Convolutional Neural Network - 1

CNN or ConvNet

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Computer Vision Challenges

Image Classification

Is it Cat?
[0/1]

Object Detection

Neural Style Transfer

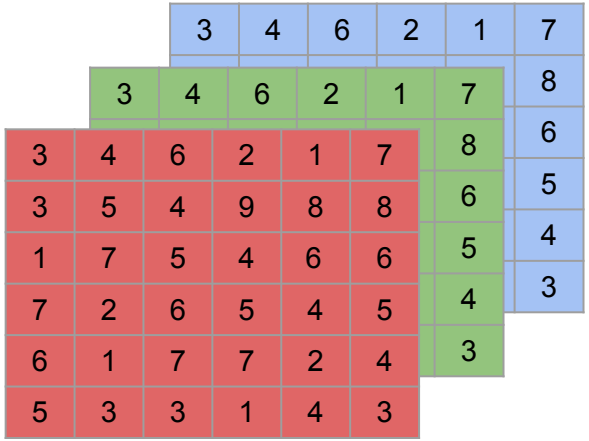
Content Image +
Style Image =
Generated Imgae

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

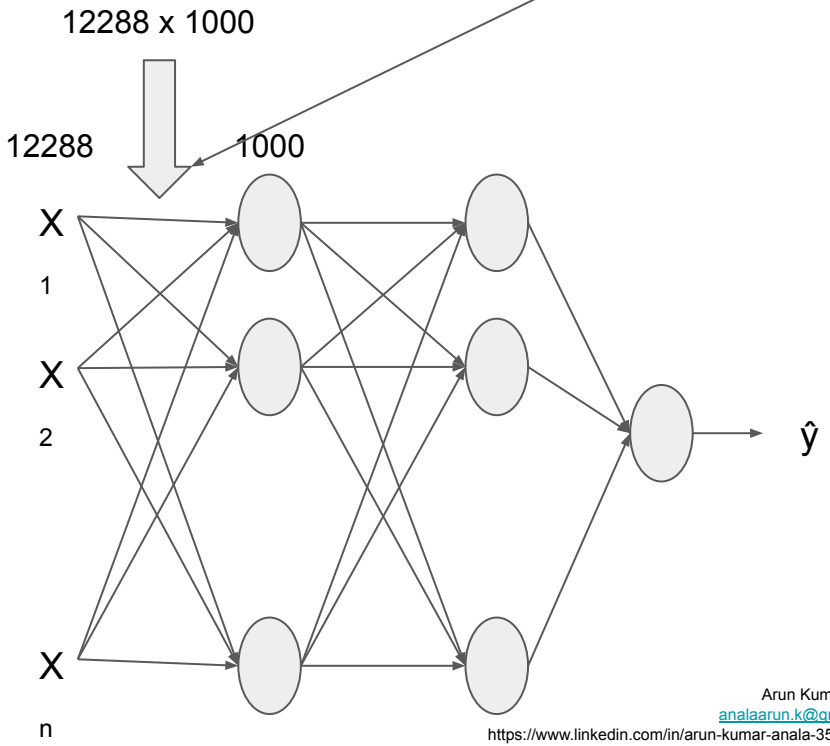
Fully Connected Network on Images

Since this layer has too much capacity, this may lead to overfitting.

Image Classification

64 X 64 X 3
= 12288

Is it Cat?
[0/1]



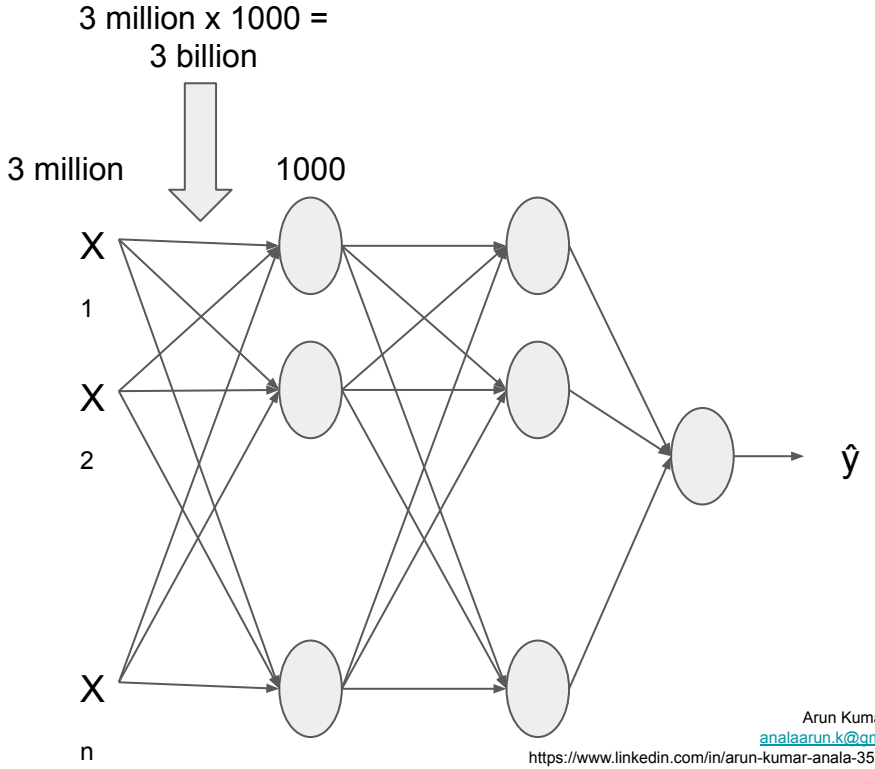
Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Fully Connected Network on Images

Image Classification

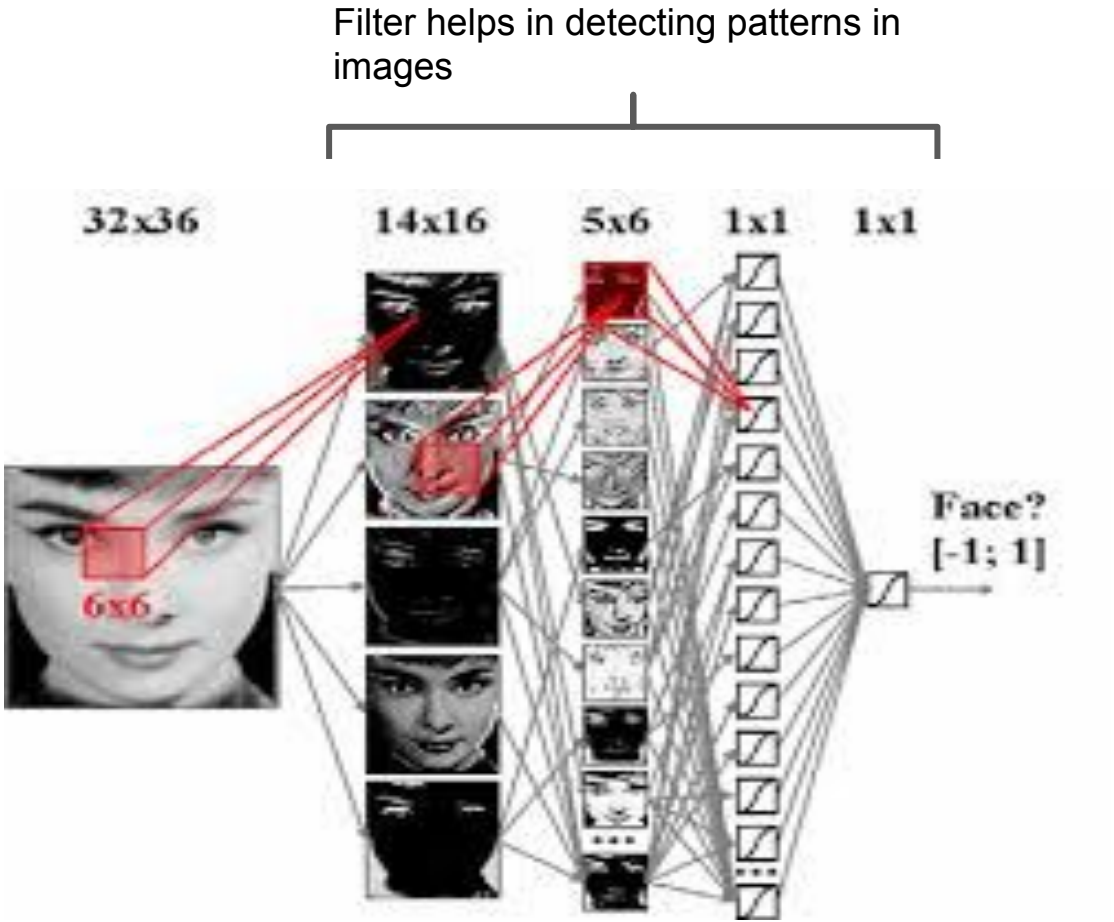
Is it Cat?
[0/1]

1000 X 1000 X 3
= 3 million



Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

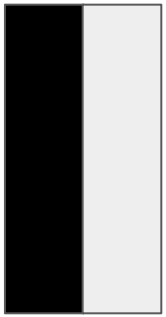
CNN - High Level



Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

=

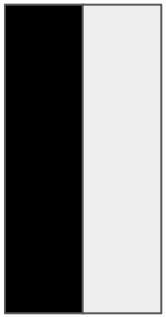
0			

[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

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

=

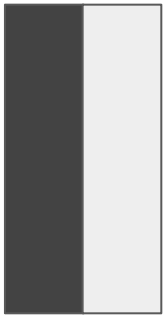
0	30		

[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

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Filter - I know it

Detect Vertical Edge



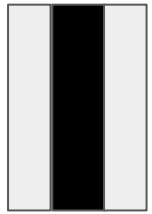
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0
10	10	10	0	0	0

*

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

=

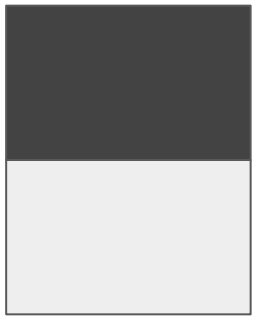
0	30	30	0
0	30	30	0
0	30	30	0
0	30	30	0



Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

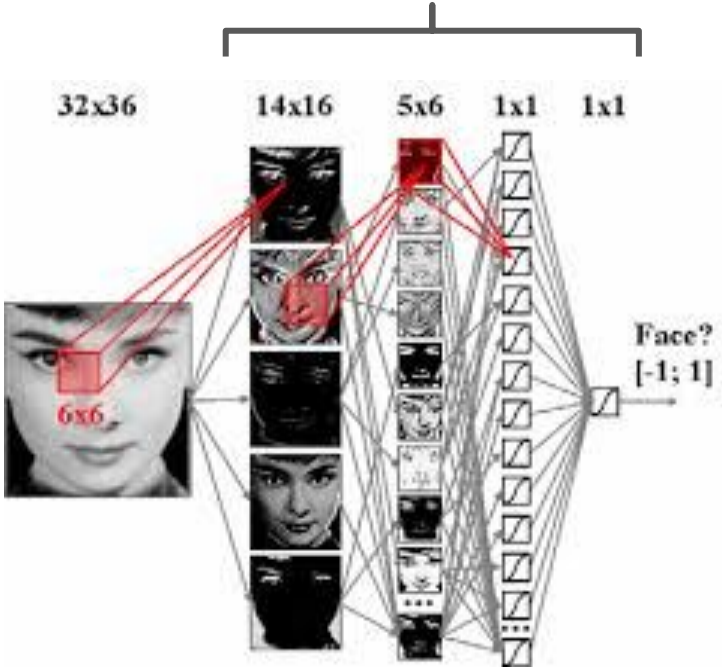
=

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

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

*

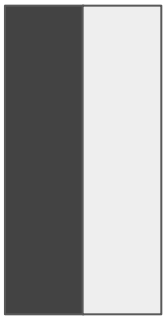
w_{11}	w_{12}	w_{13}
w_{21}	w_{22}	w_{23}
w_{31}	w_{32}	w_{33}

?

=

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

*

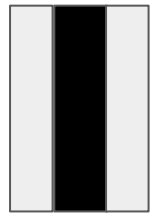
f x f
3 x 3

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

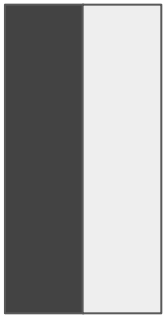
Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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



*

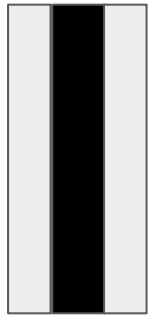
f x f
3 x 3

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

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

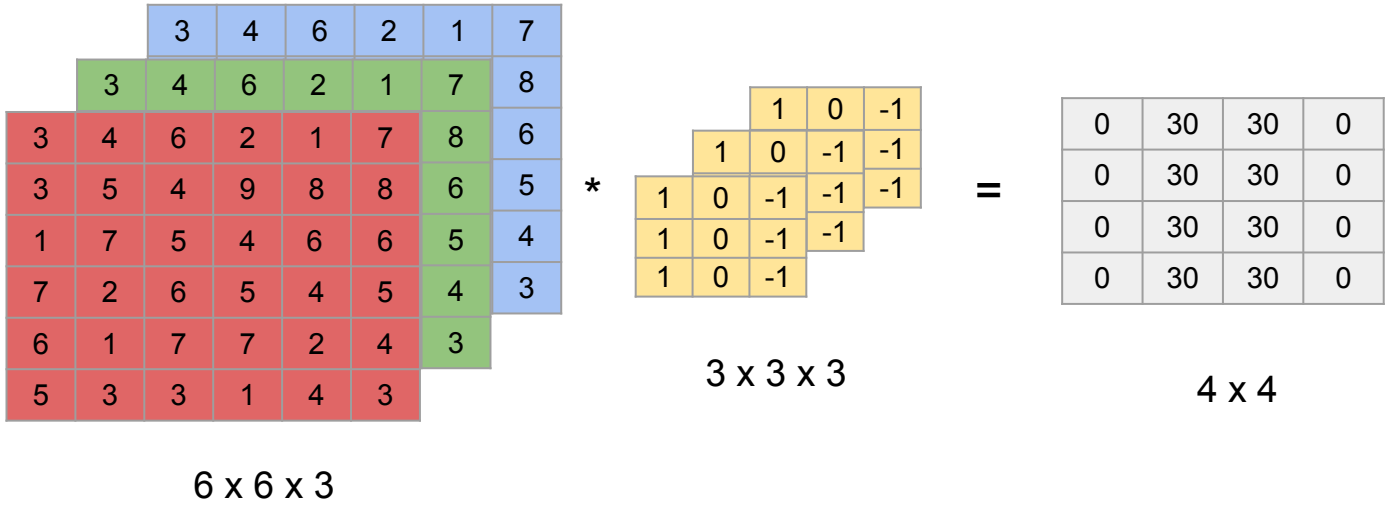
=

3 x 3

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

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Filter for RGB



Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Filter for RGB

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

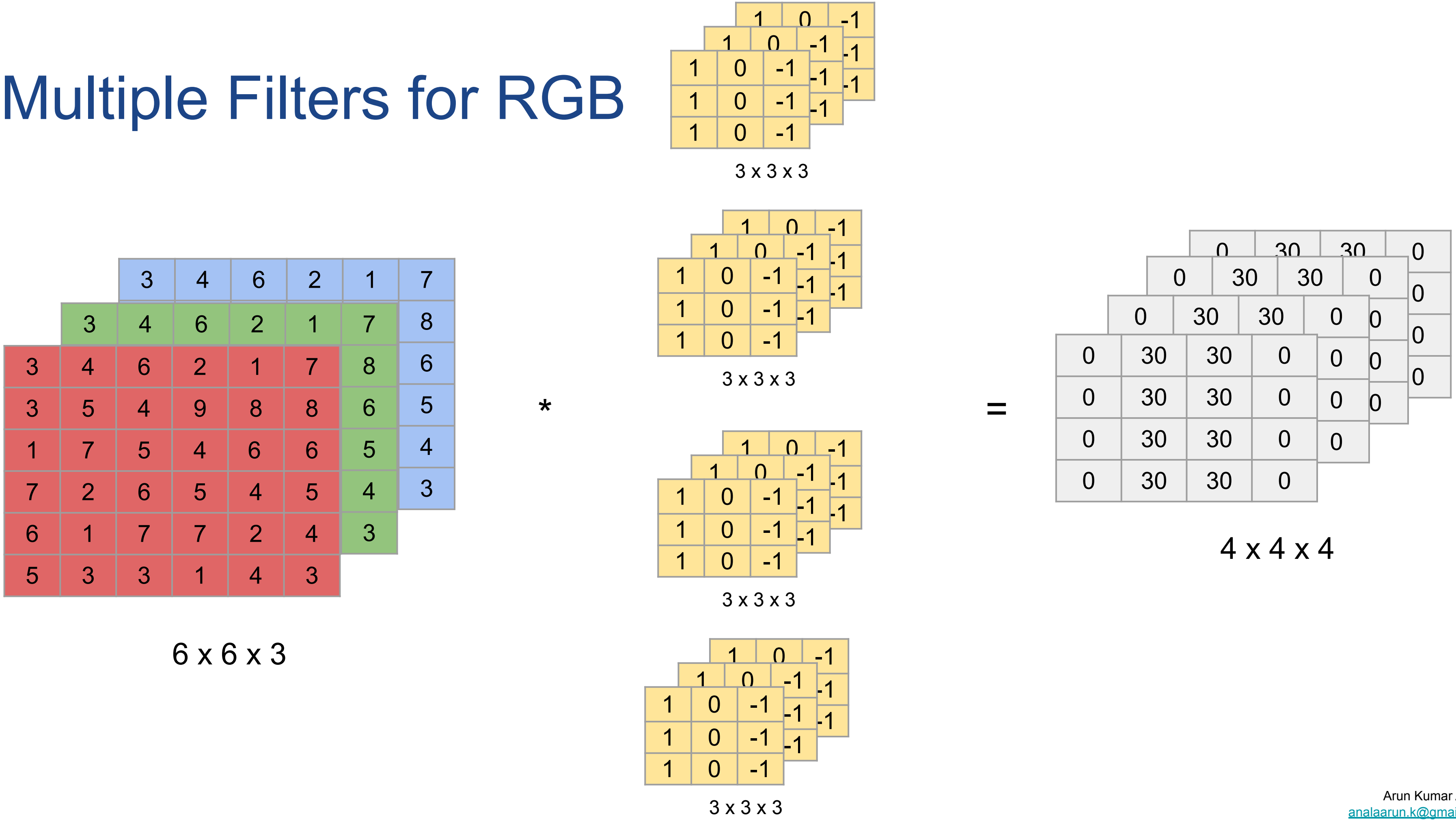
				3	4	6	2	1	7		
				3	5	4	9	8	8		
				1	7	5	4	6	6		
			3	4	6	2	1	7	5	4	5
			3	5	4	9	8	8	7	2	4
			1	7	5	4	6	6	1	4	3
3	4	6	2	1	7	5	4	5			
3	5	4	9	8	8	7	2	4			
1	7	5	4	6	6	1	4	3			
7	2	6	5	4	5						
6	1	7	7	2	4						
5	3	3	1	4	3						

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						

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Multiple Filters for RGB



Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Question

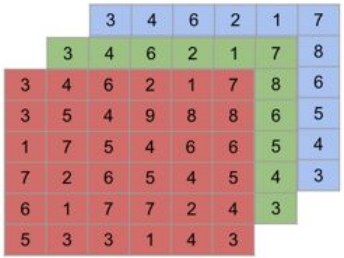
In a layer, if you have 20 filters of dimension 3x3x3 each, then how many parameter does that layer have?

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

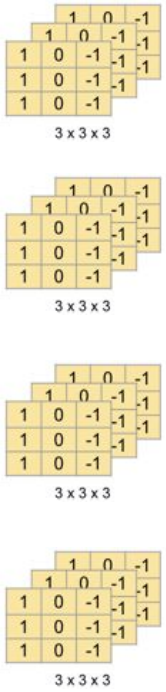
For 20 filters in a layer
28 x 20 = **560 parameters**

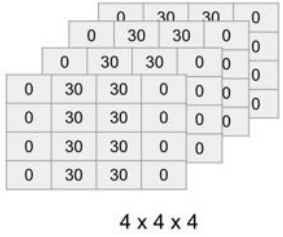
Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Example of Convolutional layer

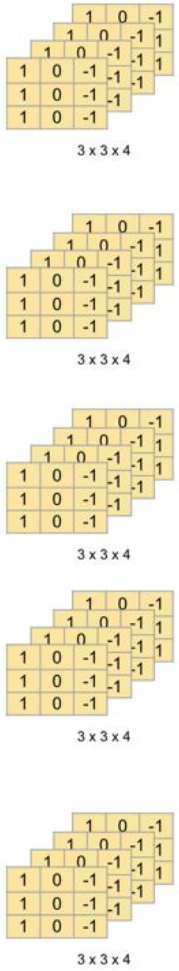


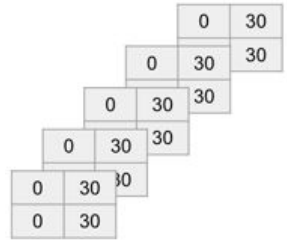
108





64



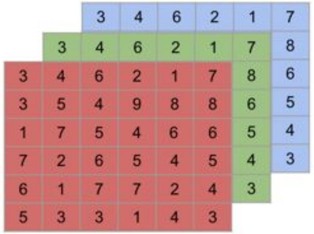


20

Length Decreases
Width Decreases
Depth Increases

Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

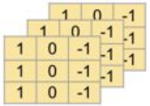
Input : (L-1)



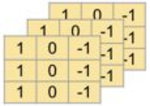
6 x 6 x 3

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

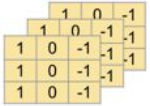
Layer : (L-1)



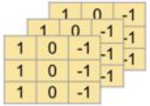
3 x 3 x 3



3 x 3 x 3



3 x 3 x 3



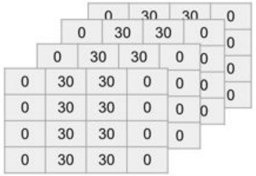
3 x 3 x 3

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

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

Output : (L-1)

Input : (L)



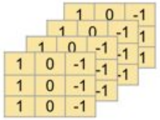
4 x 4 x 4

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

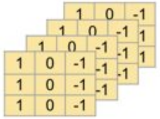
$n^{L-1}_H = n^{L-2}_H - f^{L-1}_H + 1$

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

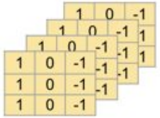
Layer : (L)



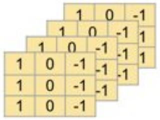
3 x 3 x 4



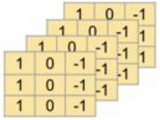
3 x 3 x 4



3 x 3 x 4



3 x 3 x 4

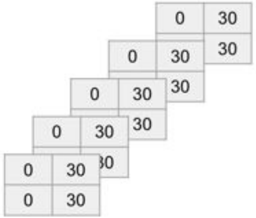


3 x 3 x 4

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

s^{L} p^{L}

Output : (L)



2 x 2 x 5

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

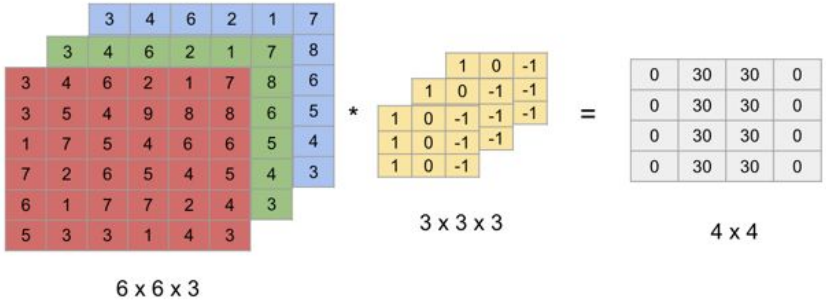
$n^{L}_H = n^{L-1}_H - f^{L}_H + 1$

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

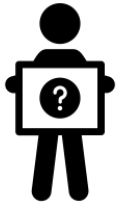
Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Types of layer in Convolutional Network

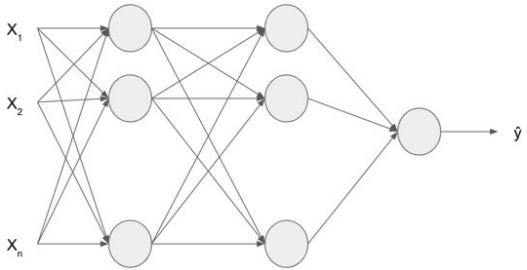
Convolution



Pool



Fully Connected



Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

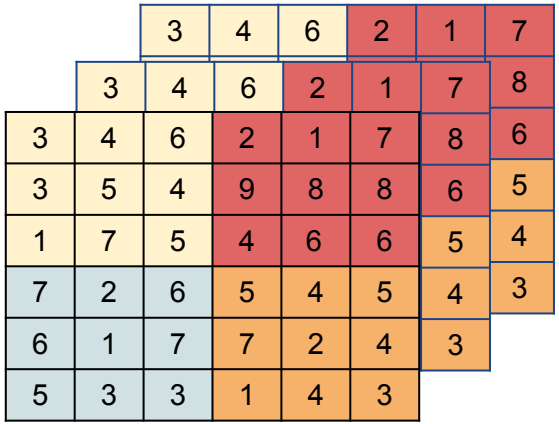
f = 3

7	9
7	7

2 x 2 x 1

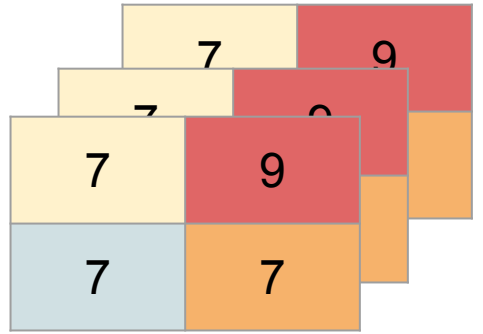
Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Max Pooling Layer



6 x 6 x 3

f = 3



2 x 2 x 3

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

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

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CONV 1

f=5
f # 6
s=1

POOL 1

maxpool

f=2

CONV 2

f=5
f # 16
s=1

POOL 2

maxpool

f=2

32 x 32 x 3
3072

5 x 5 x 3 x 6
$n^L = (n^{L-1} + 2p^L - f^L)/s^L + 1$
=(32 + 0 - 5)/1 + 1 = 28

28 x 28 x 6
4704

$n^L = 28/2 = 14$

14 x 14 x 6
1176

5 x 5 x 6 x 16
$n^L = (n^{L-1} + 2p^L - f^L)/s^L + 1$
=(14 + 0 - 5)/1 + 1 = 10

10 x 10 x 16
1600

$n^L = 10/2 = 5$

5 x 5 x 16
400

CNN Example

Image Classification using CIFAR10 dataset

FC 3

FC 4

Softmax Output

400

120

84

10

X_1

X_2

X_n

#9
Truck

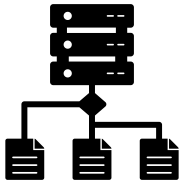
Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Exercise Image Classification

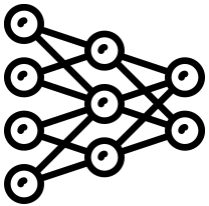
Load Dataset

Analyze Dataset

Prepare Dataset



Define Model



Train & Evaluate Model

Summarize Results

Predict New Image

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

Model Summary

Layer (type)	Filter/Kernel for CNN Neurons for FCN	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	

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN vs Fully Connected Network on Images

Image Classification

64 X 64 X 3
= 12288

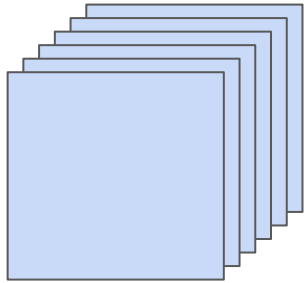
Is it Cat?
[0/1]

64 X 64 X 3 =
12288

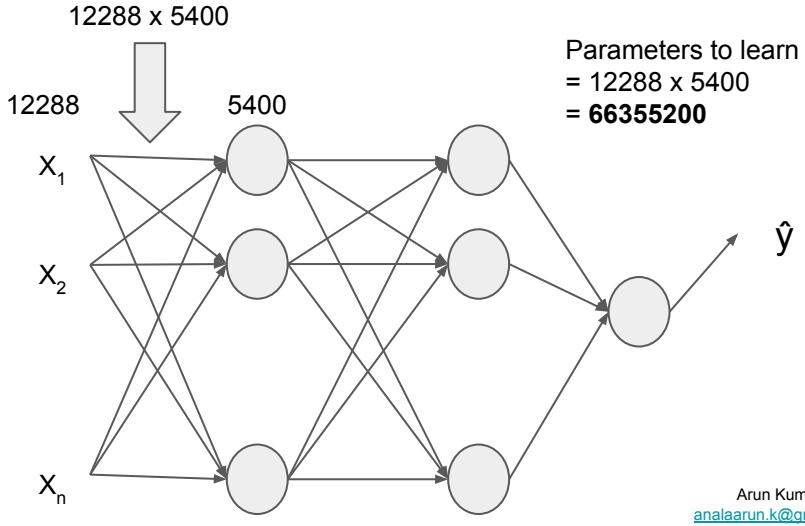
Filters# 6
5 x 5 x 3

Strides = 2

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



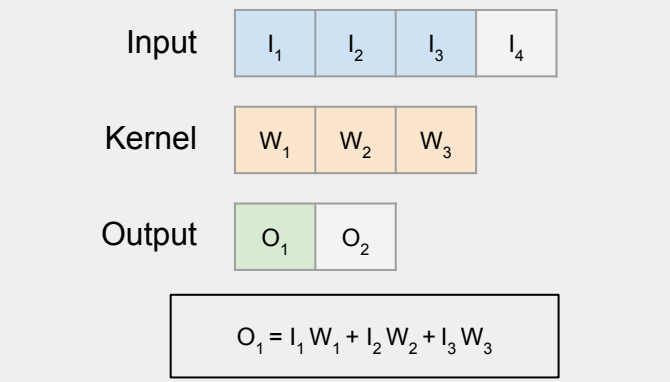
30 X 30 X 6 =
5400

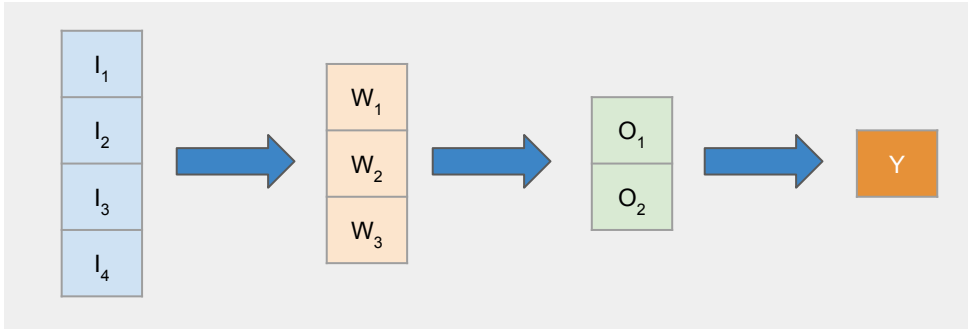


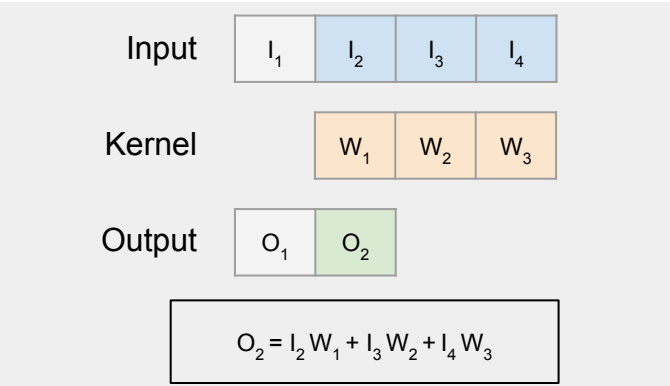
Parameters to learn
= 12288 x 5400
= **66355200**

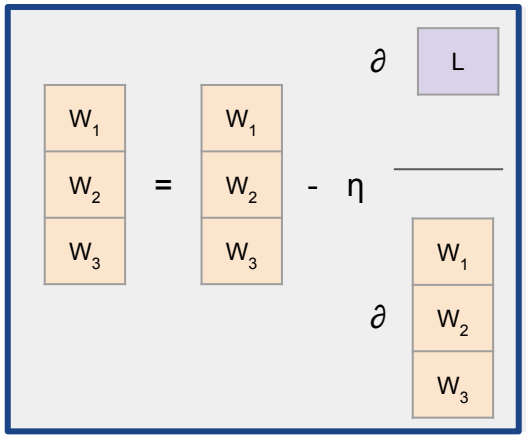
Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

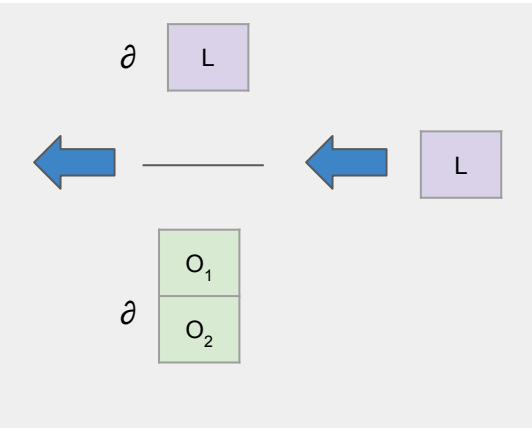
CNN Back Prop





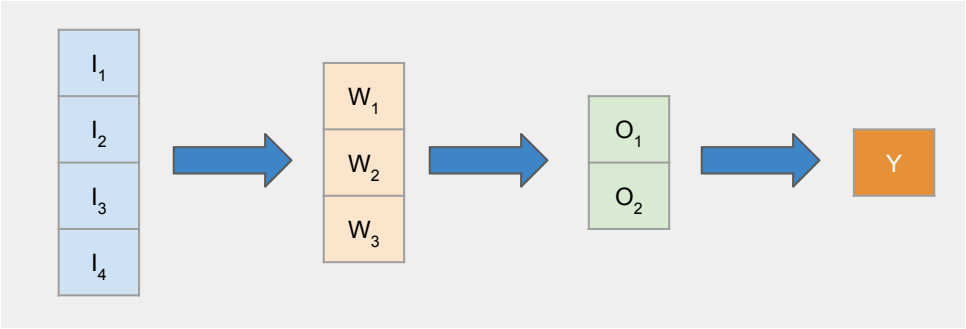


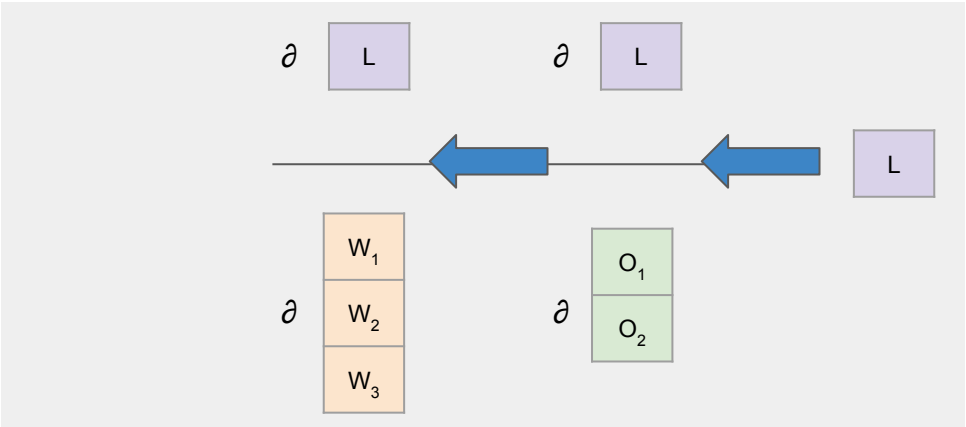


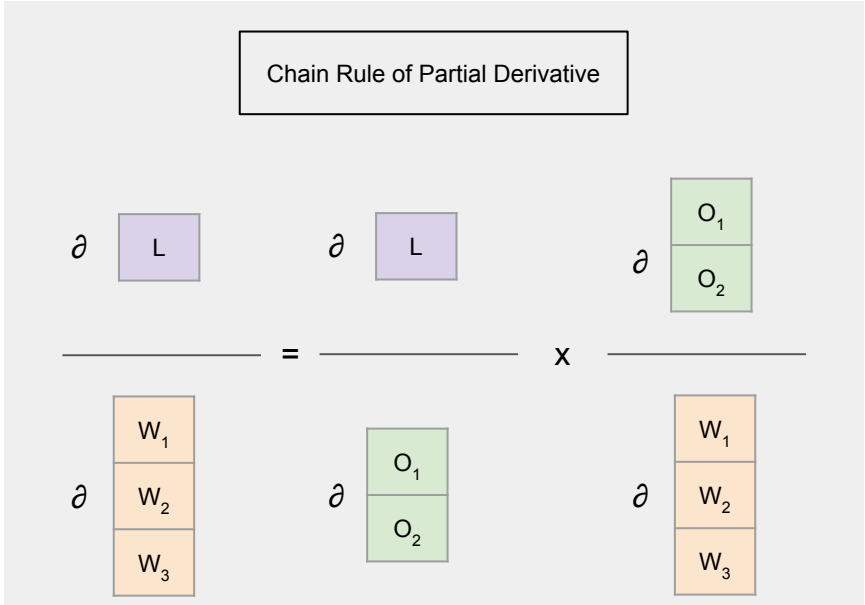


Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop







Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Just Input & Output

Output = f(Input)

$$\begin{bmatrix} O_1 \\ O_2 \end{bmatrix} = f \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}$$

$$y = f(x)$$

$$\partial y / \partial x = f`(x)$$

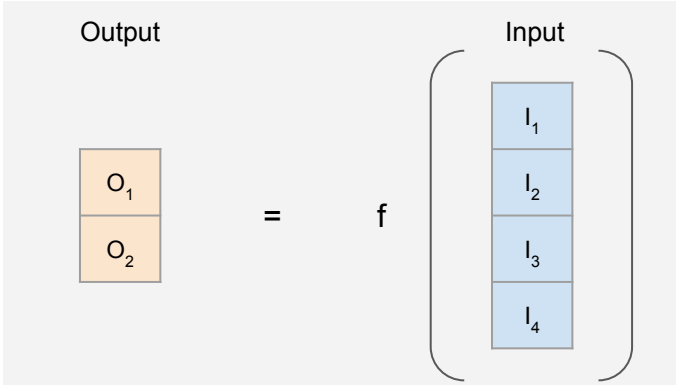
$$O_1 = I_1 W_1 + I_2 W_2 + I_3 W_3$$

$$O_2 = I_2 W_1 + I_3 W_2 + I_4 W_3$$

$$\frac{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}}{\partial \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}} = \begin{bmatrix} \partial O_1 / \partial I_1 & \partial O_1 / \partial I_2 & \partial O_1 / \partial I_3 & \partial O_1 / \partial I_4 \\ \partial O_2 / \partial I_1 & \partial O_2 / \partial I_2 & \partial O_2 / \partial I_3 & \partial O_2 / \partial I_4 \end{bmatrix} = \begin{bmatrix} & & & \\ & & & \end{bmatrix}$$

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Just Input & Output



$$y = f(x)$$

$$\partial y/\partial x = f`(x)$$

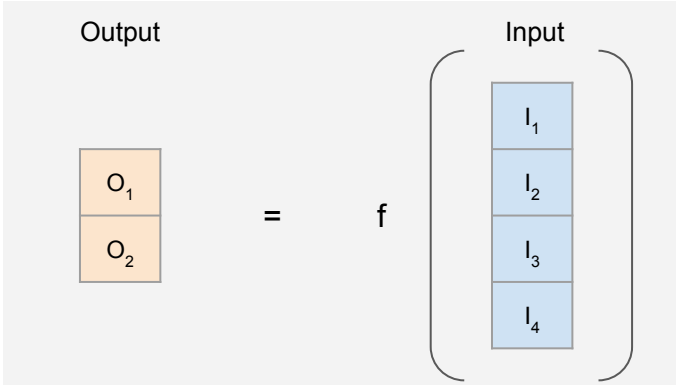
$$O_1 = I_1 W_1 + I_2 W_2 + I_3 W_3$$

$$O_2 = I_2 W_1 + I_3 W_2 + I_4 W_3$$

$$\frac{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}}{\partial \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}} = \begin{bmatrix} \partial O_1/\partial I_1 & \partial O_1/\partial I_2 & \partial O_1/\partial I_3 & \partial O_1/\partial I_4 \\ \partial O_2/\partial I_1 & \partial O_2/\partial I_2 & \partial O_2/\partial I_3 & \partial O_2/\partial I_4 \end{bmatrix} = \begin{bmatrix} W_1 & & & \\ & & & \end{bmatrix}$$

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Just Input & Output



$$y = f(x)$$

$$\partial y/\partial x = f`(x)$$

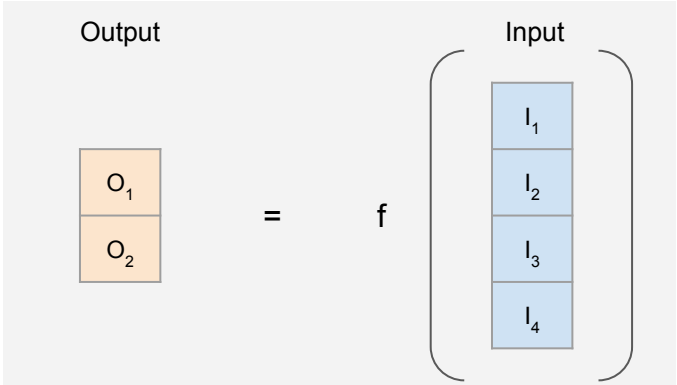
$$O_1 = I_1 W_1 + I_2 W_2 + I_3 W_3$$

$$O_2 = I_2 W_1 + I_3 W_2 + I_4 W_3$$

$$\frac{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}}{\partial \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}} = \begin{bmatrix} \partial O_1/\partial I_1 & \partial O_1/\partial I_2 & \partial O_1/\partial I_3 & \partial O_1/\partial I_4 \\ \partial O_2/\partial I_1 & \partial O_2/\partial I_2 & \partial O_2/\partial I_3 & \partial O_2/\partial I_4 \end{bmatrix} = \begin{bmatrix} W_1 & W_2 & & \\ & & & \end{bmatrix}$$

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Just Input & Output



$$y = f(x)$$

$$\partial y/\partial x = f`(x)$$

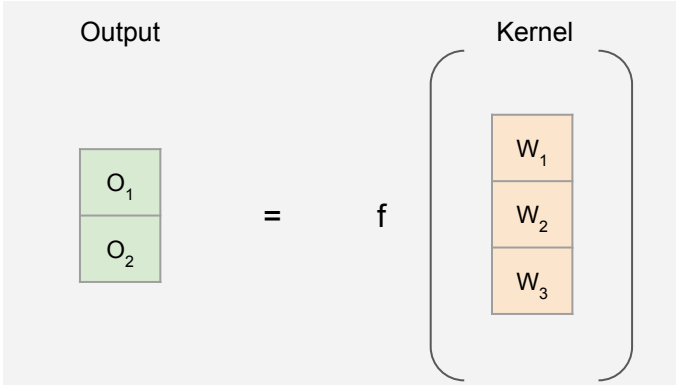
$$O_1 = I_1 W_1 + I_2 W_2 + I_3 W_3$$

$$O_2 = I_2 W_1 + I_3 W_2 + I_4 W_3$$

$$\frac{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}}{\partial \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}} = \begin{bmatrix} \partial O_1/\partial I_1 & \partial O_1/\partial I_2 & \partial O_1/\partial I_3 & \partial O_1/\partial I_4 \\ \partial O_2/\partial I_1 & \partial O_2/\partial I_2 & \partial O_2/\partial I_3 & \partial O_2/\partial I_4 \end{bmatrix} = \begin{bmatrix} W_1 & W_2 & W_3 & 0 \\ 0 & W_1 & W_2 & W_3 \end{bmatrix}$$

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Just Kernal & Output



$$y = f(x)$$

$$\partial y/\partial x = f`(x)$$

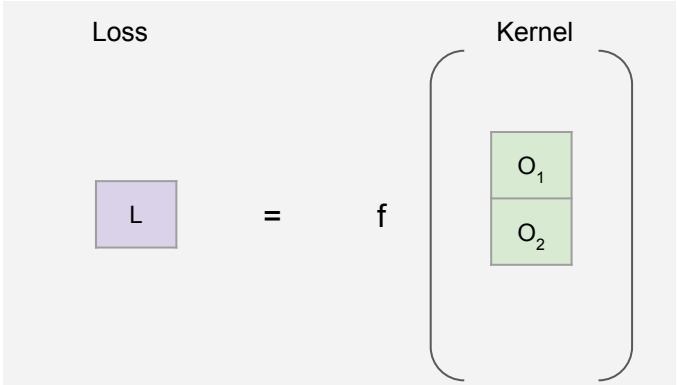
$$O_1 = I_1 W_1 + I_2 W_2 + I_3 W_3$$

$$O_2 = I_2 W_1 + I_3 W_2 + I_4 W_3$$

$$\frac{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}}{\partial \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix}} = \begin{bmatrix} \partial O_1/\partial W_1 & \partial O_1/\partial W_2 & \partial O_1/\partial W_3 \\ \partial O_2/\partial W_1 & \partial O_2/\partial W_2 & \partial O_2/\partial W_3 \end{bmatrix} = \begin{bmatrix} I_1 & I_2 & I_3 \\ I_2 & I_3 & I_4 \end{bmatrix}$$

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Consider Loss and Output



$$y = f(x)$$

$$\partial y/\partial x = f`(x)$$

$$\frac{\partial L}{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}} = \begin{bmatrix} \partial L / \partial O_1 & \partial L / \partial O_2 \end{bmatrix}$$

Chain Role of Partial Derivative

$$\frac{\partial L}{\partial \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix}} = \frac{\partial L}{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}} \times \frac{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}}{\partial \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix}}$$

mar Anala
gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Consider Loss and Output

$$\frac{\partial L}{\partial \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix}} = \frac{\partial L}{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}} \times \frac{\partial \begin{bmatrix} O_1 \\ O_2 \end{bmatrix}}{\partial \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix}} = \begin{bmatrix} \partial L / \partial O_1 & \partial L / \partial O_2 \end{bmatrix} \times \begin{bmatrix} I_1 & I_2 & I_3 \\ I_2 & I_3 & I_4 \end{bmatrix}$$

1 x 2 × 2 x 3

$$\begin{bmatrix} \partial L / \partial W \end{bmatrix} = \begin{bmatrix} \partial L / \partial O_1 \times I_1 + \partial L / \partial O_2 \times I_2 & \partial L / \partial O_1 \times I_2 + \partial L / \partial O_2 \times I_3 & \partial L / \partial O_1 \times I_3 + \partial L / \partial O_2 \times I_4 \end{bmatrix}$$

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Consider Loss and Output

$$\frac{\partial L}{\partial W} = \left[\frac{\partial L}{\partial O_1} \times I_1 + \frac{\partial L}{\partial O_2} \times I_2 \quad \frac{\partial L}{\partial O_1} \times I_2 + \frac{\partial L}{\partial O_2} \times I_3 \quad \frac{\partial L}{\partial O_1} \times I_3 + \frac{\partial L}{\partial O_2} \times I_4\right]$$

Input	I_1	I_2	I_3	I_4
Loss	$\frac{\partial L}{\partial O_1}$	$\frac{\partial L}{\partial O_2}$		

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Consider Loss and Output

$$\frac{\partial L}{\partial W} = \frac{\partial L}{\partial O_1} \times I_1 + \frac{\partial L}{\partial O_2} \times I_2 \quad \frac{\partial L}{\partial O_1} \times I_2 + \frac{\partial L}{\partial O_2} \times I_3 \quad \frac{\partial L}{\partial O_1} \times I_3 + \frac{\partial L}{\partial O_2} \times I_4$$

Input	I_1	I_2	I_3	I_4
Loss	$\partial L / \partial O_1$	$\partial L / \partial O_2$		

Input	I_1	I_2	I_3	I_4
Loss		$\partial L / \partial O_1$	$\partial L / \partial O_2$	

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN Back Prop - Consider Loss and Output

$\partial L / \partial W$ = $\partial L / \partial O_1 \times I_1 + \partial L / \partial O_2 \times I_2$ | $\partial L / \partial O_1 \times I_2 + \partial L / \partial O_2 \times I_3$ | $\partial L / \partial O_1 \times I_3 + \partial L / \partial O_2 \times I_4$

Input | I_1 | I_2 | I_3 | I_4

Loss | $\partial L / \partial O_1$ | $\partial L / \partial O_2$

Input | I_1 | I_2 | I_3 | I_4

Loss | $\partial L / \partial O_1$ | $\partial L / \partial O_2$

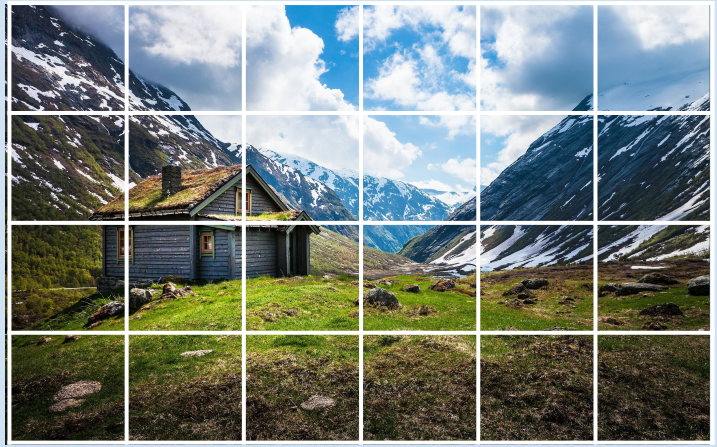
Hence, backward propagation of a convolution is also as convolution

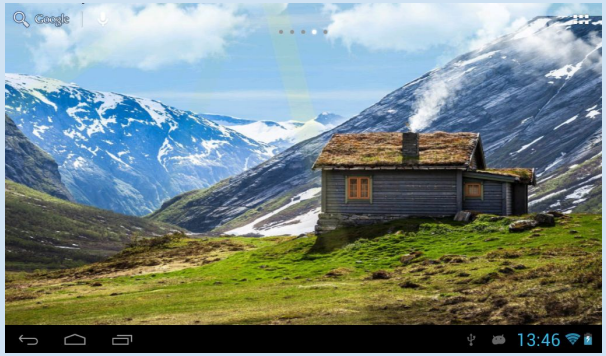
Input | I_1 | I_2 | I_3 | I_4

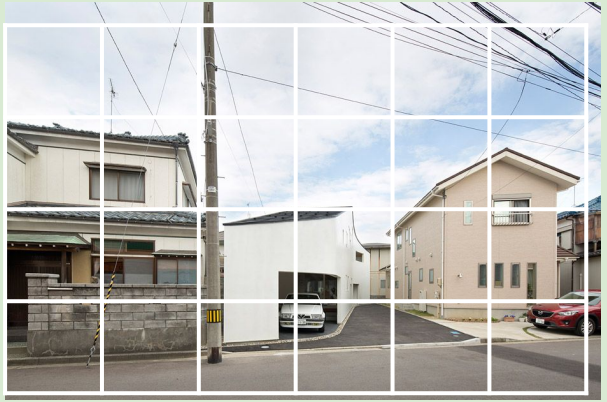
Loss | $\partial L / \partial O_1$ | $\partial L / \partial O_2$

Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/

CNN - Translation Invariance







Arun Kumar Anala
analaarun.k@gmail.com
https://www.linkedin.com/in/arun-kumar-anala-35760523/