Convolutional Neural Network

CNN or ConvNet

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Computer Vision Challenges

Image Classification

Is it Cat?
[0/1]

Object Detection

Neural Style Transfer

Content Image +
Style Image =
Generated Imgae

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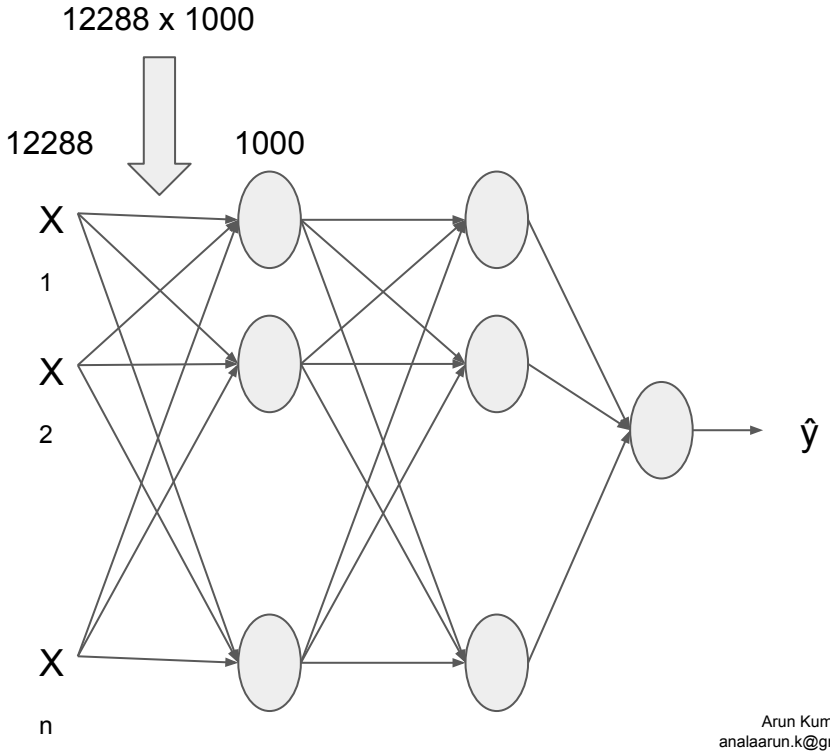
Fully Connected Network on Images

Image Classification

64 X 64 X 3
= 12288

Is it Cat?
[0/1]



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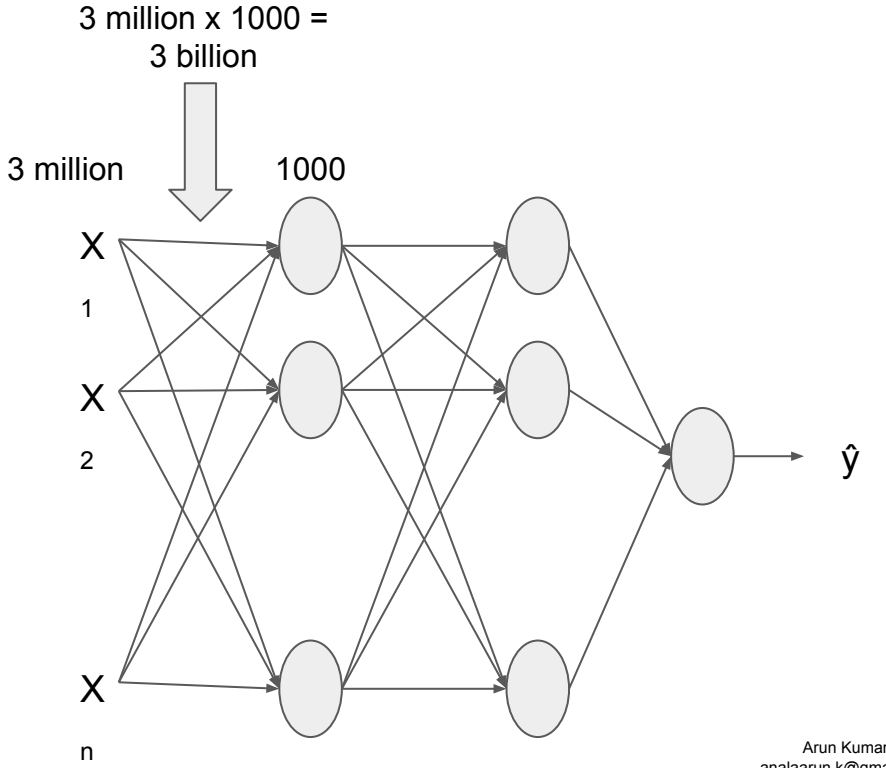
Fully Connected Network on Images

Image Classification

Is it Cat?
[0/1]

1000 X 1000 X 3
= 3 million



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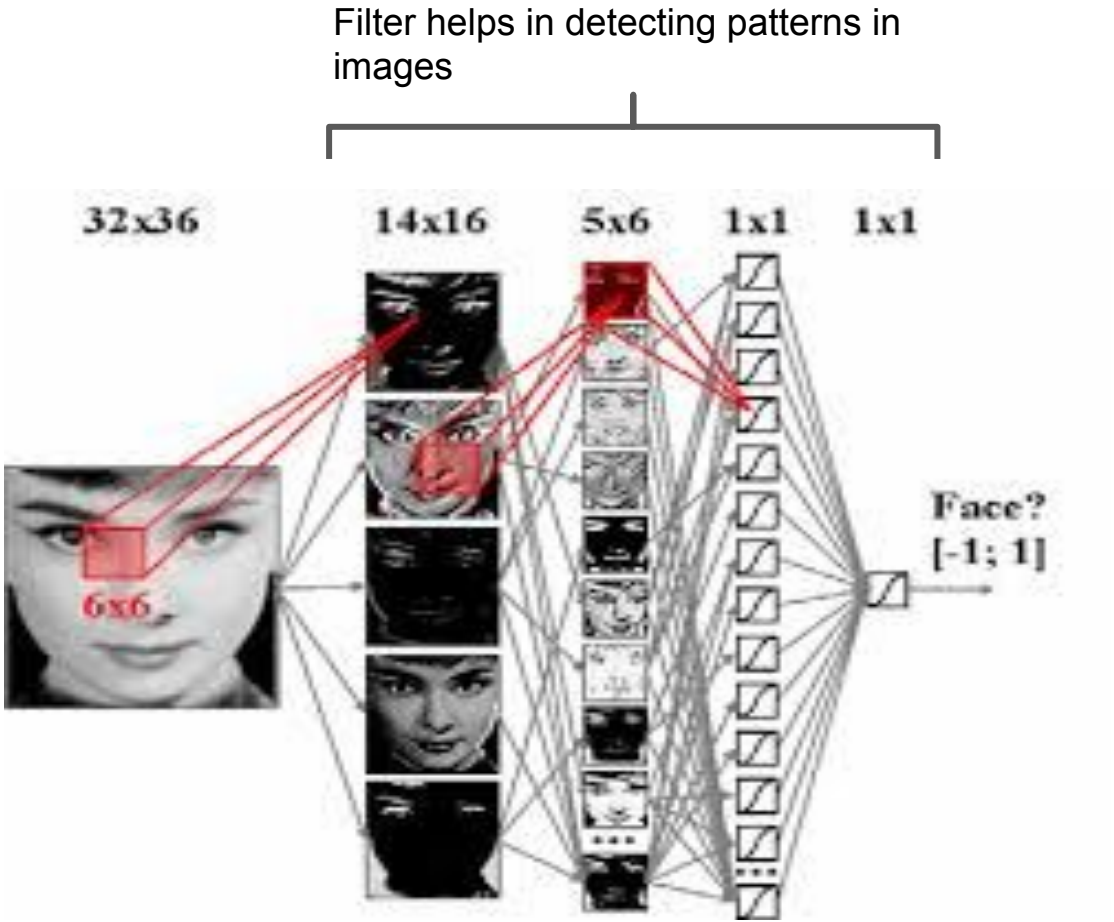
CNN - High Level



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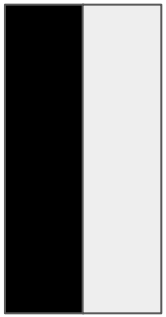
Filter - I know it

Detect Vertical Edge



10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0

*

1	0	-1
1	0	-1
1	0	-1

=

0			

[10 x 1 + 10 x 0 + 10 x (-1)] + [10 x 1 + 10 x 0 + 10 x (-1)] + [10 x 1 + 10 x 0 + 10 x (-1)] = 0

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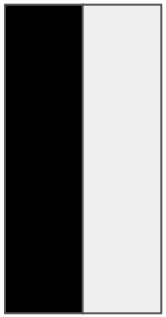
Filter - I know it

Detect Vertical Edge



10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0

*

1	0	-1
1	0	-1
1	0	-1

=

0	30		

[10 x 1 + 10 x 0 + 0 x (-1)] + [10 x 1 + 10 x 0 + 0 x (-1)] + [10 x 1 + 10 x 0 + 0 x (-1)] = 30

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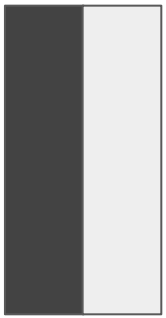
Filter - I know it

Detect Vertical Edge



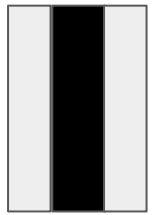
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0

*

1	0	-1
1	0	-1
1	0	-1

=

0	30	30	0
0	30	30	0
0	30	30	0
0	30	30	0



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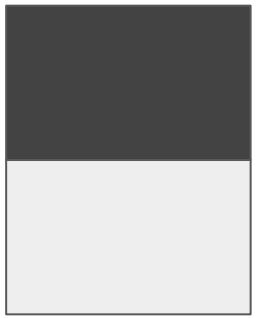
Filter - I know it

Detect Horizontal Edge



10	10	10	10	10	10
10	10	10	10	10	10
10	10	10	10	10	10
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

*

1	1	1
0	0	0
-1	-1	-1

=

0	0	0	0
30	30	30	30
30	30	30	30
0	0	0	0

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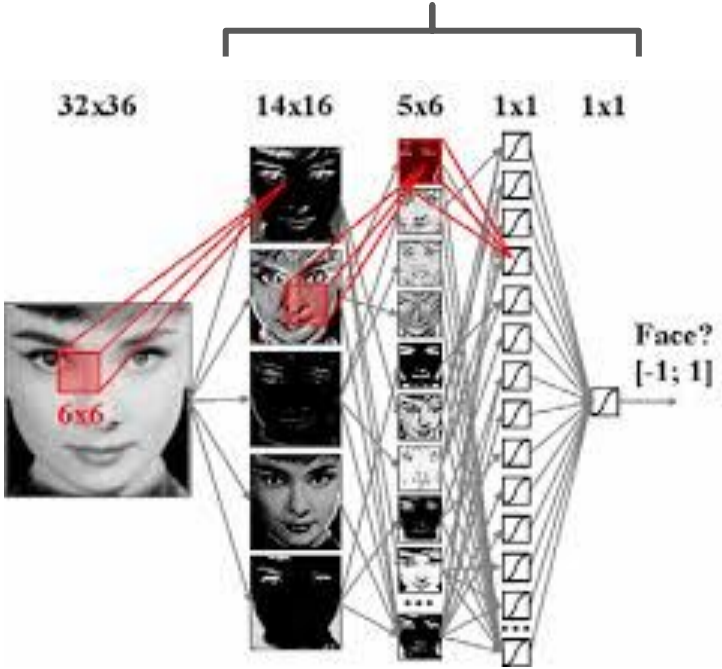
Filter - I don’t know, but let CNN learn it

Filter helps in detecting patterns in images



Detect Pattern in Images

112	76	144	55	43	23
164	43	43	34	25	13
12	13	30	67	44	14
6	45	24	77	87	89
64	64	60	67	65	67
34	35	54	60	44	56

*

w_{11}	w_{12}	w_{13}
w_{21}	w_{22}	w_{23}
w_{31}	w_{32}	w_{33}

?

=

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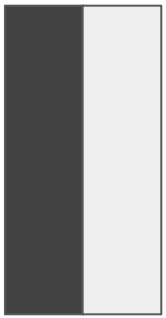
Valid Convolution



n x n
6 x 6

10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0

*

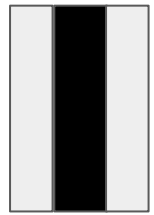
f x f
3 x 3

1	0	-1
1	0	-1
1	0	-1

=

(n - f + 1) x (n - f + 1)
4 x 4

0	30	30	0
0	30	30	0
0	30	30	0
0	30	30	0



Output size is less than the input size

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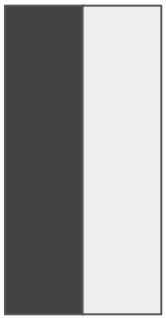
Same Convolution - Padding



p = 1

n x n
6 x 6

0	0	0	0	0	0	0	0
0	10	10	10	0	0	0	0
0	10	10	10	0	0	0	0
0	10	10	10	0	0	0	0
0	10	10	10	0	0	0	0
0	10	10	10	0	0	0	0
0	10	10	10	0	0	0	0
0	0	0	0	0	0	0	0

*

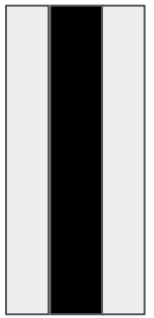
f x f
3 x 3

1	0	-1
1	0	-1
1	0	-1

=

(n + 2p - f + 1) x (n + 2p - f + 1)
6 x 6

a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}
a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}
a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}
a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}
a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}
a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	a_{66}



Pad so that the output size is same as the input size

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Strided Convolution

$$\left[\frac{(n+2p-f)}{s}+1\right] \times \left[\frac{(n+2p-f)}{s}+1\right]$$

s = 2

n x n
7 x 7

10	10	10	0	0	0	0
10	10	10	0	0	0	0
10	10	10	0	0	0	0
10	10	10	0	0	0	0
10	10	10	0	0	0	0
10	10	10	0	0	0	0
10	10	10	0	0	0	0

*

f x f
3 x 3

1	0	-1
1	0	-1
1	0	-1

=

3 x 3

a_{11}	a_{12}	a_{13}
a_{21}	a_{22}	a_{23}
a_{31}	a_{32}	a_{33}

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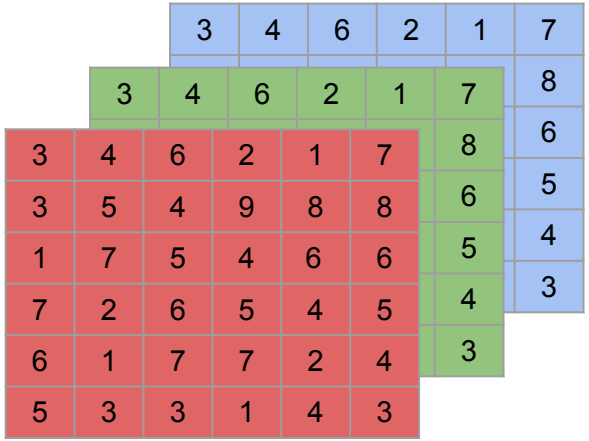
Image - RGB vs B&W

3	4	6	2	1	7
3	5	4	9	8	8
1	7	5	4	6	6
7	2	6	5	4	5
6	1	7	7	2	4
5	3	3	1	4	3

6 x 6 x 1



6 x 6 x 3

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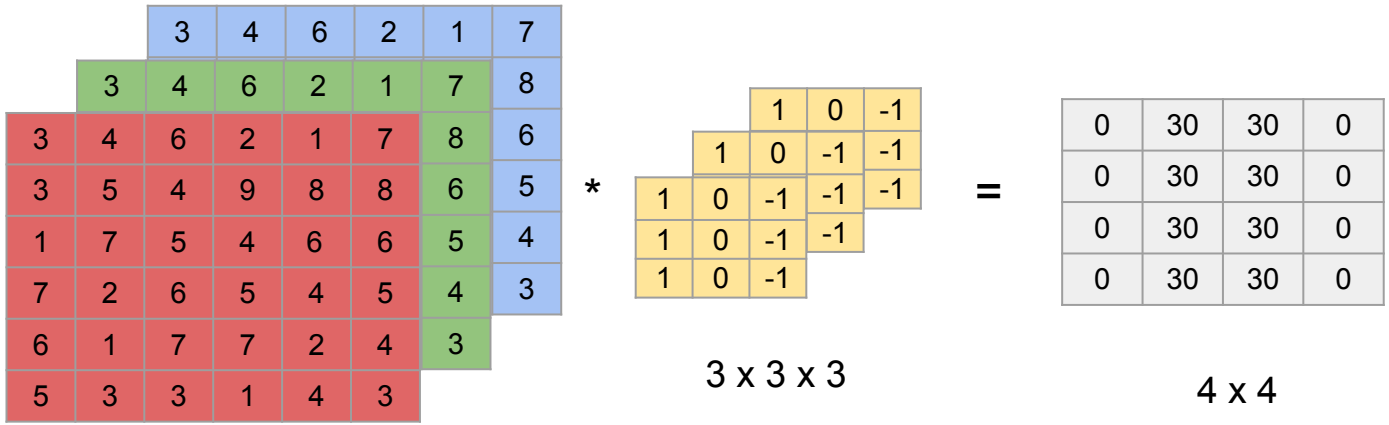
Filter for RGB



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Filter for RGB

1	0	-1	
1	0	-1	-1
1	0	-1	-1	-1
1	0	-1	-1	
1	0	-1		

0	30	30	0
0	30	30	0
0	30	30	0
0	30	30	0

						3	4	6	2	1	7
						3	5	4	9	8	8
						1	7	5	4	6	6
			3	4	6	2	1	7	5	4	5
			3	5	4	9	8	8	7	2	4
			1	7	5	4	6	6	1	4	3
3	4	6	2	1	7	5	4	5			
3	5	4	9	8	8	7	2	4			
1	7	5	4	6	6	1	4	3			
7	2	6	5	4	5						
6	1	7	7	2	4						
5	3	3	1	4	3						

0	30	30	0
0	30	30	0
0	30	30	0
0	30	30	0

						3	4	6	2	1	7
						3	5	4	9	8	8
						1	7	5	4	6	6
			3	4	6	2	1	7	5	4	5
			3	5	4	9	8	8	7	2	4
			1	7	5	4	6	6	1	4	3
3	4	6	2	1	7	5	4	5			
3	5	4	9	8	8	7	2	4			
1	7	5	4	6	6	1	4	3			
7	2	6	5	4	5						
6	1	7	7	2	4						
5	3	3	1	4	3						

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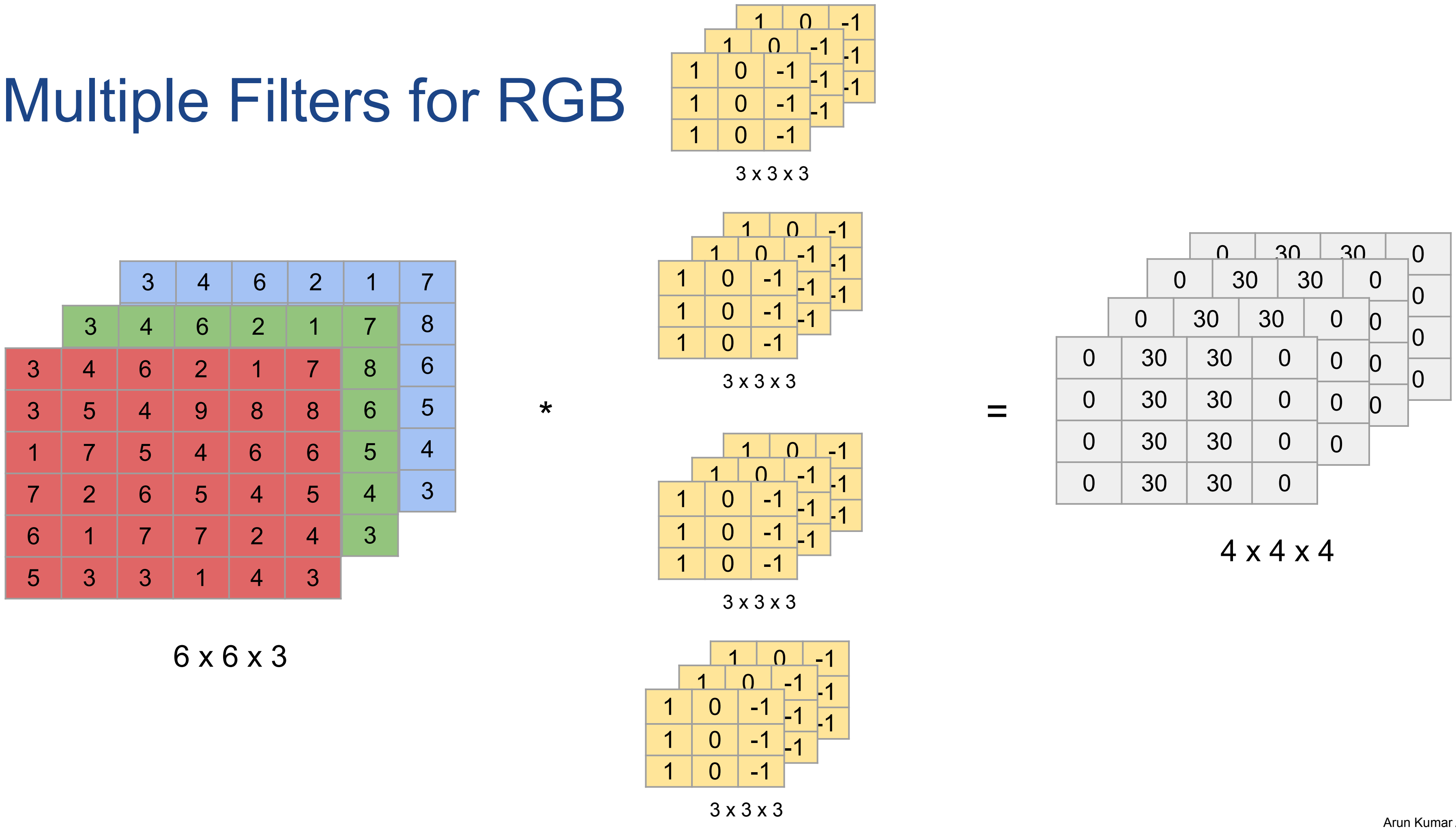
Multiple Filters for RGB



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Question

In a layer, if you have 20 filters of dimension 3x3x3 each, then how many parameter does that layer have?

For 1 filter
3 x 3 x 3 = 27 weights
1 = bias
So 28 parameter for 1 layer

For 20 filters in a layer
28 x 20 = **560 parameters**

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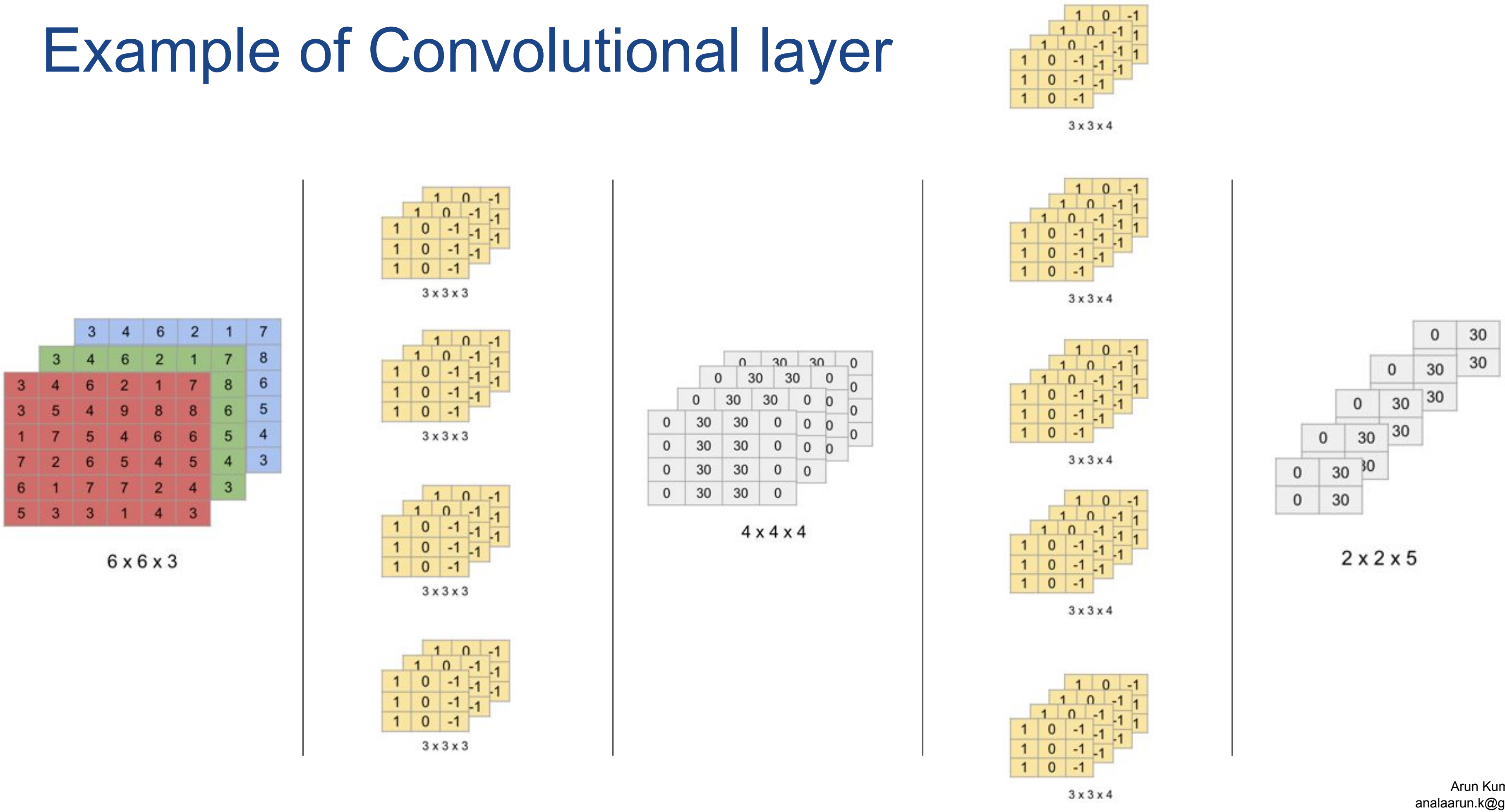
Example of Convolutional layer



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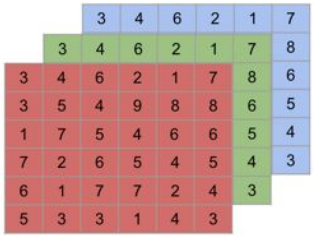
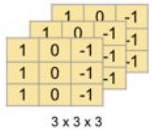
Input : (L-1)



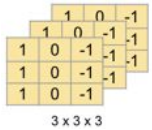
6 x 6 x 3

$n^{L-2}_H \times n^{L-2}_W \times n^{L-2}_C$

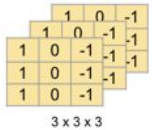
Layer : (L-1)



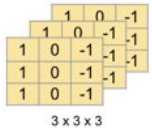
3 x 3 x 3



3 x 3 x 3



3 x 3 x 3



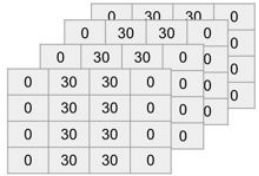
3 x 3 x 3

$f^{L-1}_H \times f^{L-1}_W \times n^{L-2}_C \times n^{L-1}_C$

s^{L-1} p^{L-1}

Output : (L-1)

Input : (L)



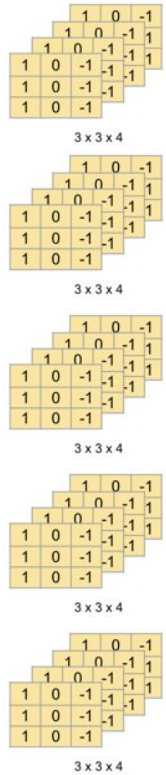
4 x 4 x 4

$n^{L-1}_H \times n^{L-1}_W \times n^{L-1}_C$

$n^{L-1}_H = n^{L-2}_H - f^{L-1}_H + 1$

$n^{L-1}_H = (n^{L-2}_H + 2p^{L-1} - f^{L-1}_H)/s^{L-1} + 1$

Layer : (L)



3 x 3 x 4

3 x 3 x 4

3 x 3 x 4

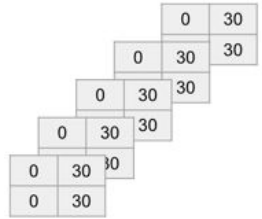
3 x 3 x 4

3 x 3 x 4

$f^L_H \times f^L_W \times n^{L-1}_C \times n^L_C$

s^L p^L

Output : (L)



2 x 2 x 5

$n^L_H \times n^L_W \times n^L_C$

$n^L_H = n^{L-1}_H - f^L_H + 1$

$n^L_H = (n^{L-1}_H + 2p^L - f^L_H)/s^L + 1$

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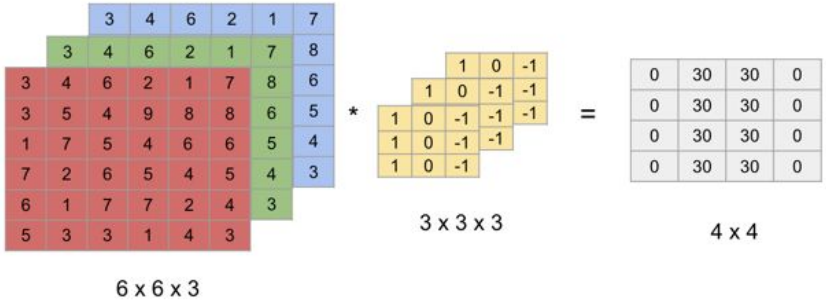
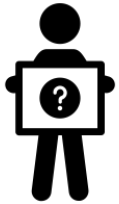
Types of layer in Convolutional Network

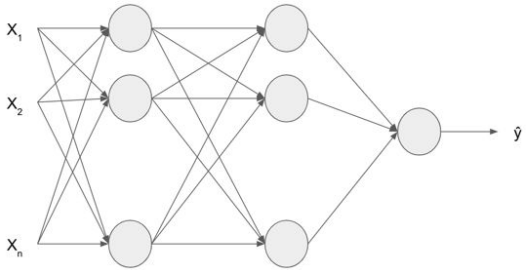
Convolution



Pool



Fully Connected



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Max Pooling Layer

3	4	6	2	1	7
3	5	4	9	8	8
1	7	5	4	6	6
7	2	6	5	4	5
6	1	7	7	2	4
5	3	3	1	4	3

6 x 6 x 1

f = 3

7	9
7	7

2 x 2 x 1

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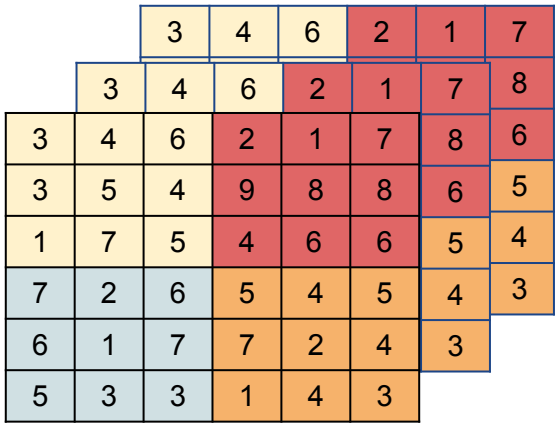
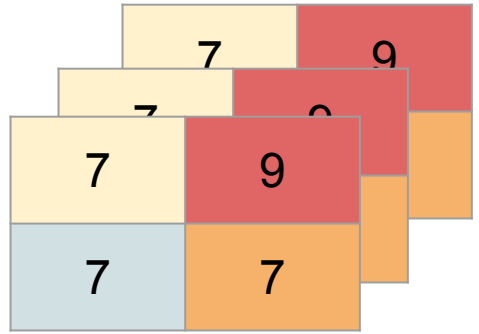
Max Pooling Layer



6 x 6 x 3

f = 3



2 x 2 x 3

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Average Pooling Layer

3	4	6	2	1	7
3	5	4	9	8	8
1	7	5	4	6	6
7	2	6	5	4	5
6	1	7	7	2	4
5	3	3	1	4	3

6 x 6 x 1

f = 3

4.22	5.66
4.44	3.89

2 x 2 x 1

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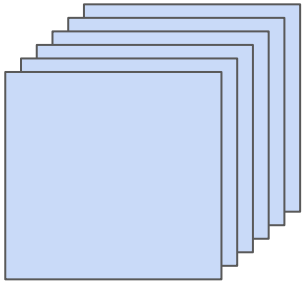
CONV 1

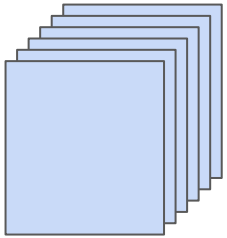
f=5
s=1



POOL 1

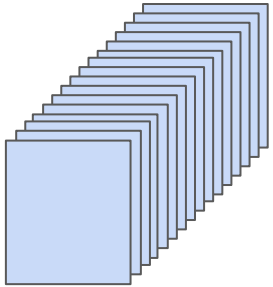
maxpool

f=2
s=2



CONV 2

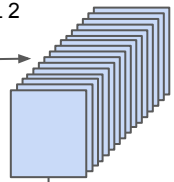
f=5
s=1



POOL 2

maxpool

f=2
s=2



32 x 32 x 3

28 x 28 x 6

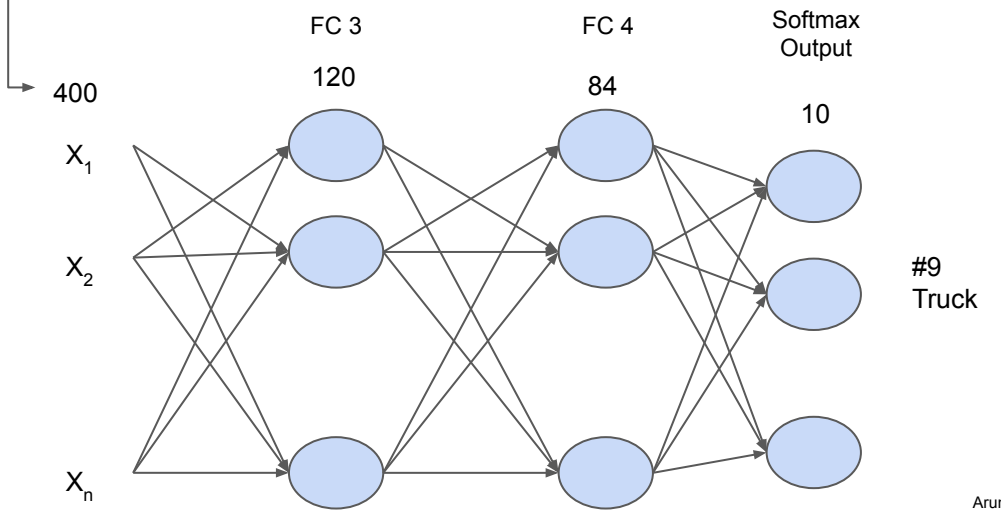
14 x 14 x 6

10 x 10 x 16

5 x 5 x 16 = 400

CNN Example

Image Classification using CIFAR10 dataset



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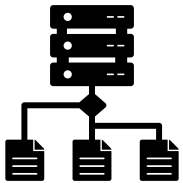
Exercise Image Classification

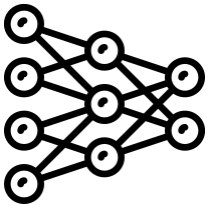
Load Dataset

Analyze Dataset

Prepare Dataset



Define Model



Train & Evaluate Model

Summarize Results

Predict New Image

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Model Summary

Layer (type)	Input layer dimensions	Output Shape	Params #	Comments
Input		(32, 32, 3)		
CONV 1	5 x 5 x 3 x 6	(28, 28, 6)	456	(5 x 5 x 3 + 1) x 6
POOL 1	2 x 2	(14, 14, 6)	0	
CONV 2	5 x 5 x 6 x 16	(10, 10, 16)	2416	(5 x 5 x 6 + 1) x 16
POOL 2	2 x 2	(5, 5, 16)	0	
FC 1	5 x 5 x 16 = 400	120	48120	(400 + 1) x 120
FC 2	120	84	10164	(120 + 1) x 84
Softmax Output	84	10	850	(84 + 1) x 10
Total			62,006	

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CNN vs Fully Connected Network on Images

Image Classification

64 X 64 X 3
= 12288

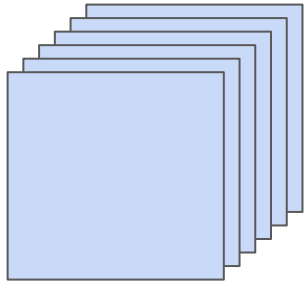
Is it Cat?
[0/1]

64 X 64 X 3 =
12288

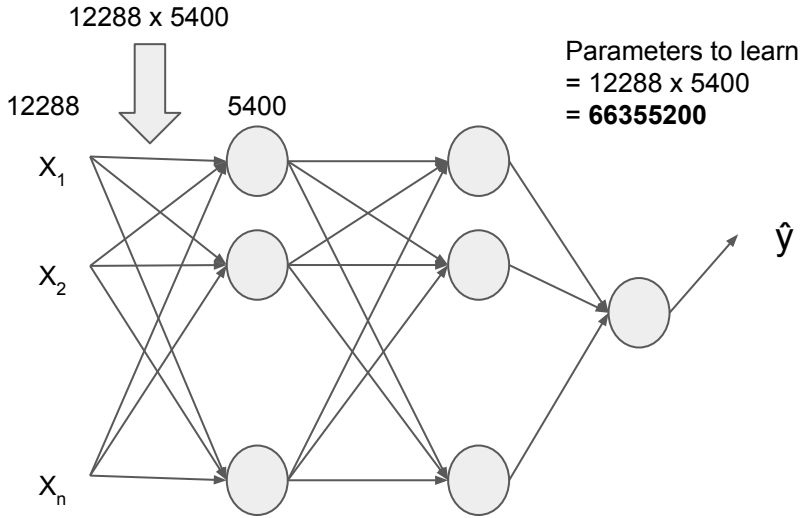
Filters# 6
5 x 5 x 3

Strides = 2

Parameters to learn
= (5 x 5 x 3 + 1) x 6
= **456**



30 X 30 X 6 =
5400



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