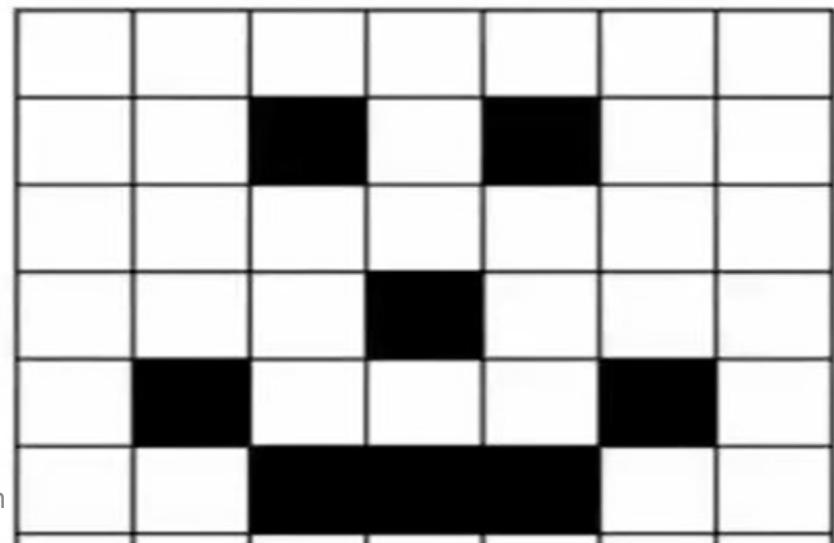
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Convolutional Neural N



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Convolutional Neural N

STEP 1: Convolution



STEP 2: Max Pooling



STEP 3: Flattening



Step 1 - Convolution

$$(f * g)(t) \stackrel{\text{def}}{=} \int_{-\infty}^{\infty} f(\tau) g(t - \tau) d\tau$$

Step 1 - Convolution

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0
0	0	0	0	0	0	0



0	0	1
1	0	0
0	1	1

Step 1 - Convolution

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0
0	0	0	0	0	0	0



0	0	1
1	0	0
0	1	1

Step 1 - Convolution

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0
0	0	0	0	0	0	0



0	0	1
1	0	0
0	1	1

Step 1 - Convolution

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0
0	0	0	0	0	0	0



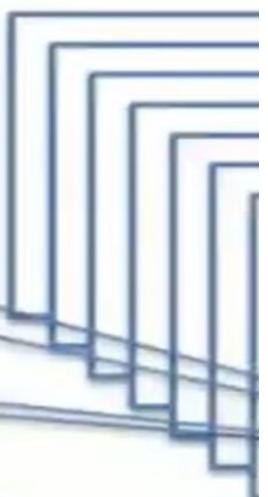
0	0	1
1	0	0
0	1	1

Step 1 - Convolution

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0
0	0	0	0	0	0	0

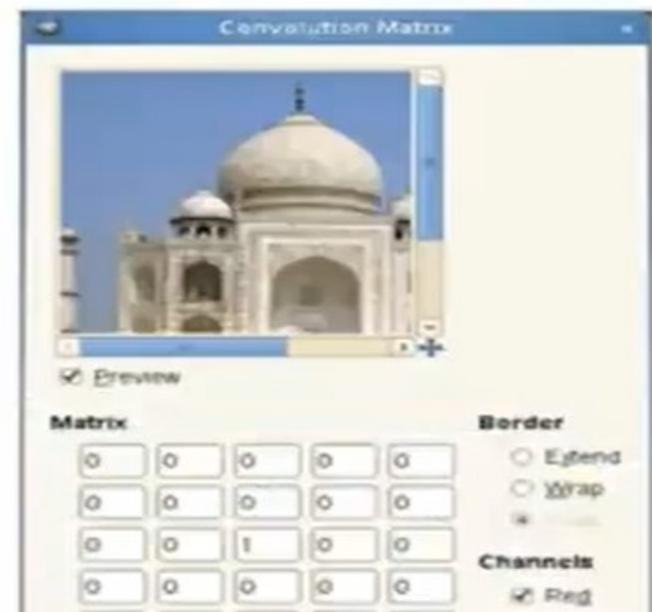
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We create many
feature maps to
obtain our first
convolution layer



Step 1 - Convolution

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Step 1 - Convolution

Sharpen:

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

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Step 1 - Convolution

Sharpen:

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

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Step 1 - Convolution

Blur:

0	0	0	0	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	0	0	0	0

4

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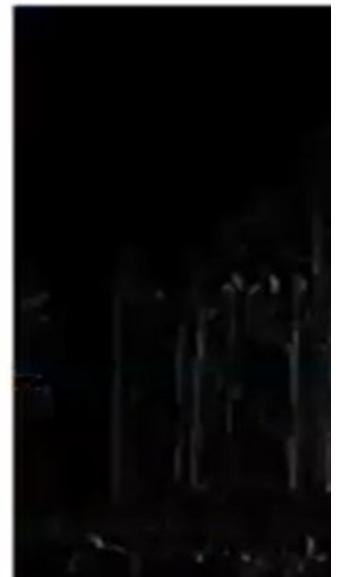
Step 1 - Convolution

Edge Enhance:



0	0	0	
-1	1	0	
0	0	0	

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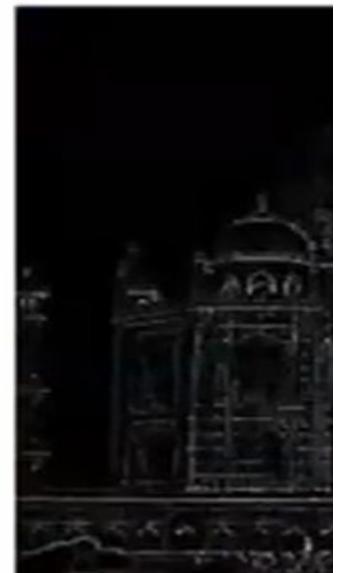


Step 1 - Convolution

Edge Detect:


$$\begin{matrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{matrix}$$

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Step 1 - Convolution

Emboss:

.	-2	-1	0
-1	1	1	.
0	1	2	.



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Step 1 - Convolution

Sharpen:

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

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Step 1 - Convolution



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*

1	0	-1
2	0	-2
1	0	-1

Step 1(B) – ReLU Layer

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0

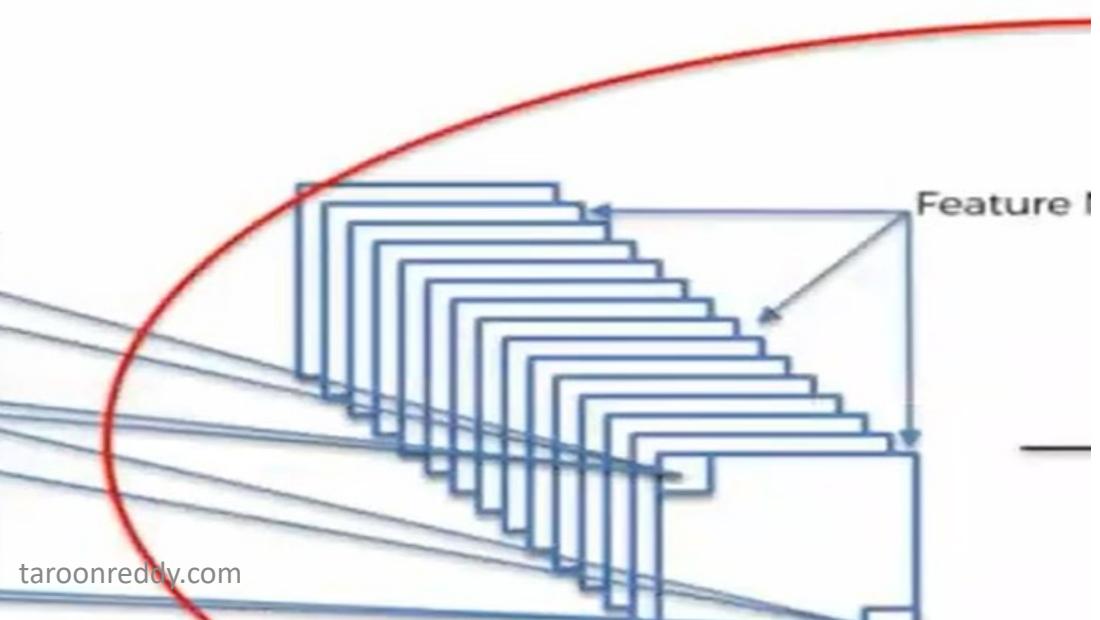
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We create many
feature maps to
obtain our first
convolution layer



Step 1(B) – ReLU Layer

0	0	0	0	0	0	0	0
0	1	0	0	0	1	0	0
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0
0	1	0	0	0	1	0	0
0	0	1	1	1	0	0	0
0	0	0	0	0	0	0	0



Step 1(B) – ReLU Layer



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Step 1(B) – ReLU Layer



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Step 1(B) – ReLU Layer



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Step 1(B) – ReLU Layer



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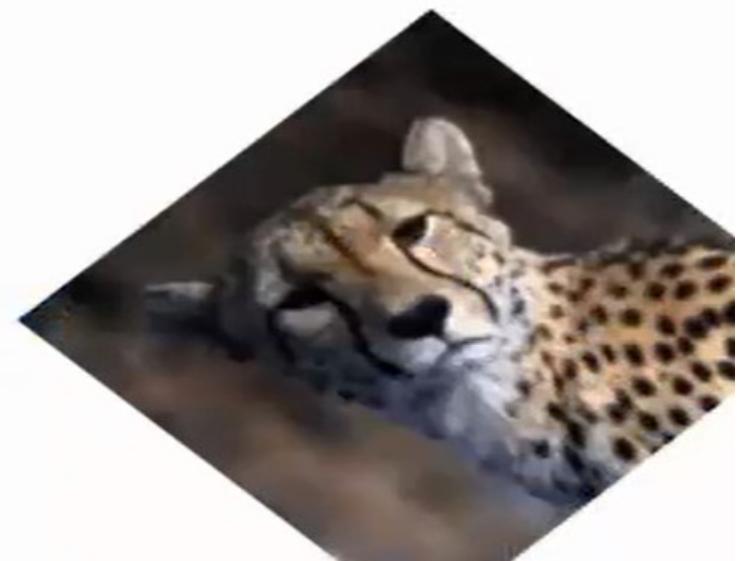
Step 2 - Max F

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Step 2 - Max Pooling



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Step 2 - Max Pooling



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Step 2 - Max Pooling

0	1	0	0	0
0	1	1	1	0
1	0	1	2	1
1	4	2	1	0
0	0	1	2	1

Max Pooling

Step 2 - Max Pooling

0	1	0	0	0
0	1	1	1	0
1	0	1	2	1
1	4	2	1	0
0	0	1	2	1



Max Pooling

Step 2 - Max Pooling

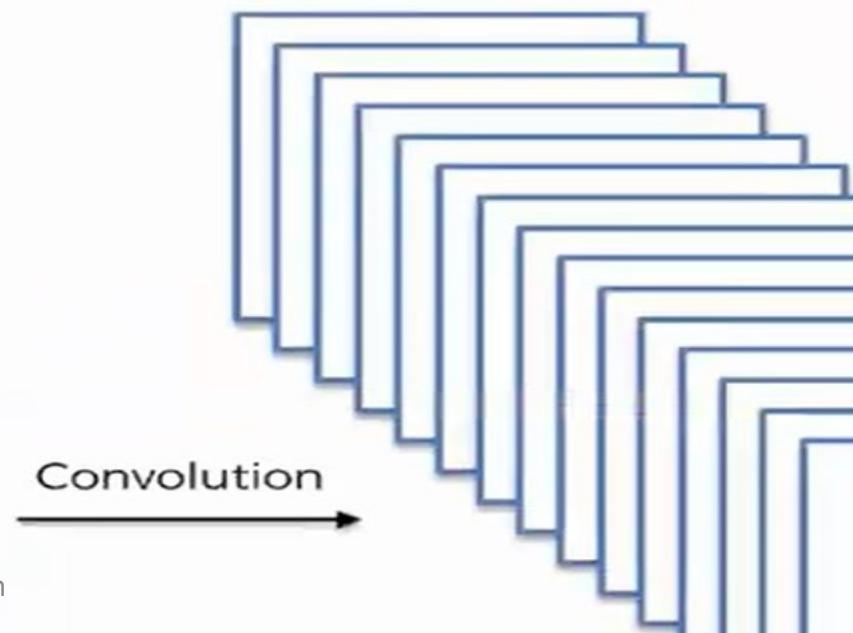
0	1	0	0	0
0	1	1	1	0
1	0	1	2	1
1	4	2	1	0
0	0	1	2	1

Max Pooling

Step 2 - Max Pooling

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0

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Step 2 - Max Pooling

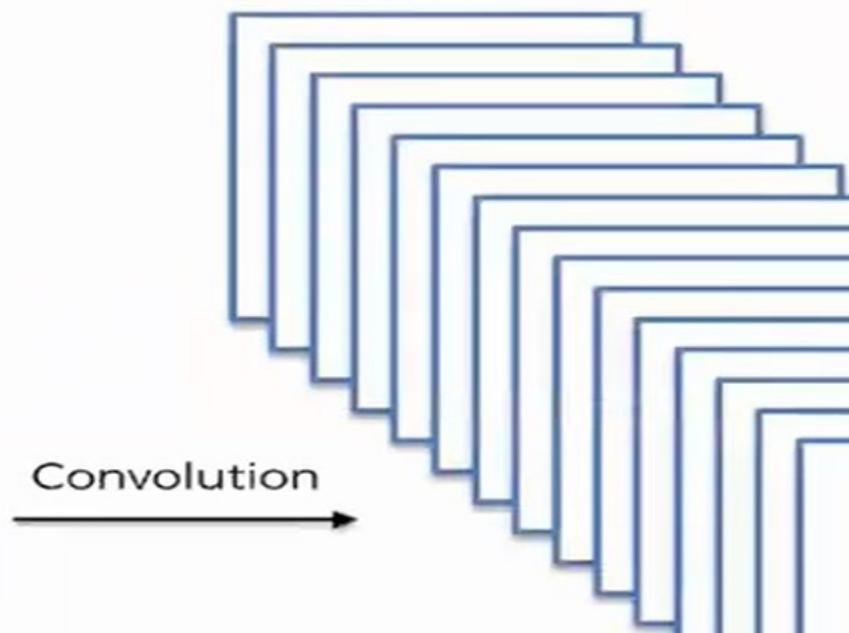
0	1	0	0	0
0	1	1	1	0
1	0	1	2	1
1	4	2	1	0
0	0	1	2	1

Max Pooling

Step 2 - Max Pooling

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0

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Step 2 - Max Pooling

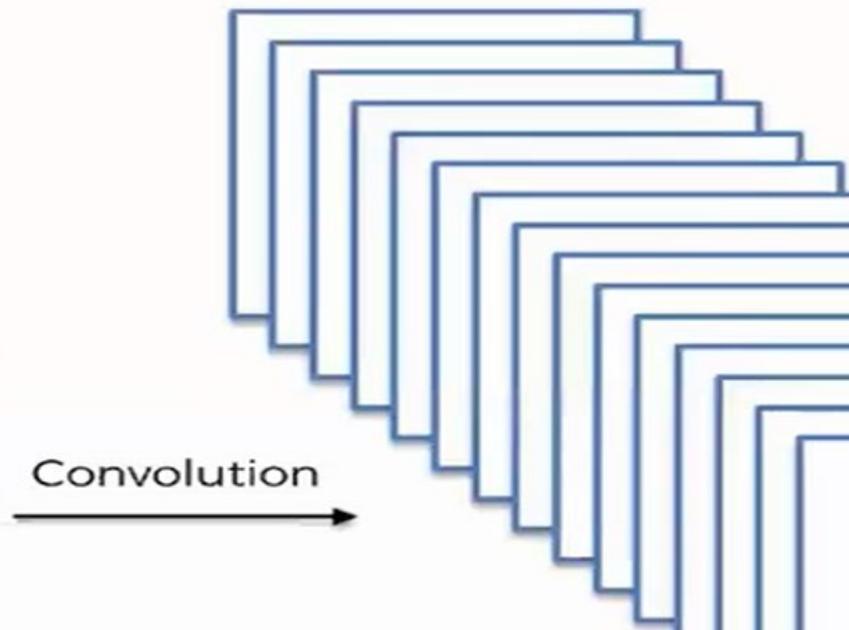
0	1	0	0	0
0	1	1	1	0
1	0	1	2	1
1	4	2	1	0
0	0	1	2	1

Max Pooling

Step 2 - Max Pooling

0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0

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Example



Example



Step 3 - Flatt

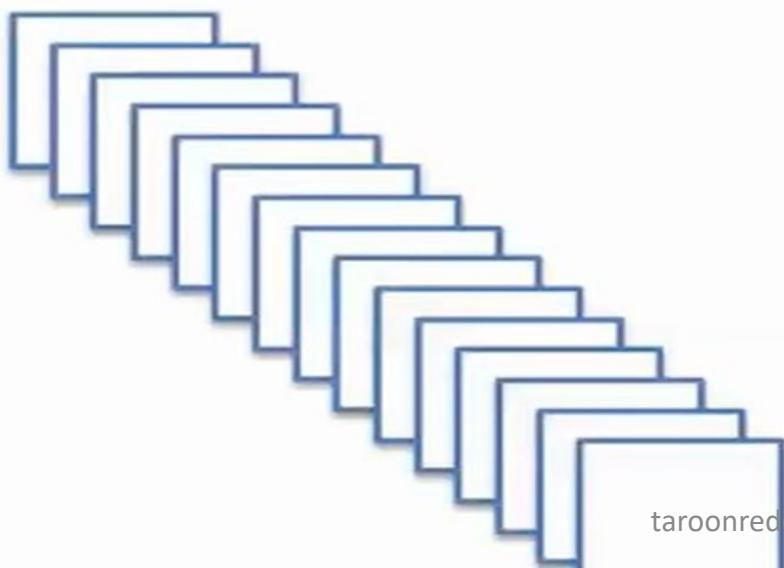
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Step 3 - Flattening

1	1	0
4	2	1
0	2	1

Flattening

Step 3 - Flattening

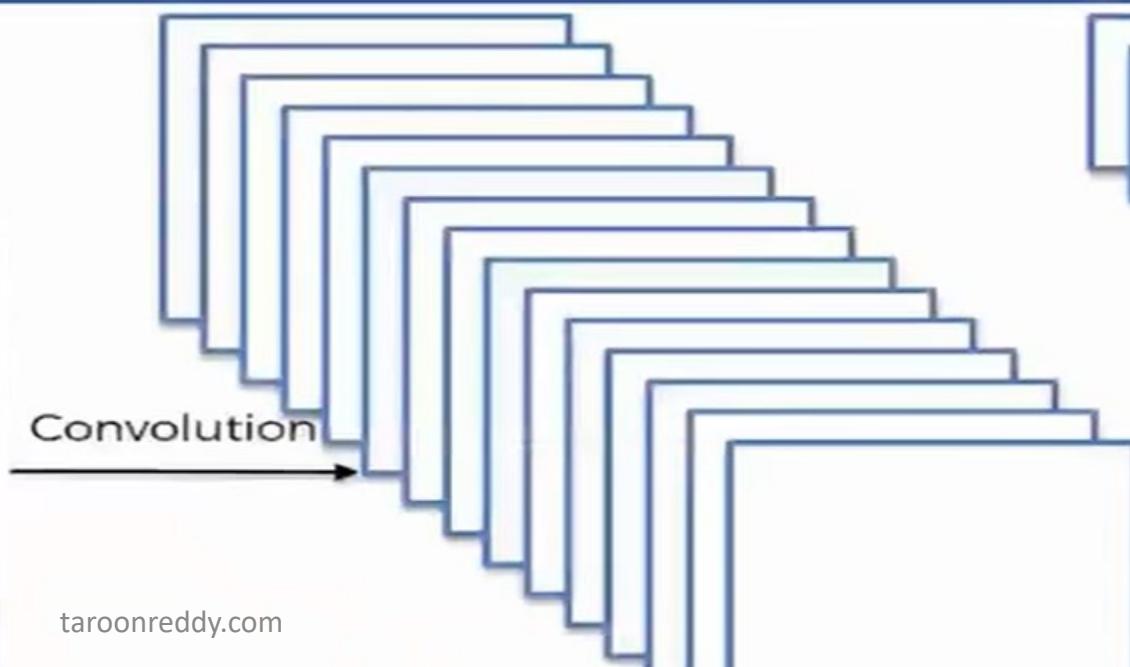


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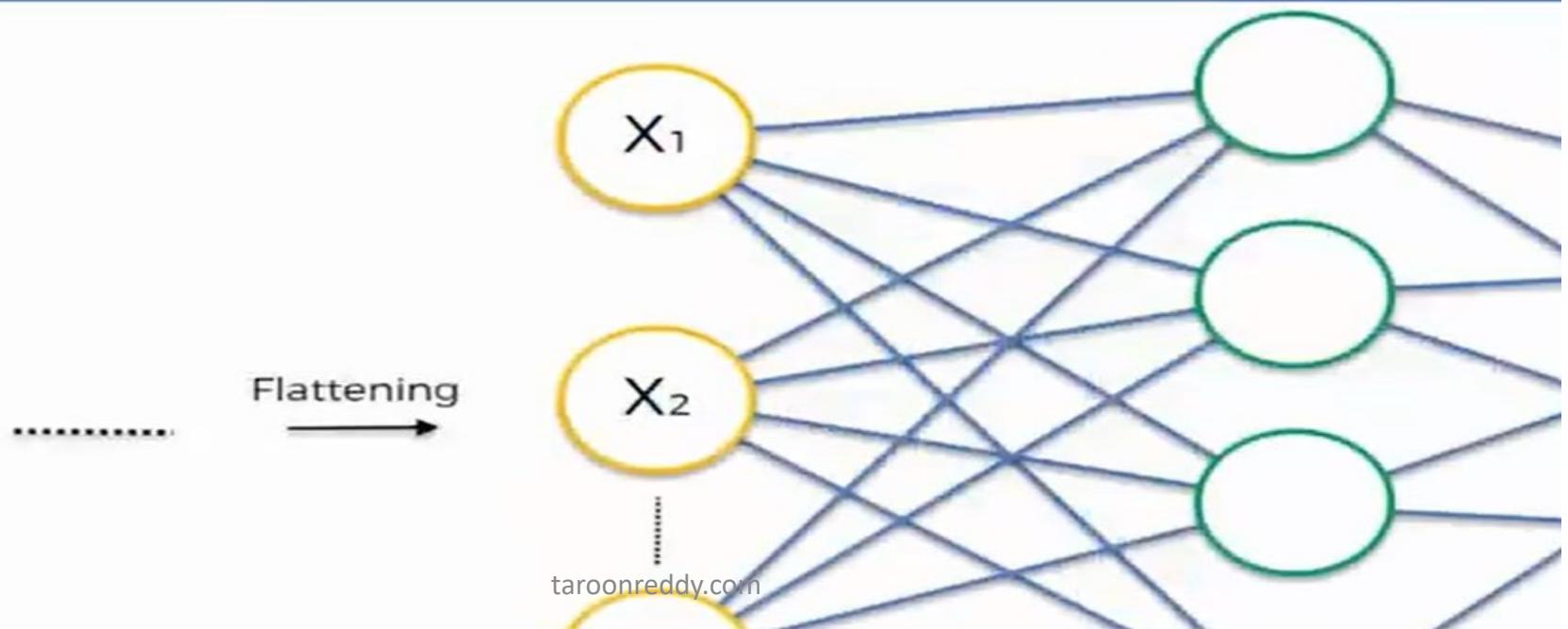
Flattening

Step 3 - Flattening

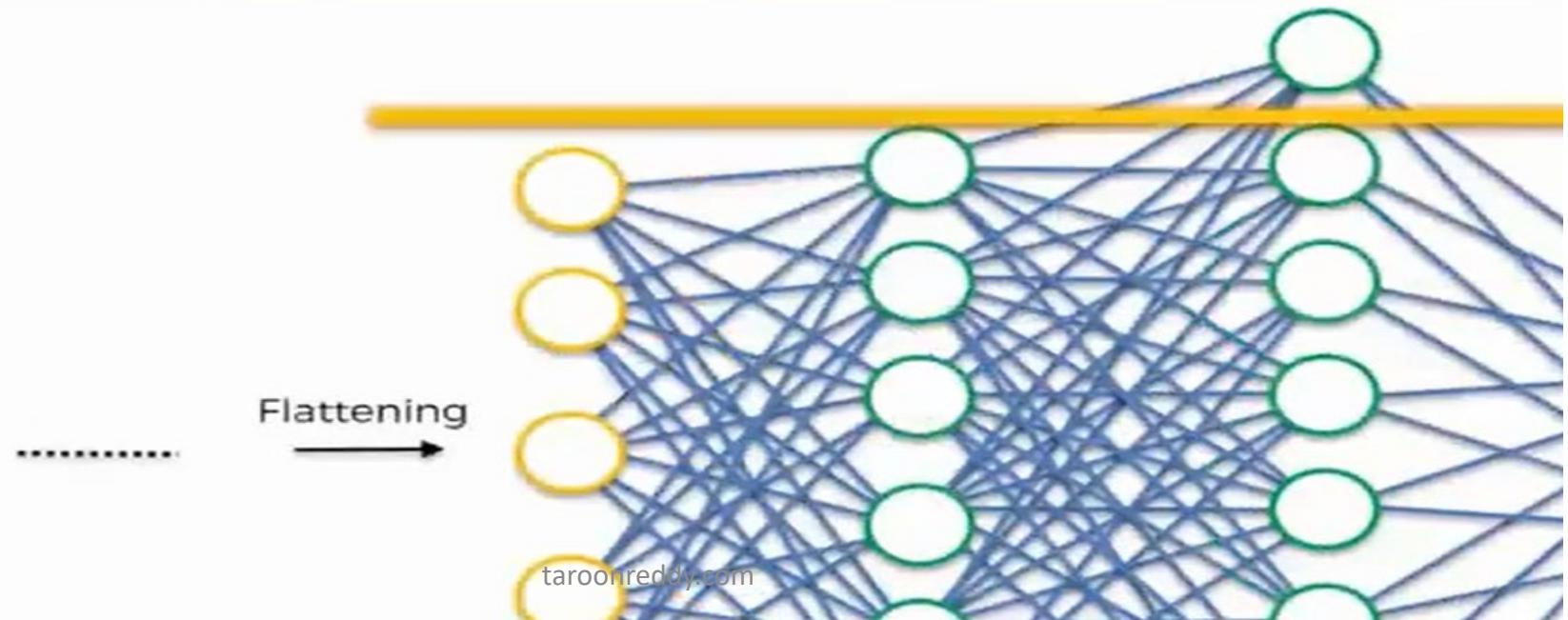
0	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	1	0	0	0	1	0
0	0	1	1	1	0	0
0	0	0	0	0	0	0



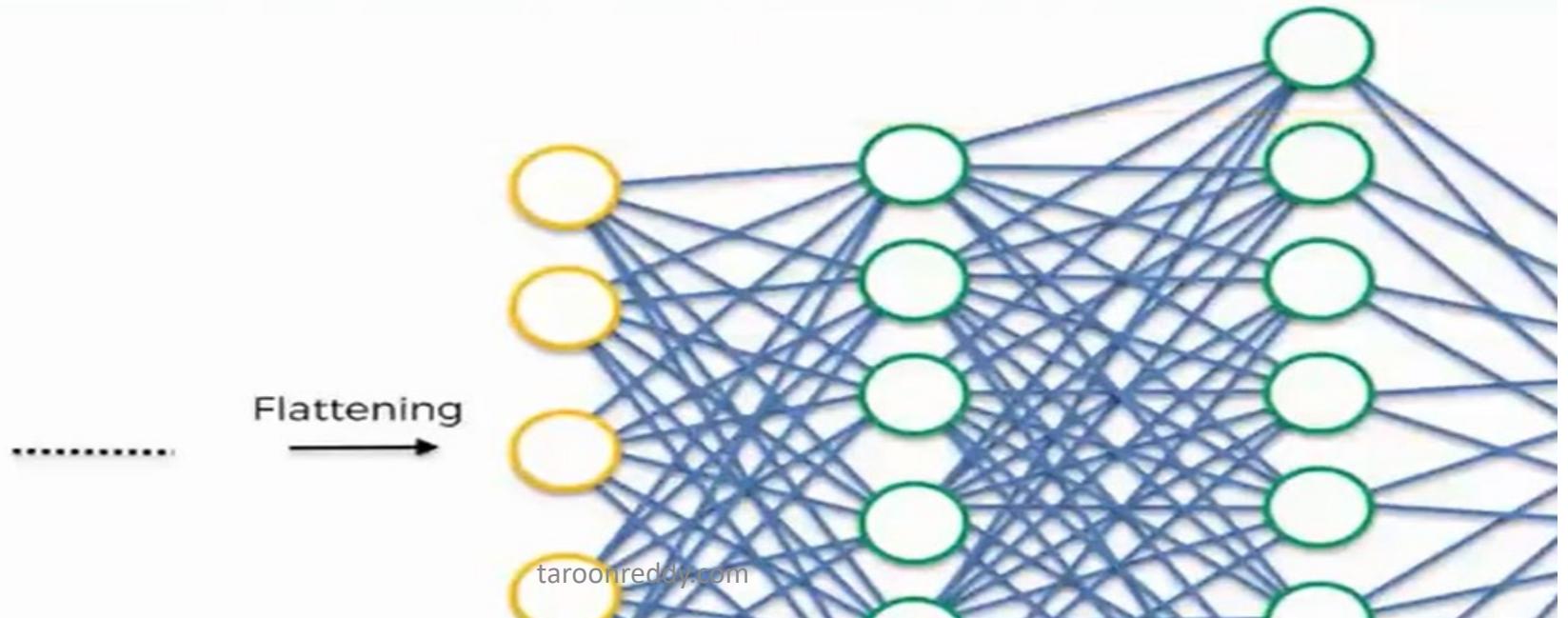
Step 4 - Full Connection



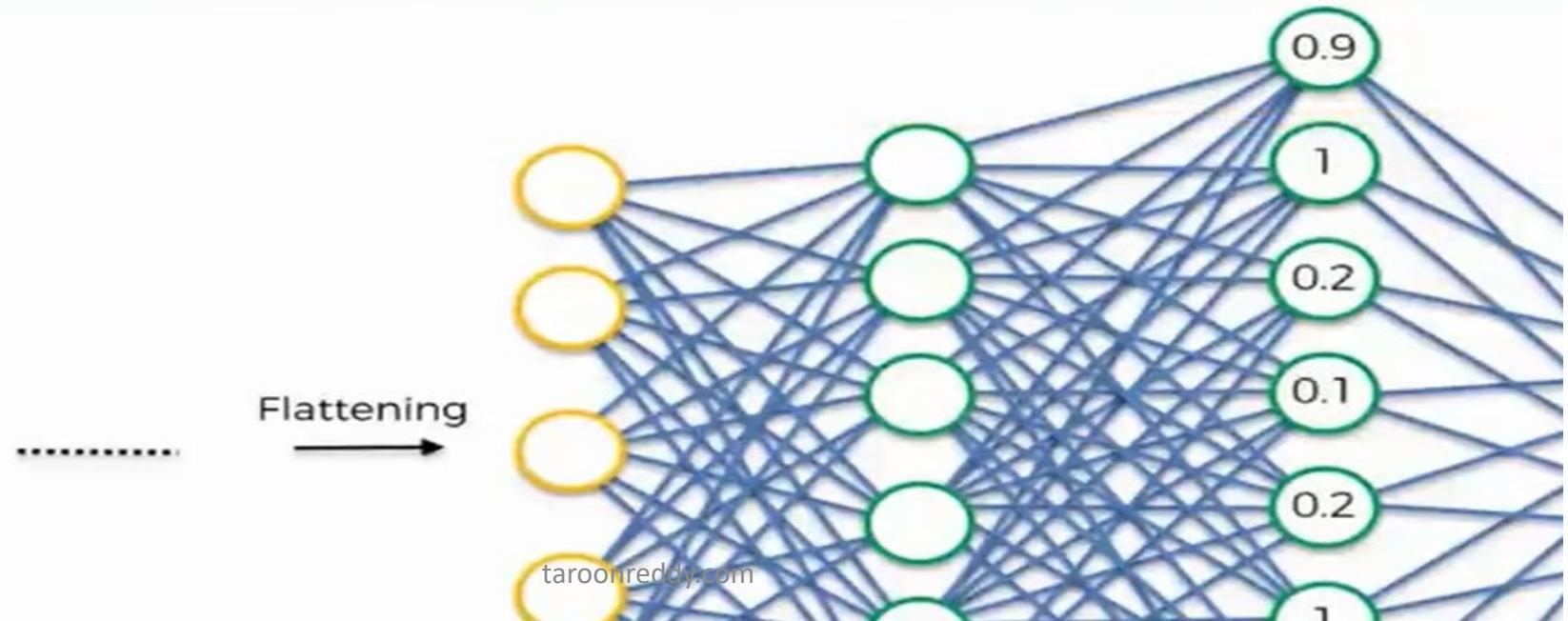
Step 4 - Full Connection



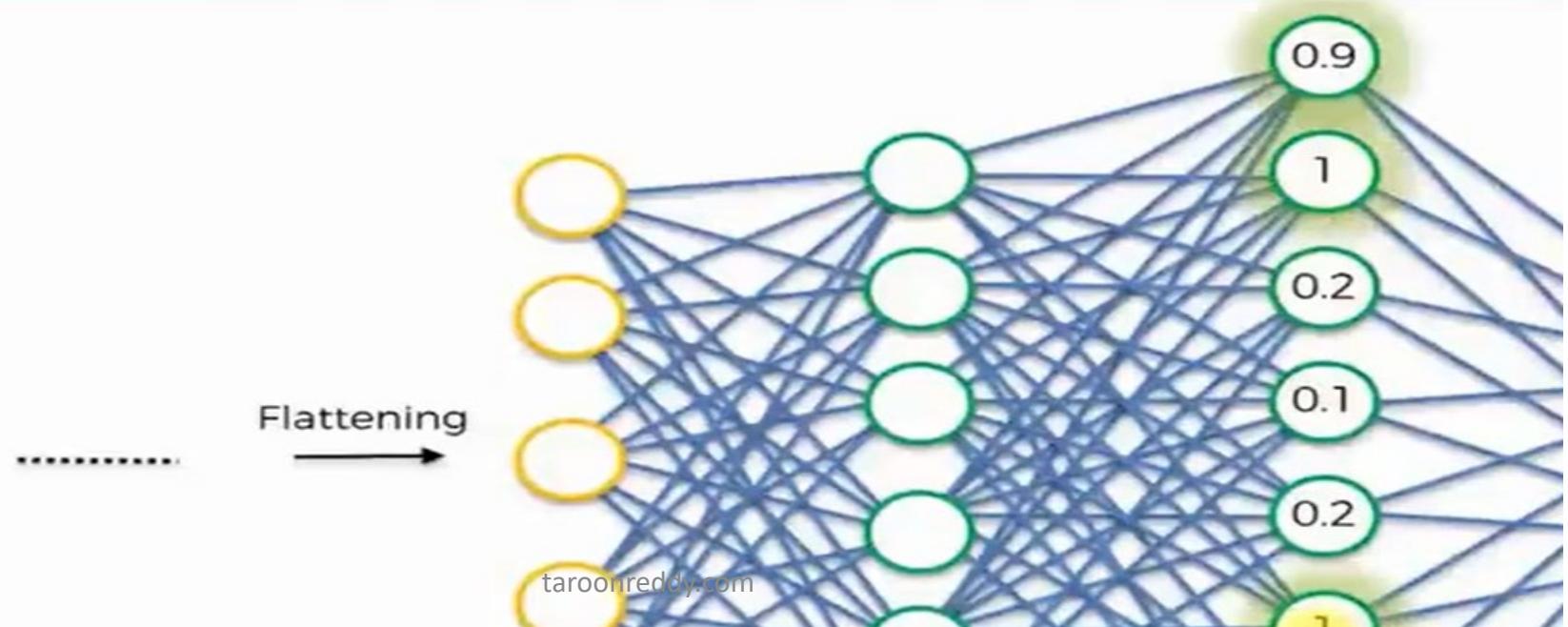
Step 4 - Full Connection



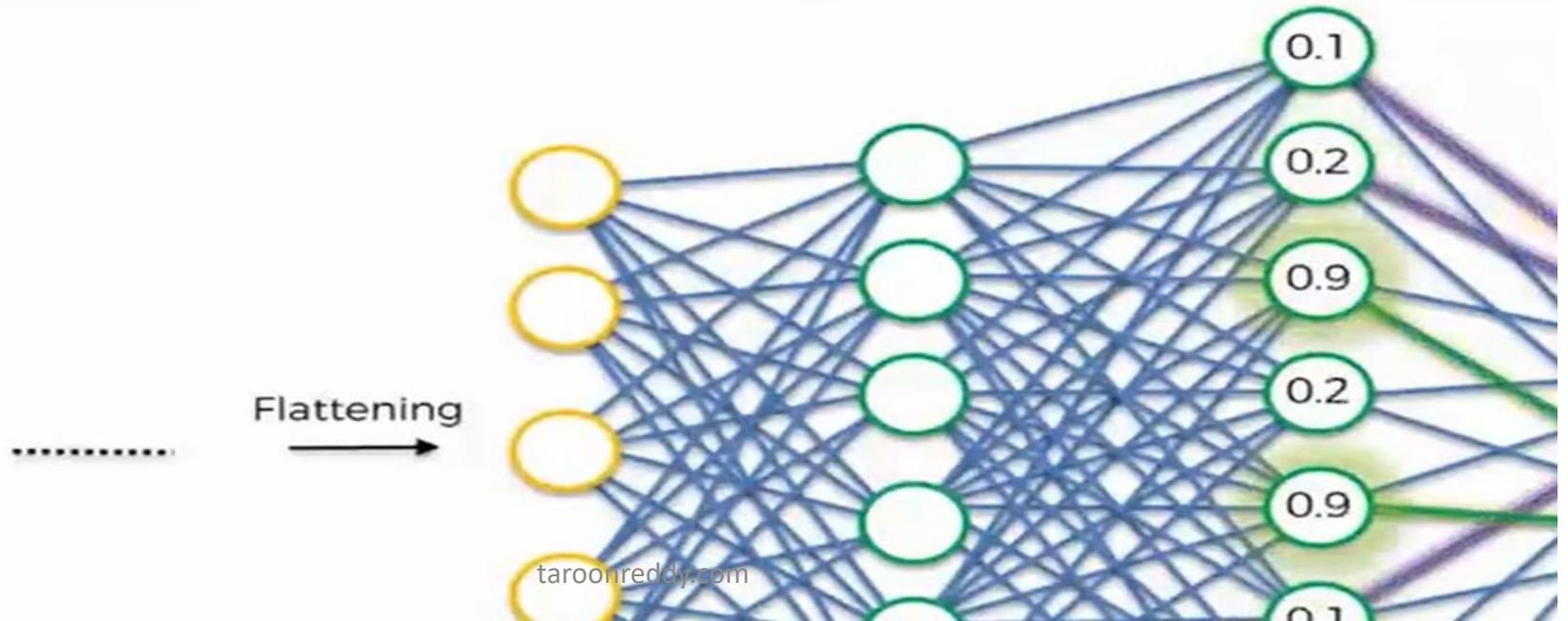
Step 4 - Full Connection



Step 4 - Full Connection



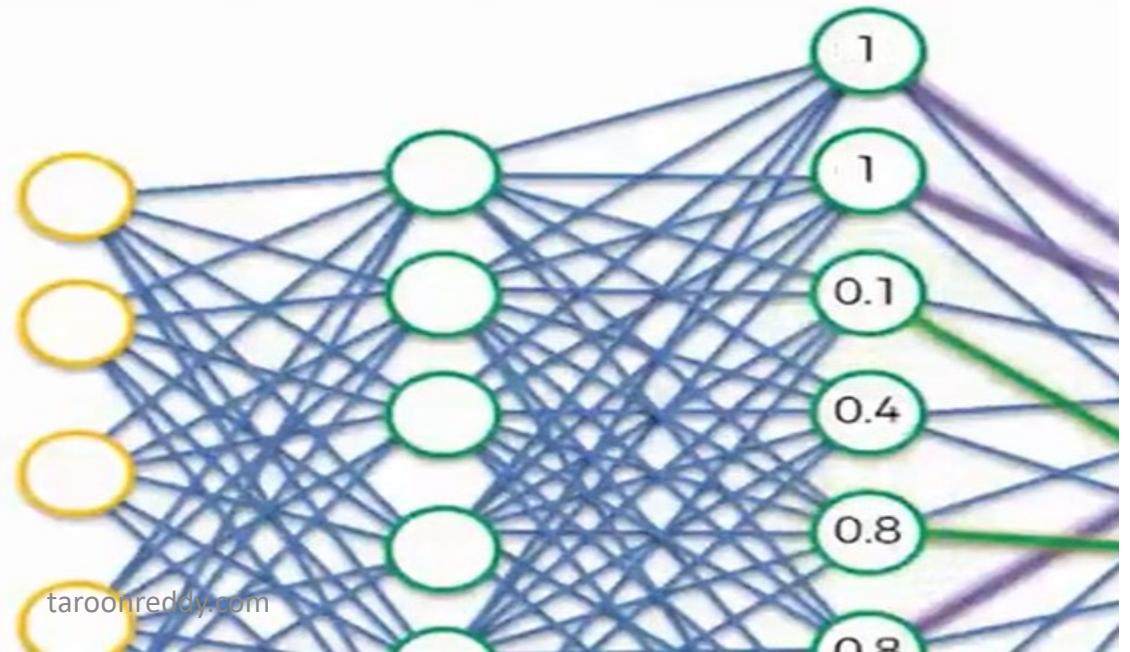
Step 4 - Full Connection



Step 4 - Full Connection



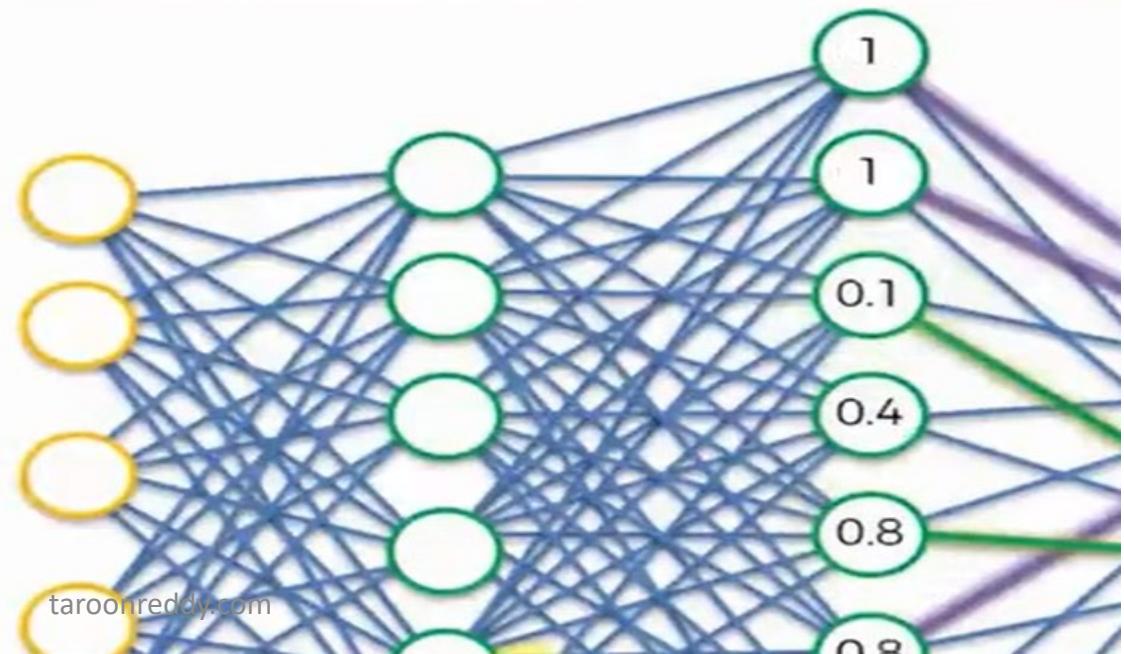
.....
Flattening
→



Step 4 - Full Connection



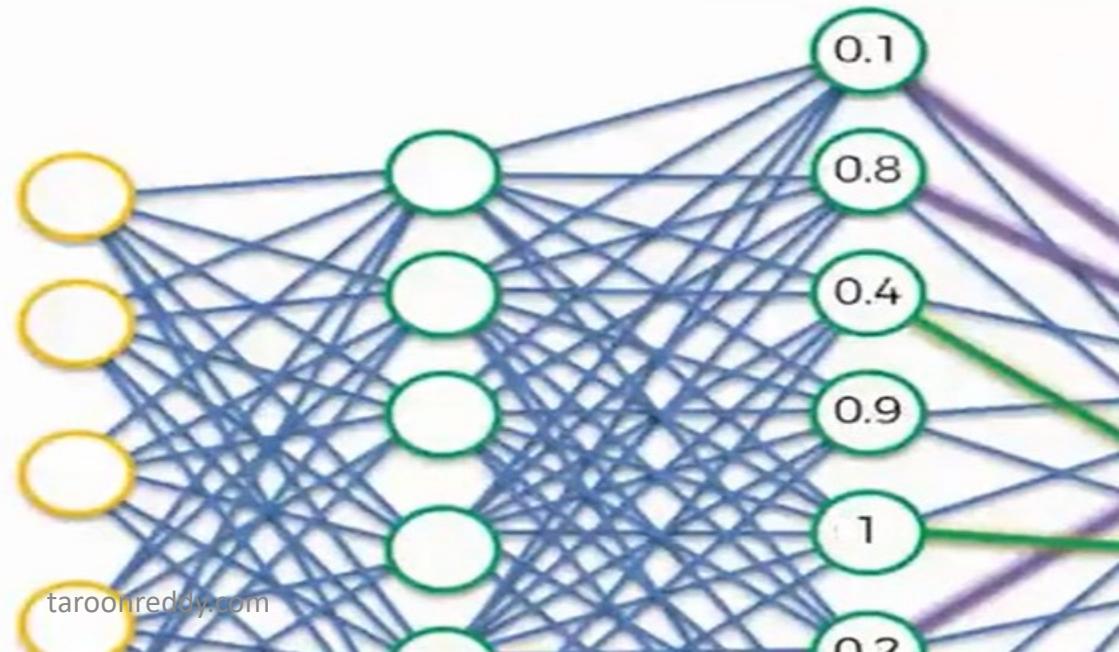
.....
Flattening
→



Step 4 - Full Connection



.....
Flattening
→



Step 4 - Full Connection



.....
Flattening
→

