



Chapter

1

CNN 개요

1. CNN 소개
2. CNN 기본

학습 목표

- ✓ CNN이 기본적으로 어떤 곳에 쓰일 수 있는지 이해한다
- ✓ Convolution 을 이해하고 레이어를 설계에 익숙해진다

주요 내용

- ✓ CNN의 정의와 필요성
- ✓ Convolution, Pooling Layer 설계 방법
- ✓ Binary, Multinomial Logistic Regression 을 통한 Cross Entropy 설명

강의에 앞서서..

❖ 본 문서는 아래의 자료들을 활용하여 만들어 졌음을 알립니다

❖ 모두를 위한 딥러닝 강좌

- 네이버 Search & Clova AI 부분 리더 김성훈 교수님
- https://www.youtube.com/playlist?list=PLIMkM4tgfjnLSOjrEJN31gZATbcj_MpUm
- <https://www.edwith.org/boostcourse-dl-tensorflow/lecture/43739/>

❖ 스탠포드 대학 CNN 강좌

- Fei-Fei Li & Andrej Karpathy & Justin Johnson
- <http://cs231n.stanford.edu/slides/2020/>

CS231n: Convolutional Neural Networks for Visual Recognition

- This course, Prof. Fei-Fei Li & Justin Johnson & Serena Yeung
- Focusing on applications of deep learning to computer vision

1

1. CNN 소개



Image Classification

Fei-Fei Li, Ranjay Krishna, Danfei Xu

Lecture 2 - 5

April 9, 2020

Image Classification: A core task in Computer Vision



This image by [hiita](#) is
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(assume given a set of labels)
{dog, cat, truck, plane, ...}



Image Classification

Fei-Fei Li, Ranjay Krishna, Danfei Xu

Lecture 2 - 14

April 9, 2020

Attempts have been made



Find edges



Find corners

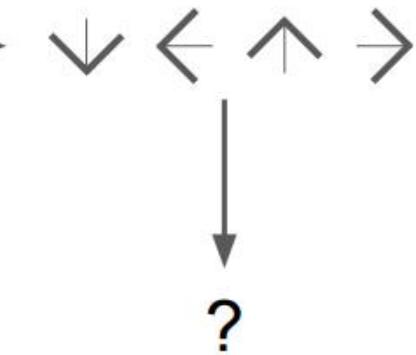


Image Classification

Fei-Fei Li, Ranjay Krishna, Danfei Xu

Lecture 2 - 15

April 9, 2020

Machine Learning: Data-Driven Approach

1. Collect a dataset of images and labels
2. Use Machine Learning algorithms to train a classifier
3. Evaluate the classifier on new images

Example training set

```
def train(images, labels):
    # Machine learning!
    return model

def predict(model, test_images):
    # Use model to predict labels
    return test_labels
```

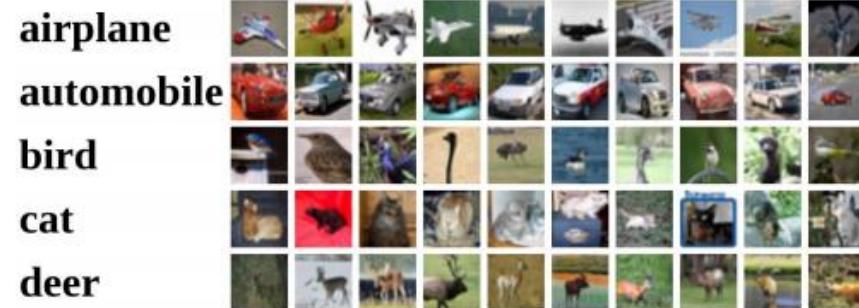
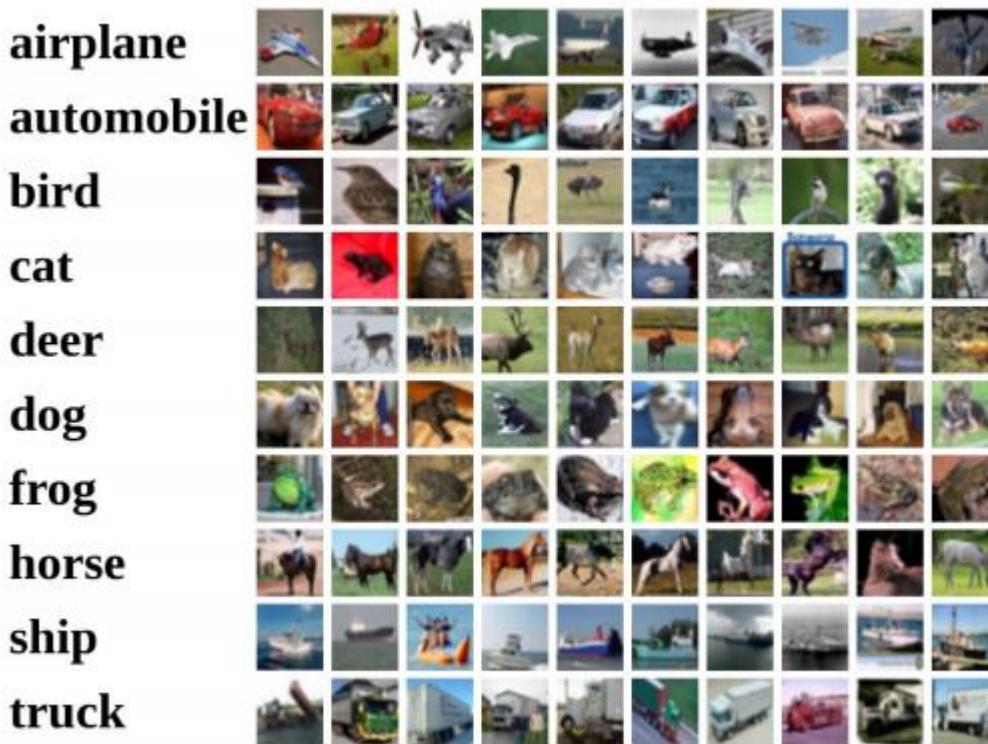


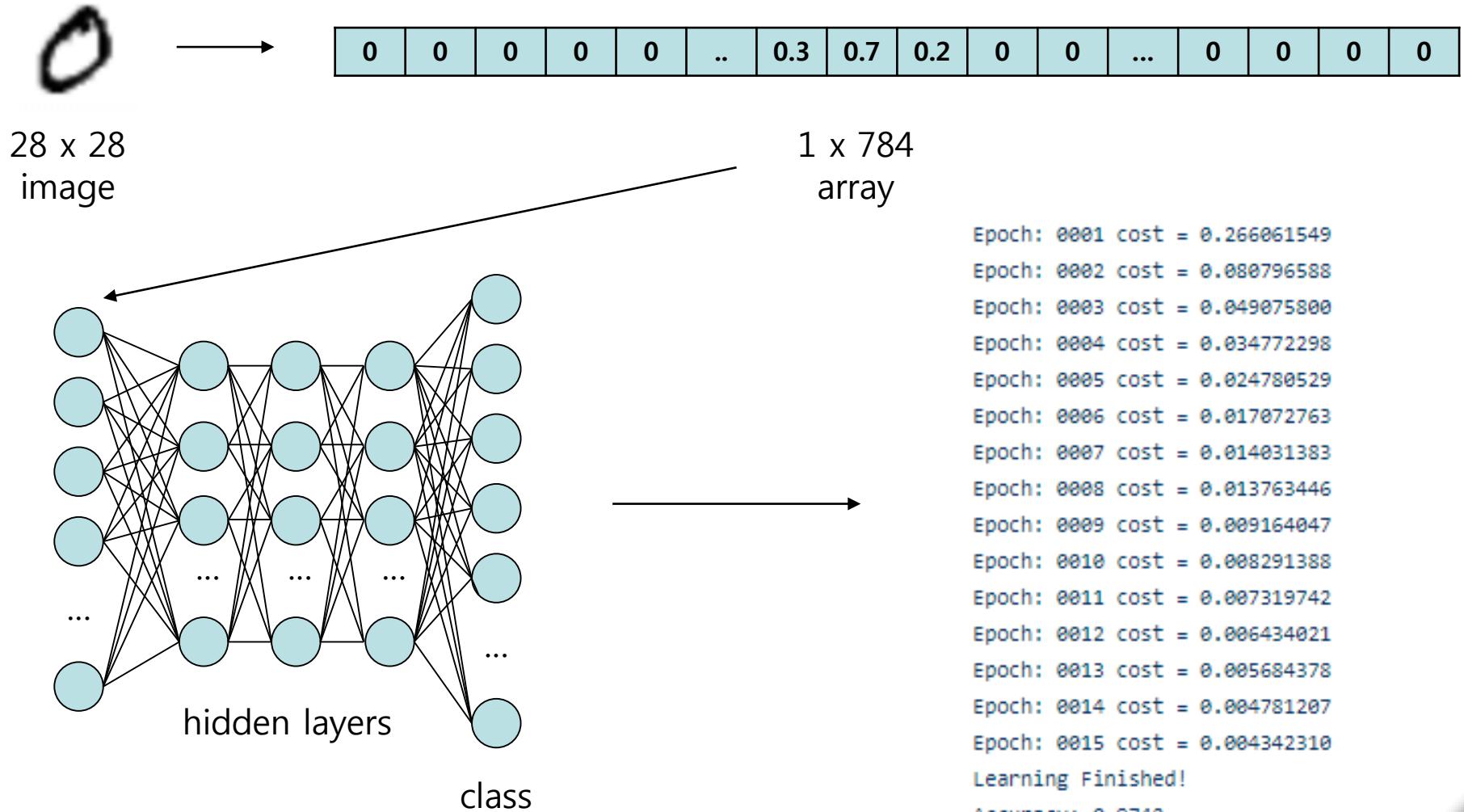
Image Classification

- ❖ CIFAR-10 dataset (<https://www.cs.toronto.edu/~kriz/cifar.html>)



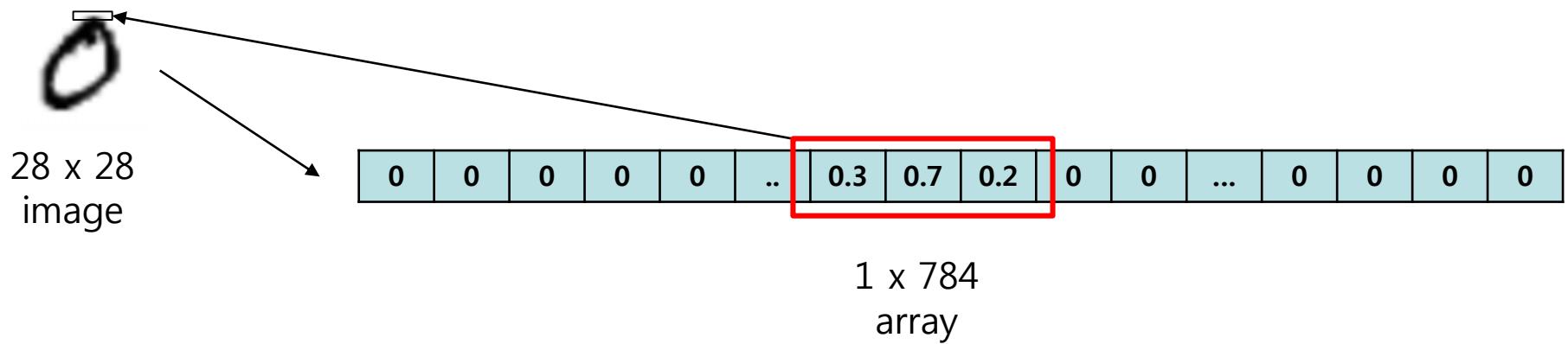
6만장 32x32 colour images, 10 classes(6,000 images per class)
50,000 training images and
10,000 test images.

MNIST with Neural Network



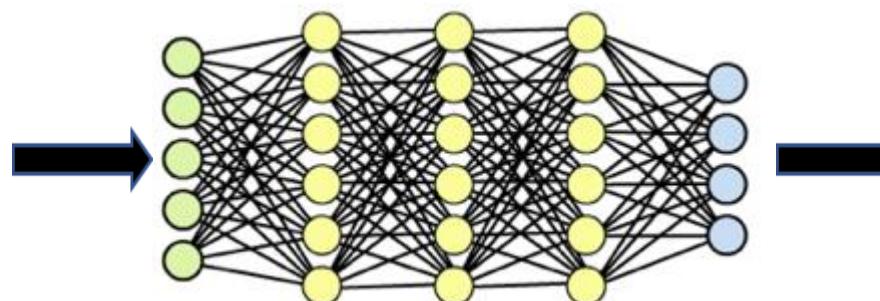
MNIST with Neural Network

- ❖ Neural network은 매우 강력하지만 전체 데이터로는 feature selection이 어렵다

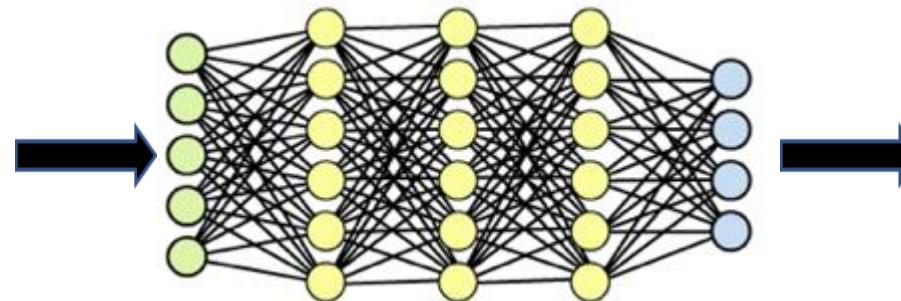


Deep Neural Network

- 데이터의 크기가 클수록, 형태가 복잡할수록 학습이 어려워짐
 - 학습시간(training time), 네트워크 크기(network size), 매개변수의 개수(parameter)

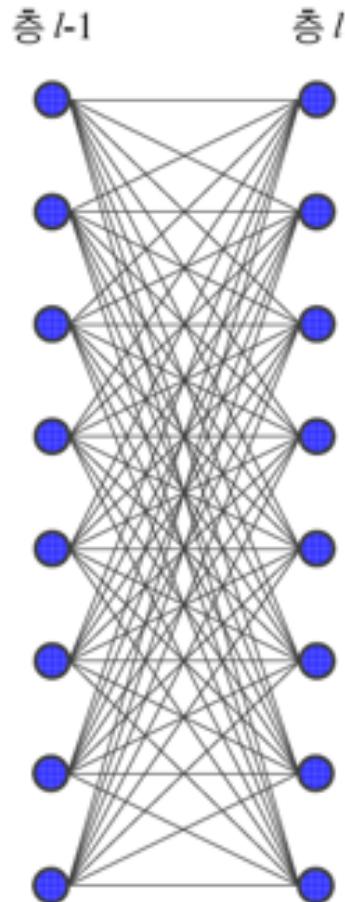


0(고양이)

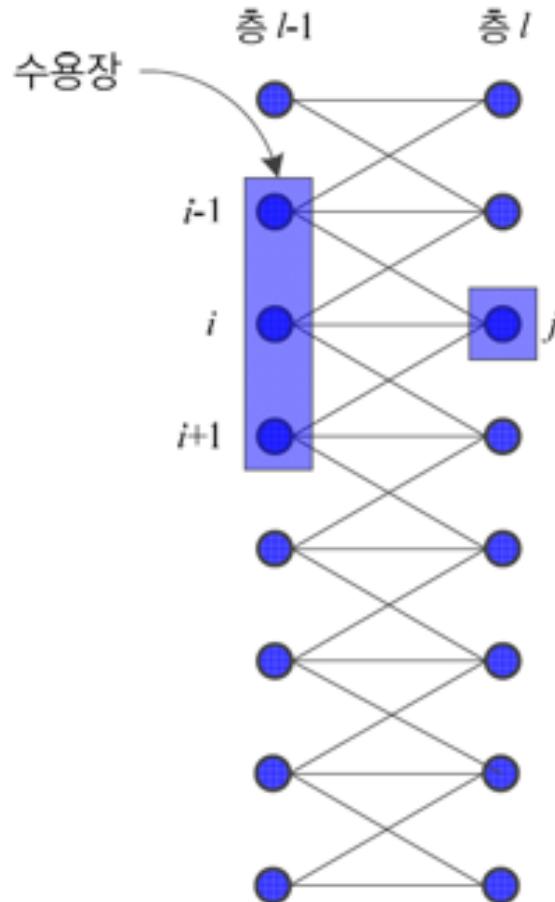


1(강아지)

Deep Neural Network & Convolutional Neural Network



(a)DNN (fully connected)



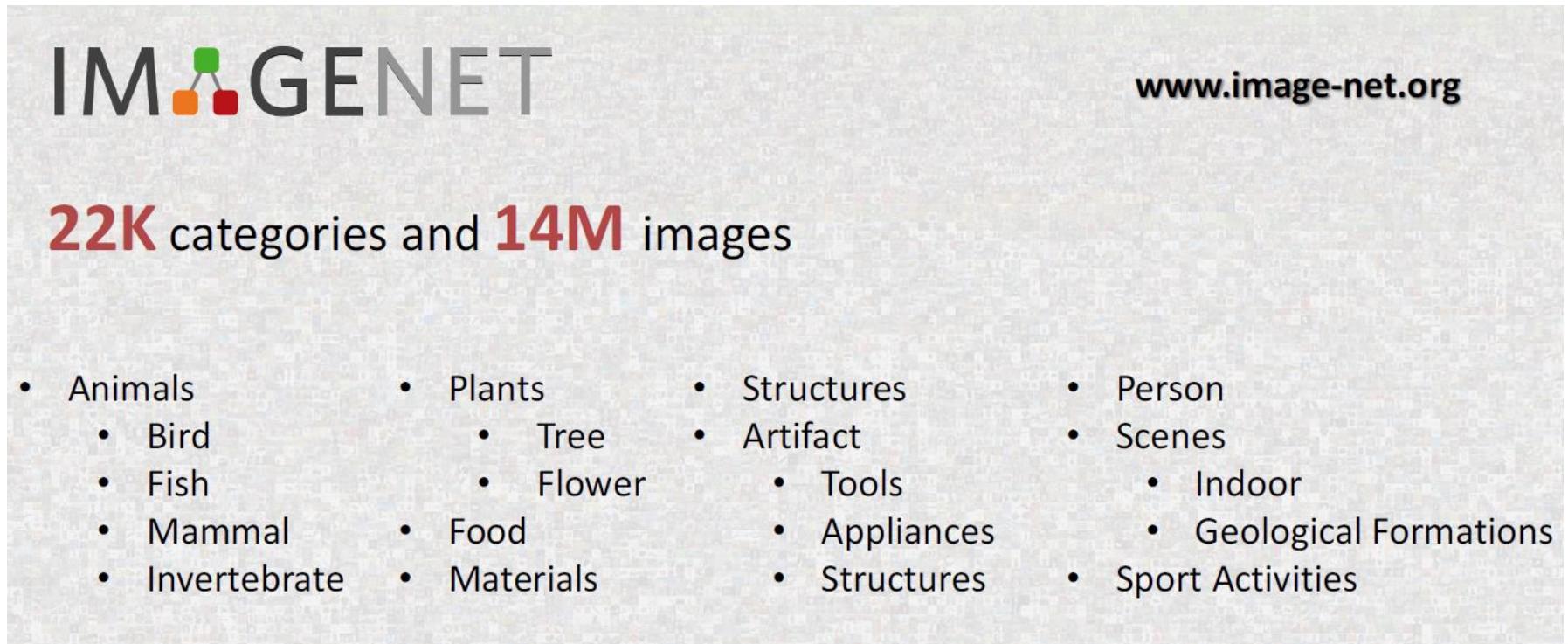
(b)CNN (sparse connected)

- 각 레이어의 입력력 데이터의 형상 유지
- 이미지의 공간 정보를 유지하면서 인접 이미지와의 특징을 효과적으로 인식
- 복수의 필터로 이미지의 특징 추출 및 학습
- 추출한 이미지의 특징을 모으고 강화하는 Pooling 레이어
- 필터를 공유 파라미터로 사용하기 때문에, 일반 인공 신경망과 비교하여 학습 파라미터가 매우 적음

Visual Object Challenge

❖ IMAGENET

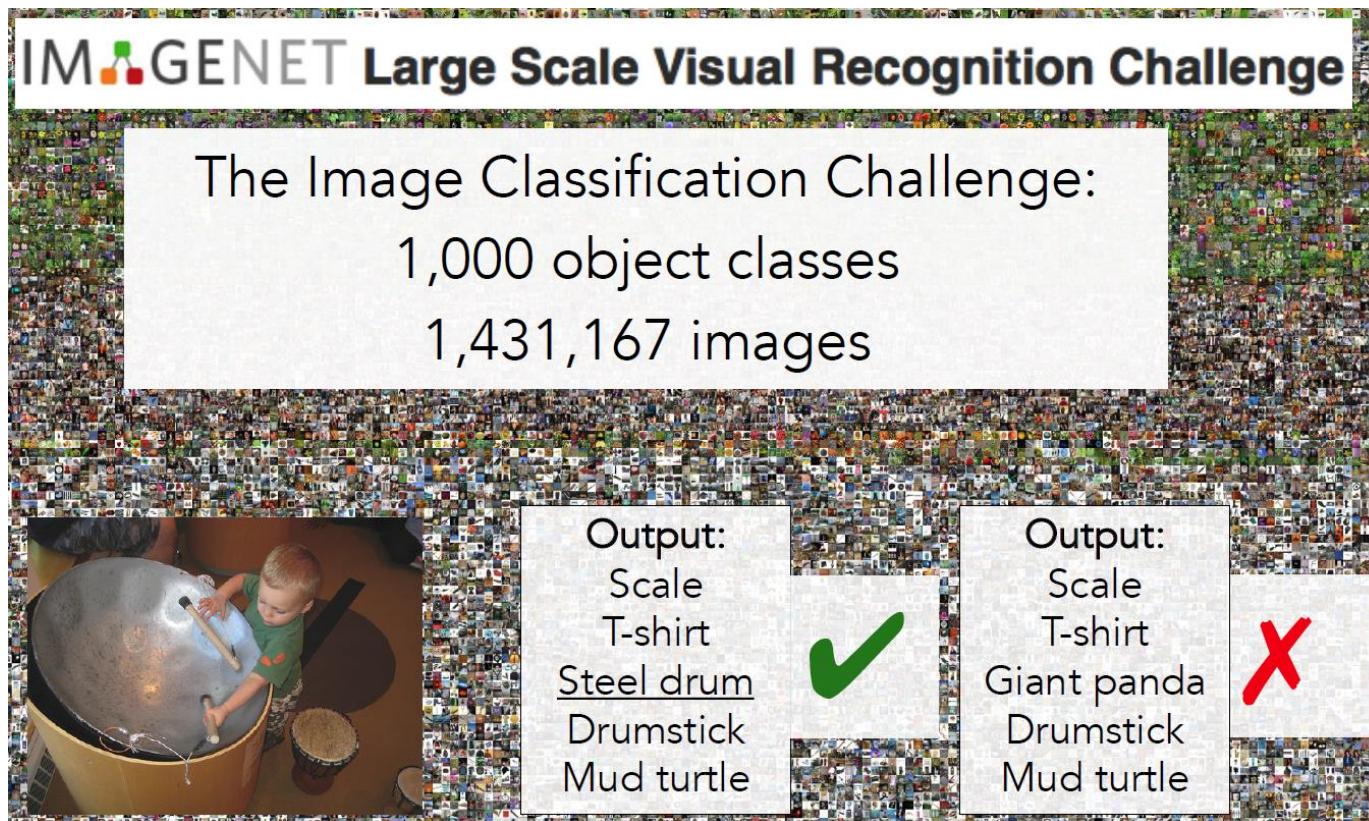
- Visual object recognition 연구를 위한 매우 큰 데이터베이스
- 22000 카테고리에 140만개의 이미지



Visual Object Challenge

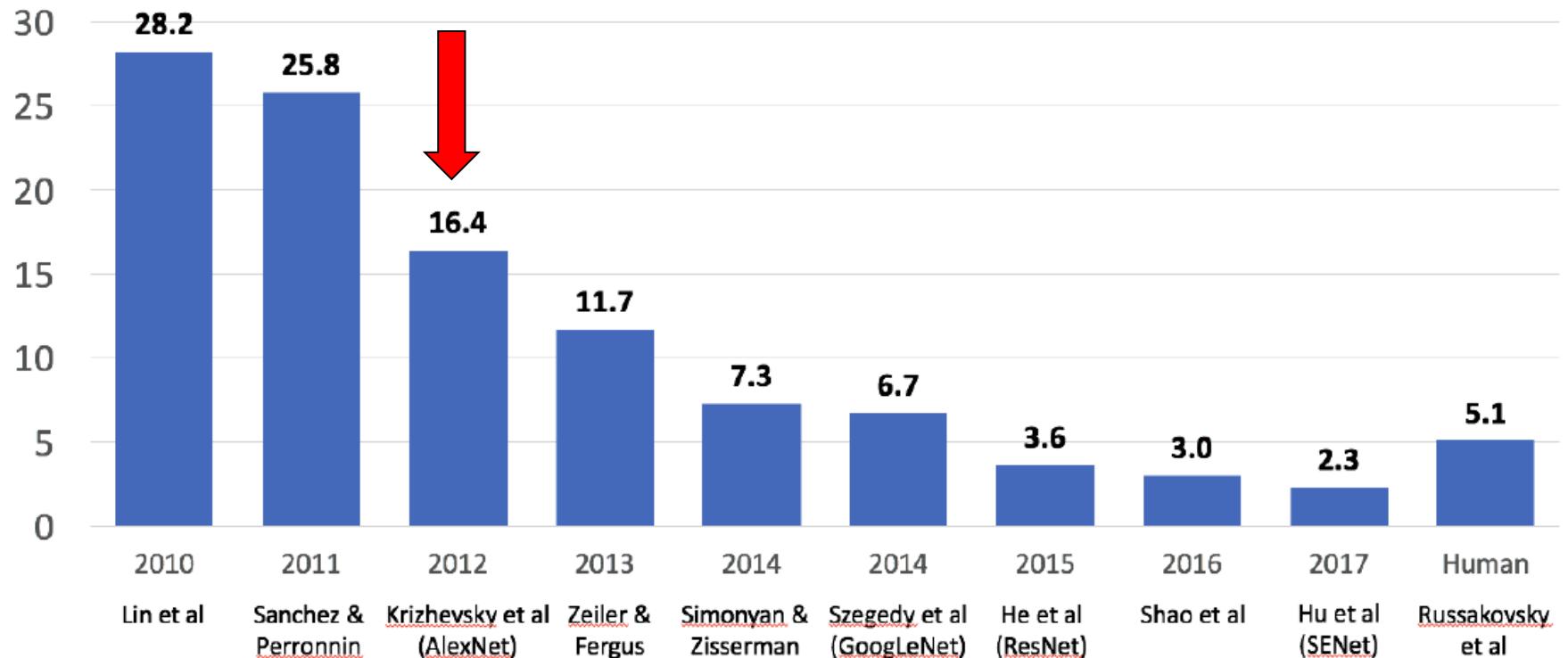
❖ ImageNet Large Scale Visual Recognition Competition(ILSVRC)

- 1000개의 카테고리, 140만개의 이미지로 이미지 인식 대회 개최



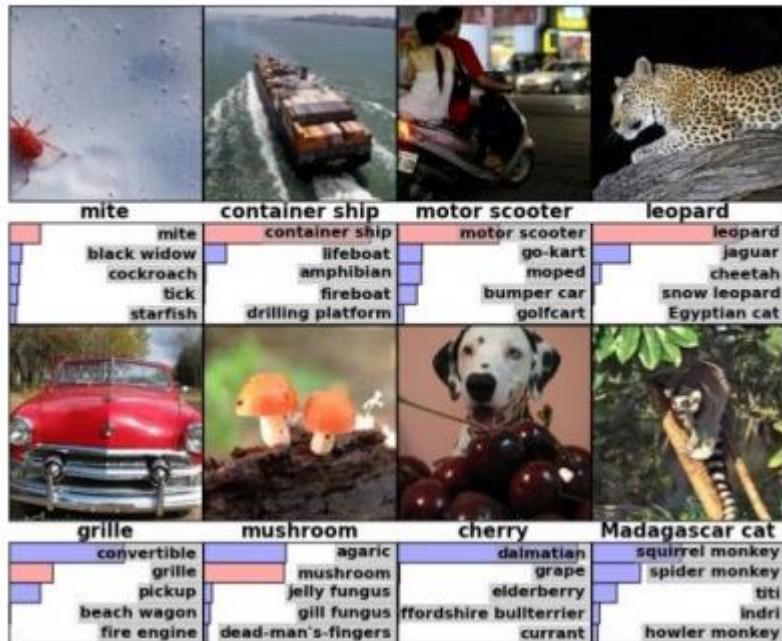
Visual Object Challenge

- 2012년 갑자기 16.4%로 오답률이 낮아짐 -> CNN
- 사람의 오답률이 5.1%인데 2015년에 사람을 뛰어넘음



Visual Recognition Problems

Classification



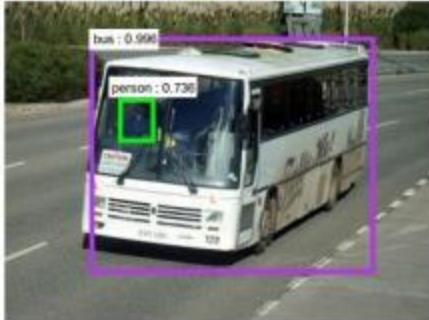
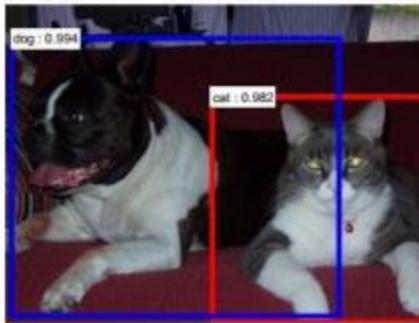
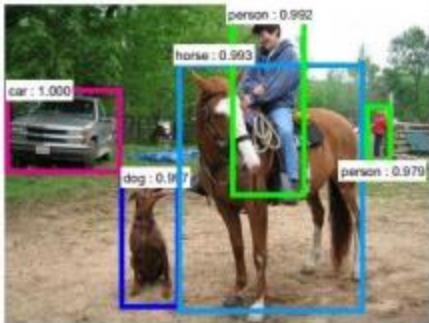
Retrieval



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Visual Recognition Problems

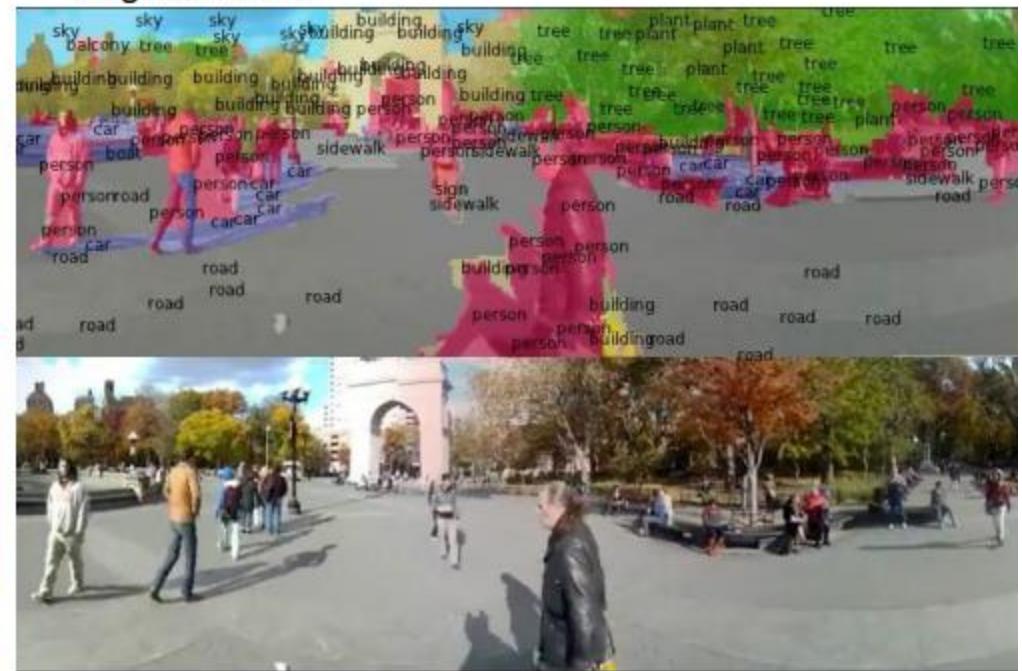
Detection



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[Faster R-CNN: Ren, He, Girshick, Sun 2015]

Segmentation



Figures copyright Clement Farabet, 2012
Reproduced with permission.

[Farabet et al., 2012]

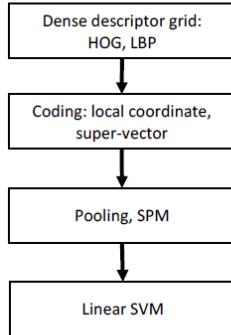
Visual Recognition Problems

- ILSVRC에서 우승한 VGG, ResNet 등의 모델이 Keras에 공개

IMAGENET Large Scale Visual Recognition Challenge

Year 2010

NEC-UIUC

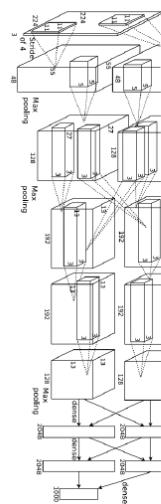


[Lin CVPR 2011]

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Year 2012

SuperVision
AlexNet



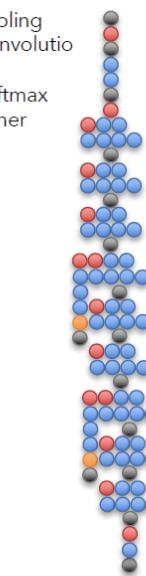
[Krizhevsky NIPS 2012]

Figure copyright Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton, 2012. Reproduced with permission.

Year 2014

GoogLeNet
Inception

● Pooling
● Convolution
● n
● Softmax
● Other

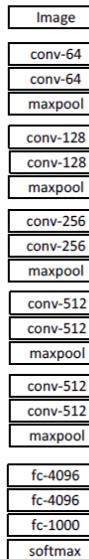


[Szegedy arxiv 2014]

[Simonyan arxiv 2014]

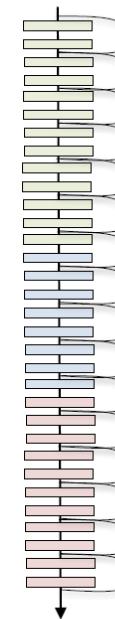
Visual Geometry Group

VGG



Year 2015

MSRA ResNet



[He ICCV 2015]

Microsoft Research

Visual Recognition Problems

Convolutional Neural Networks (CNN) have become an important tool for object recognition

Visual Recognition Problems

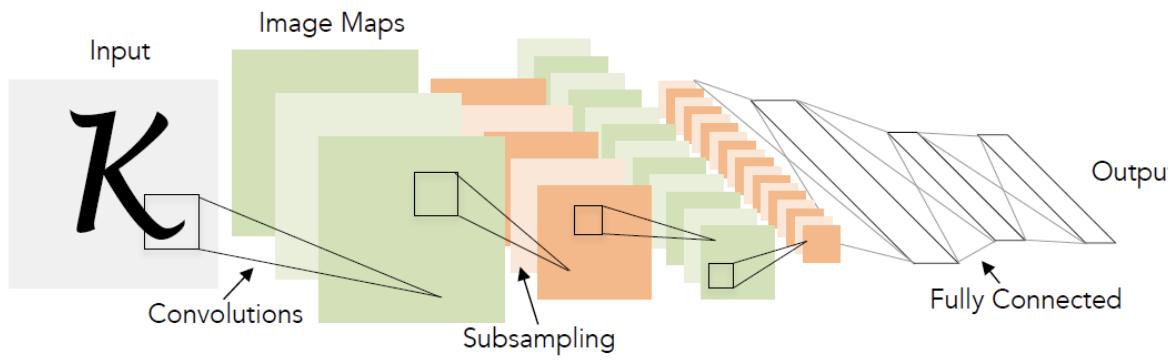
1998

LeCun et al.

LeNet-5

"Gradient-based learning applied to document recognition"

논문에서 CNN을 이용하여 필기체를 성공적으로 인식



of transistors



10^6

of pixels used in training

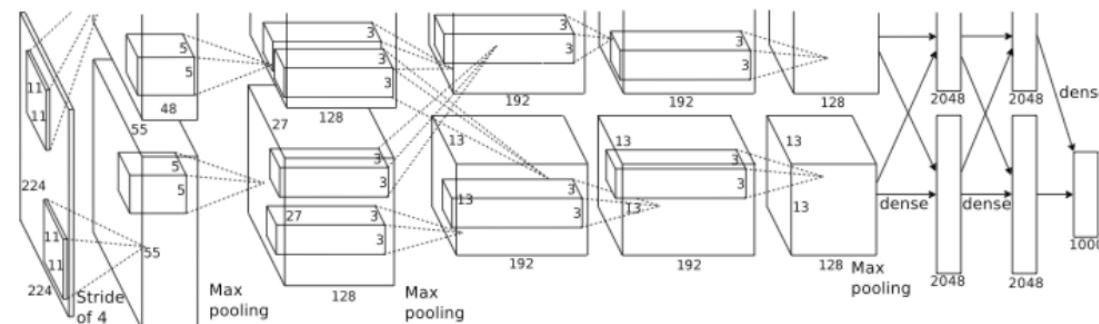
10^7 NIST

2012

Krizhevsky et al.

AlexNet

"ImageNet Classification with Deep Convolutional Neural Networks"



of transistors



10^9

GPUs



of pixels used in training

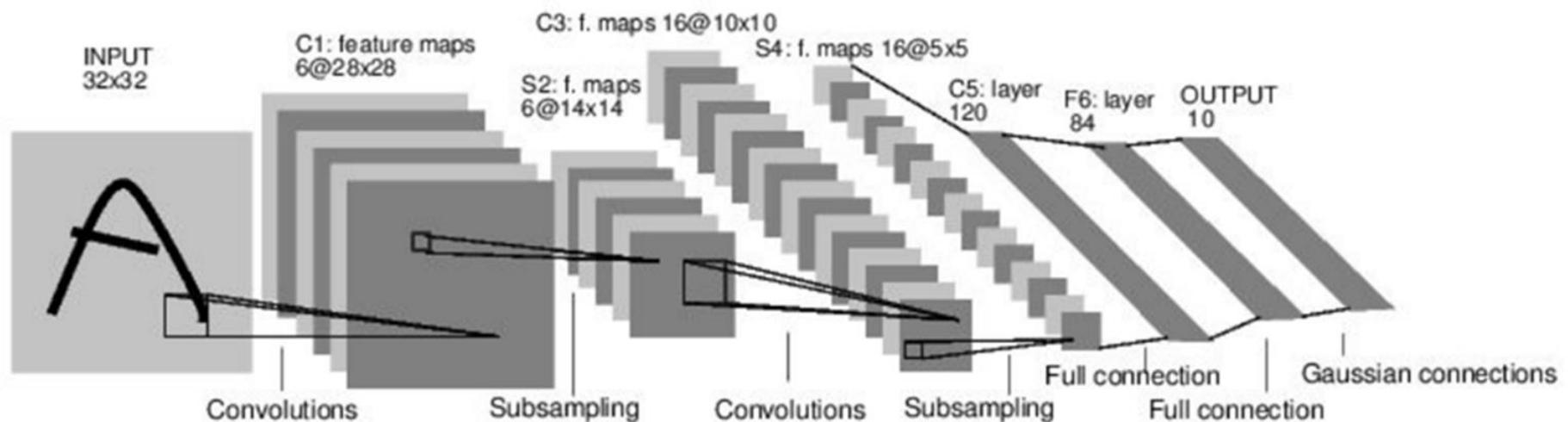
10^{14} IMGENET

Our Goal

Deep Learning 기술 중
이미지 인식에 많이 활용되는
CNN에 대한 이해와 활용능력 습득

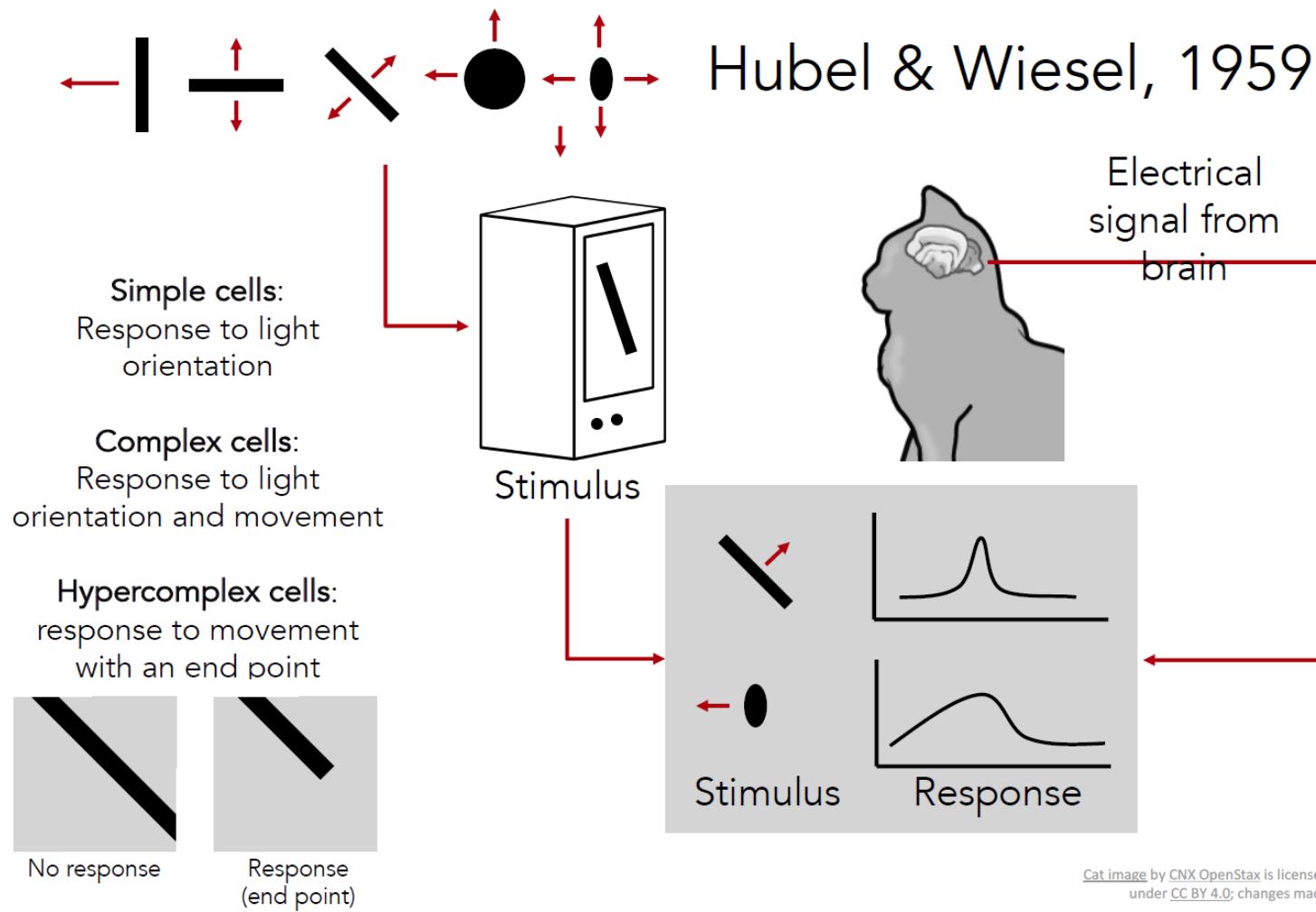
Convolutional Neural Network

- ❖ 이미지의 부분 부분을 샘플링 하여 특징을 추출

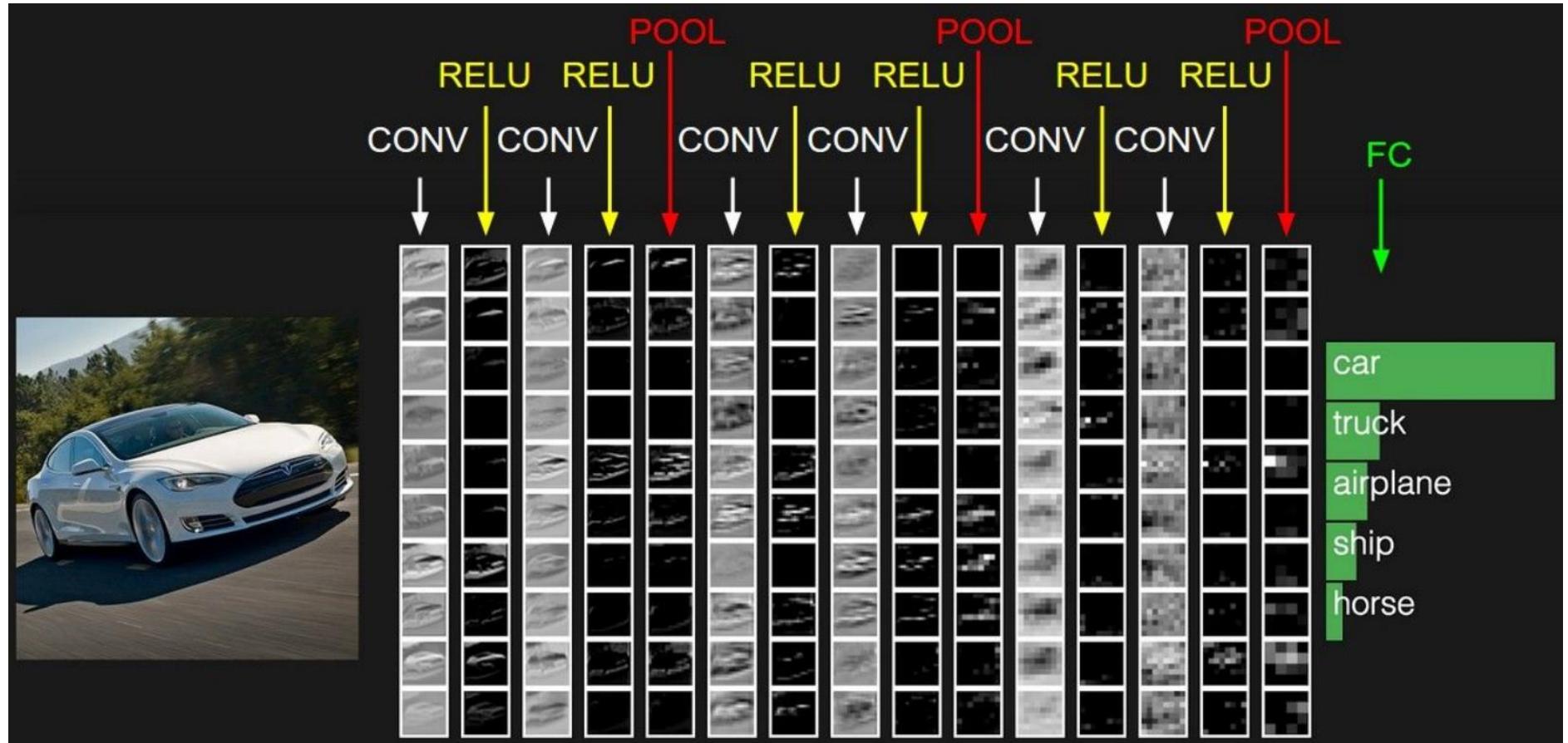


[LeNet-5, LeCun]

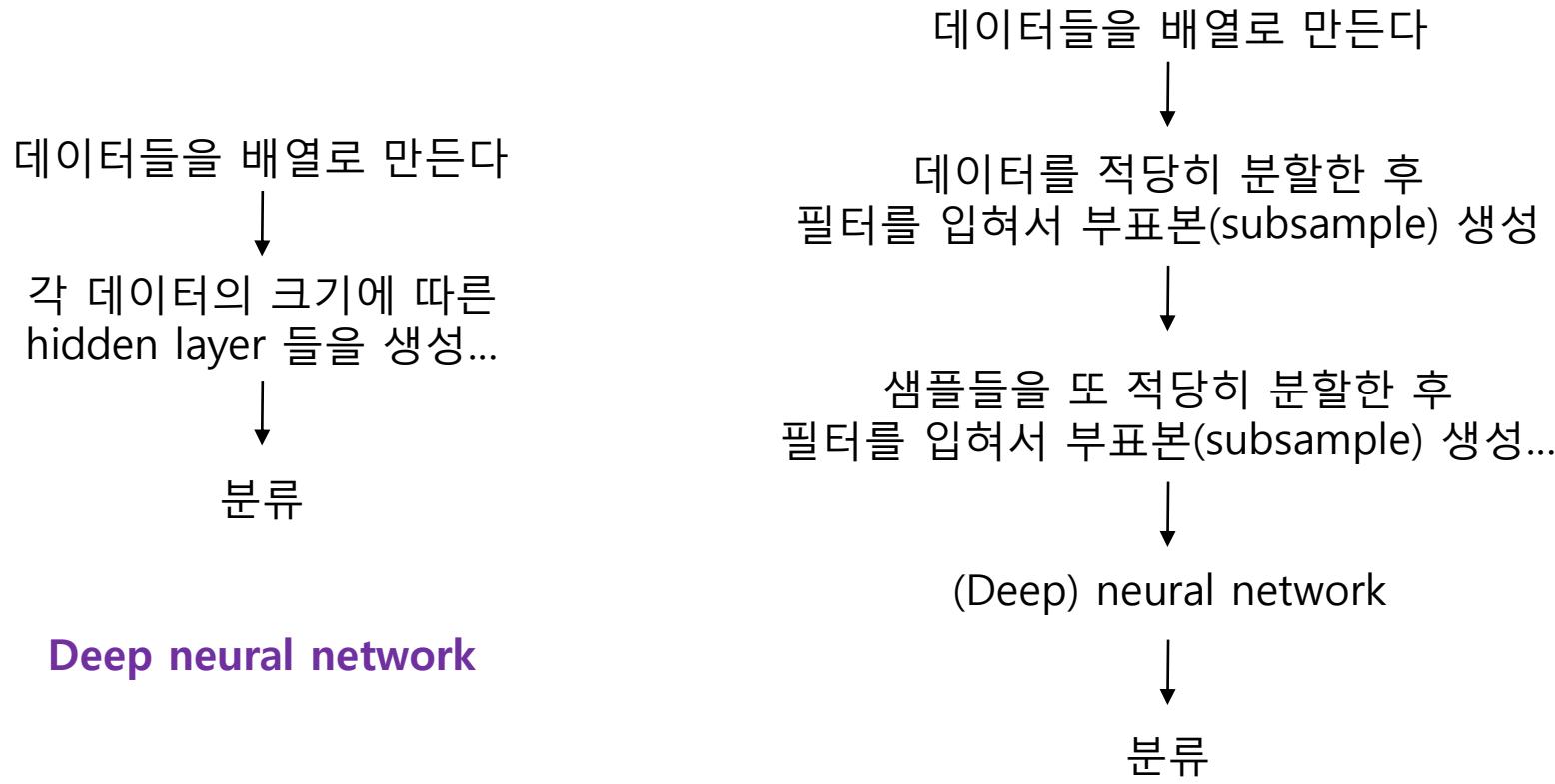
Convolutional Neural Network



Convolutional Neural Network



Convolutional Neural Network

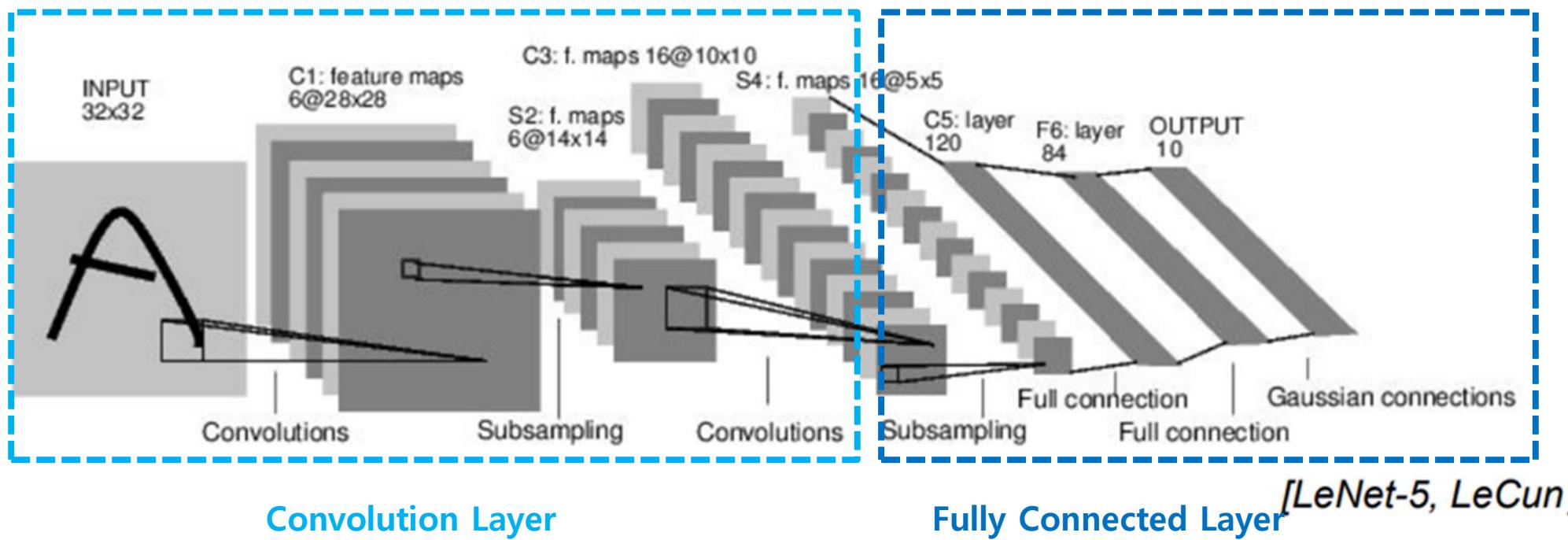


1

2. CNN 기본



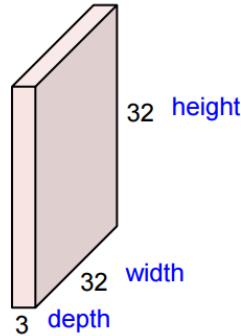
CNN 구조



CNN 구조

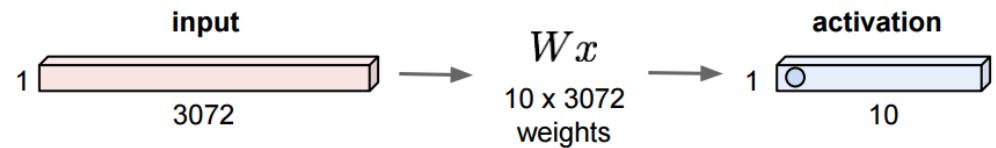
Convolution Layer

32x32x3 image -> preserve spatial structure



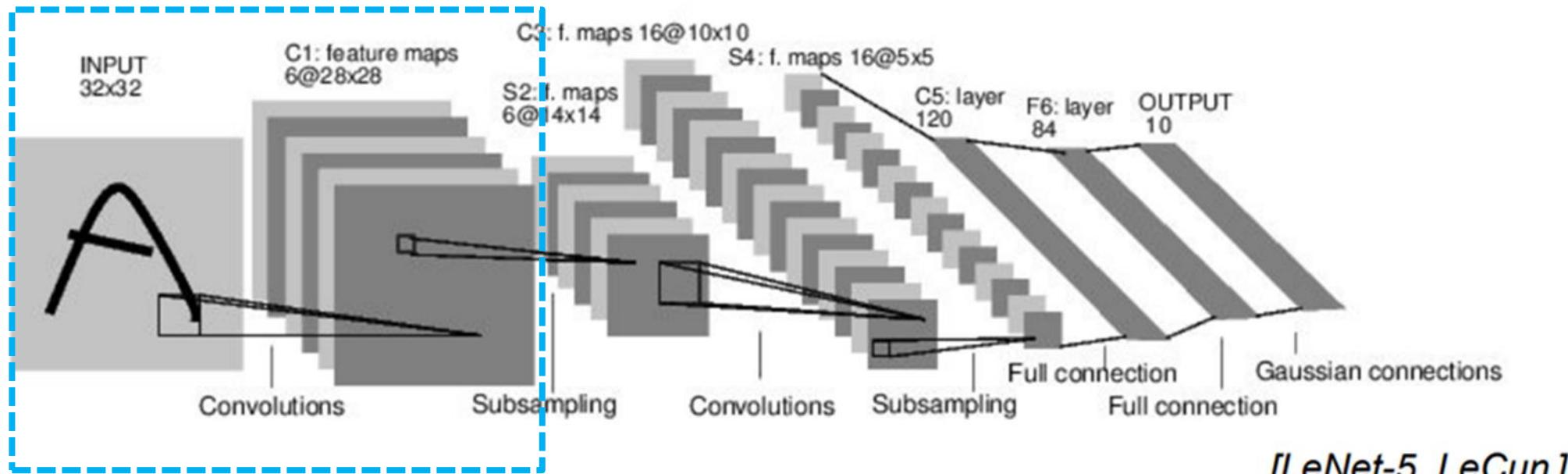
Fully Connected Layer

32x32x3 image -> stretch to 3072 x 1



Convolution Layer

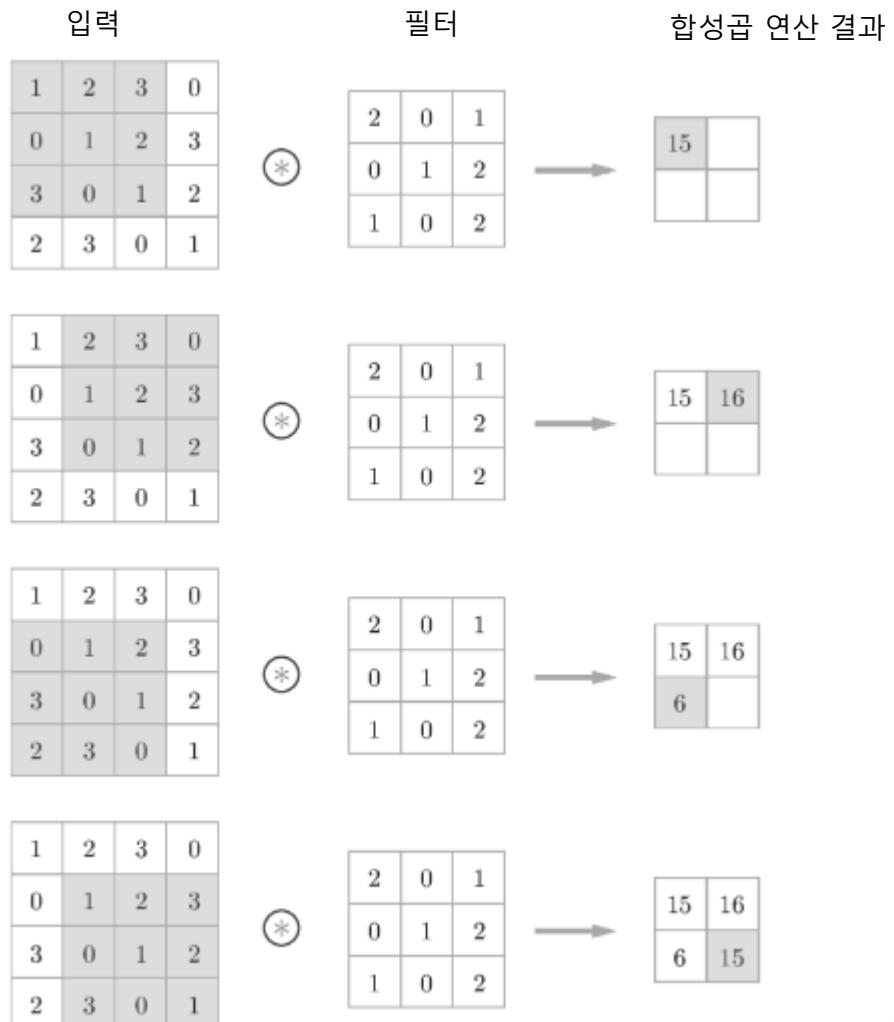
- ❖ Input에서 feature(activation) map을 만드는 과정
- ❖ Convolution(합성곱) 연산으로 처리



Convolution Layer

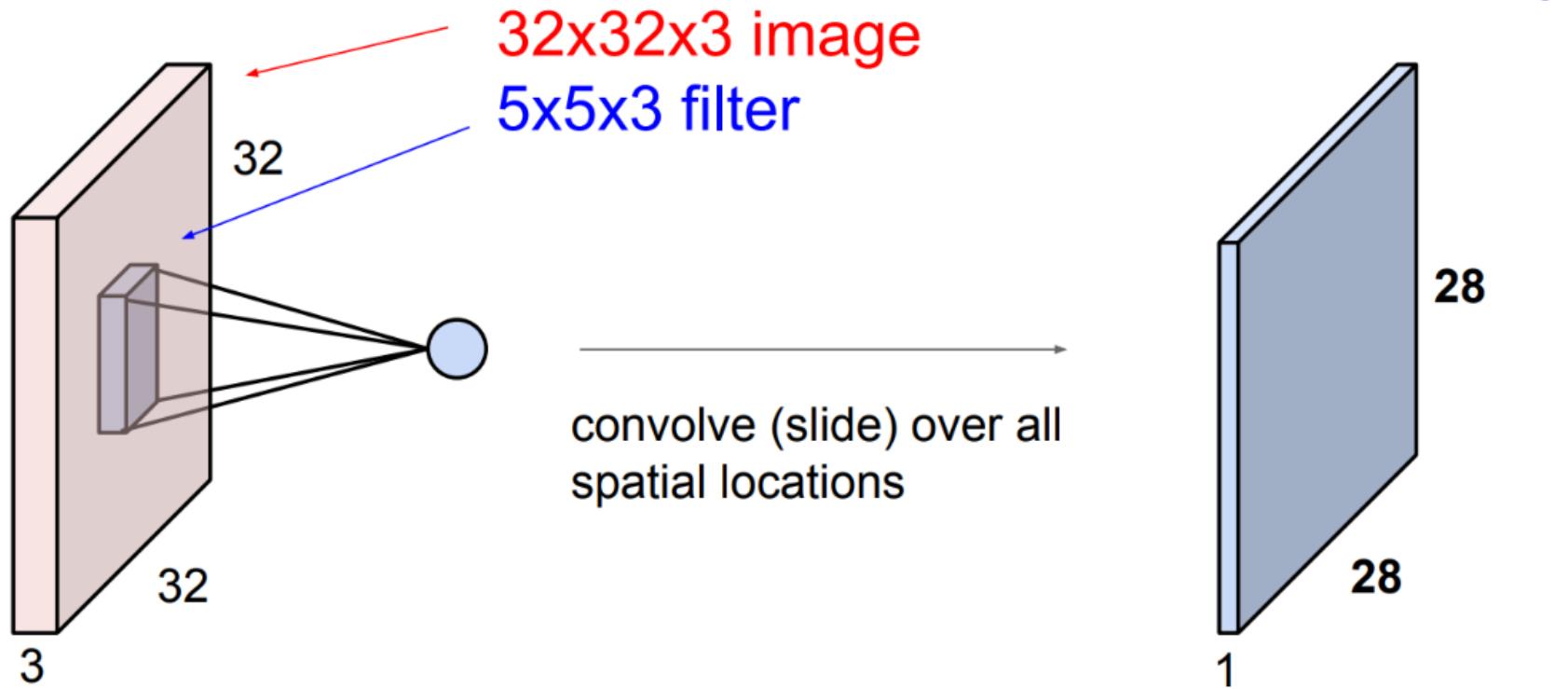
❖ Convolution(합성곱) 연산

- 필터(filter, kernel)의 윈도우를 일정 간격(stride) 이동시키면서 입력에 weighted sum을 적용
- weighted sum : 각 요소의 값을 곱하여 더함

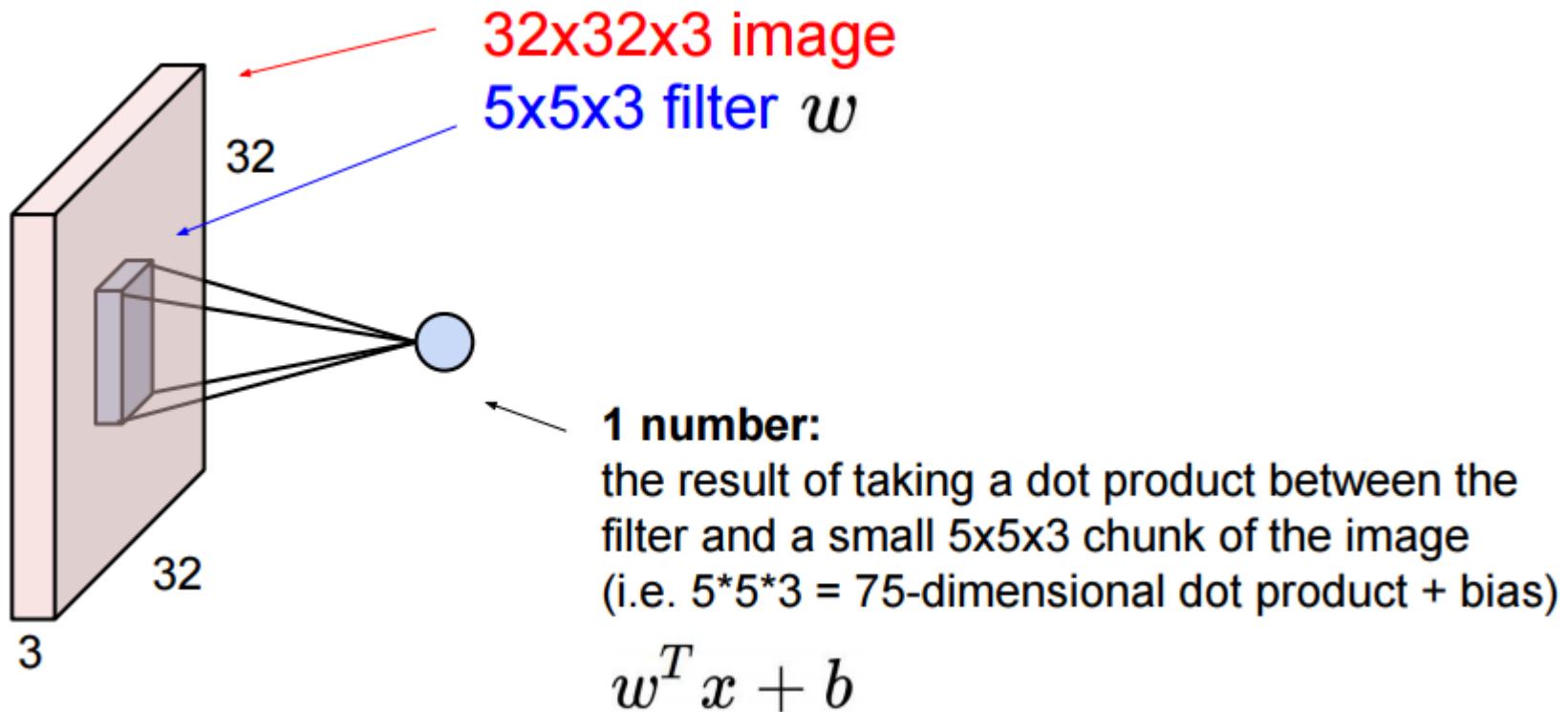


Convolution Layer

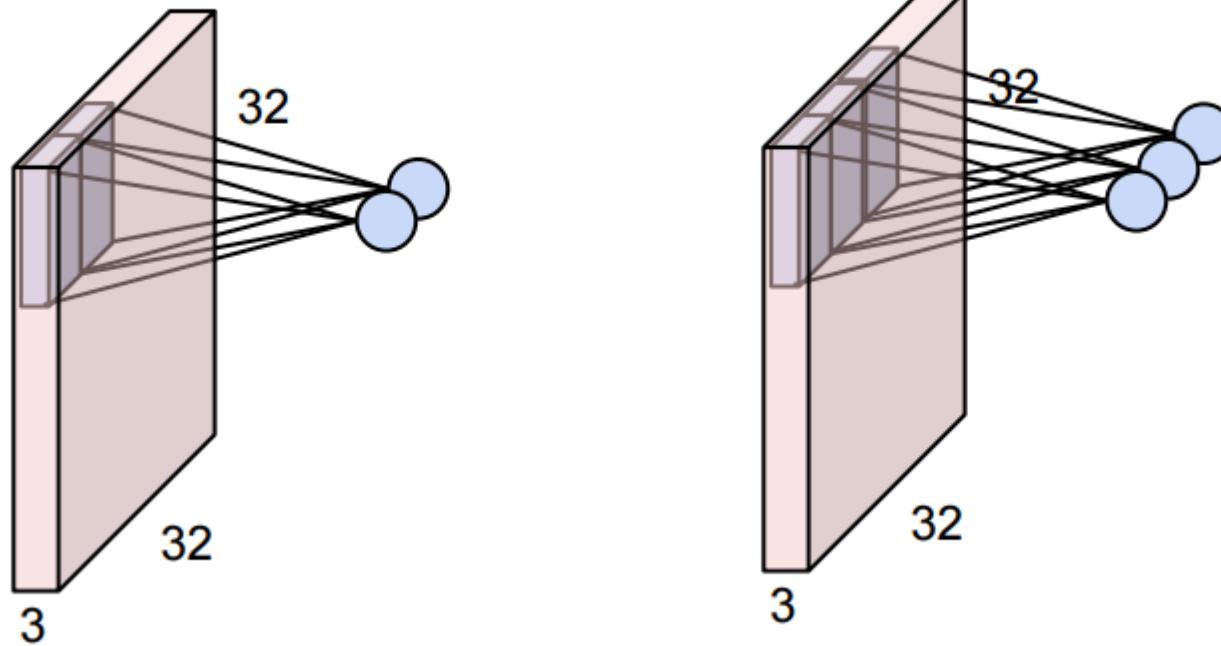
입력 이미지에 필터를 적용하여 작은 영역을 한 점으로 표현



Convolution Layer

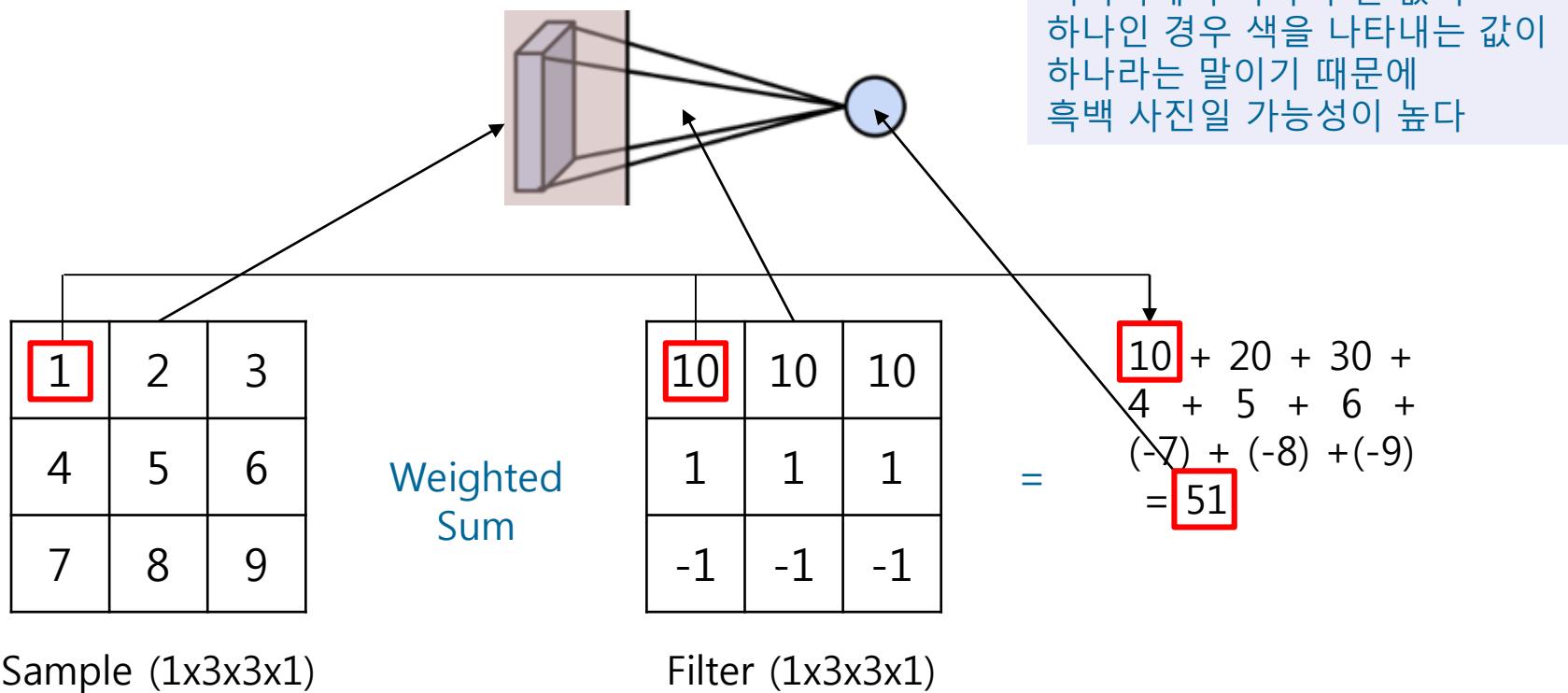


Convolution Layer



Convolution Layer

- ❖ 이미지를 Filter의 크기만큼 조각 내어 weighted sum을 한다



Convolution Layer

❖ 연습 문제

1	5	4	3
8	4	1	4
1	2	3	3
6	5	3	1

Weighted
Sum

Sample(1x4x4x1)

1	1	1	1
-1	-1	-1	-1
2	2	2	2
3	3	3	3

Filter(1x4x4x1)

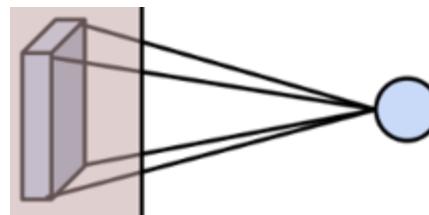
=



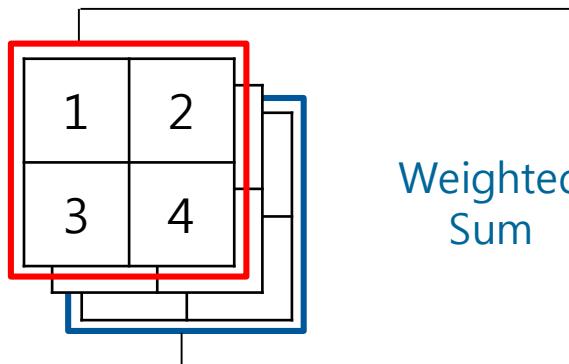
Convolution Layer

❖ Sample의 깊이에 대한 차원과 필터의 깊이에 대한 차원이 동일

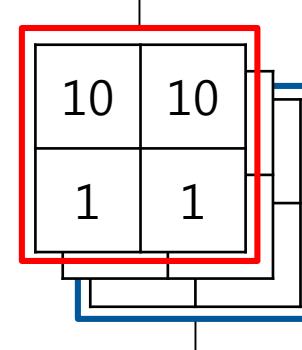
각 깊이마다 합성곱연산을 수행하여



이미지에서 하나의 셀 값이 세 개인 경우 색을 나타내는 값이 세 개이고, 이는 보통 R,G,B 이기 때문에 컬러 사진일 가능성이 높다



Sample(1x2x2x3)



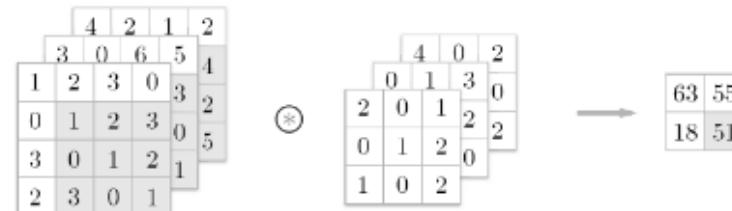
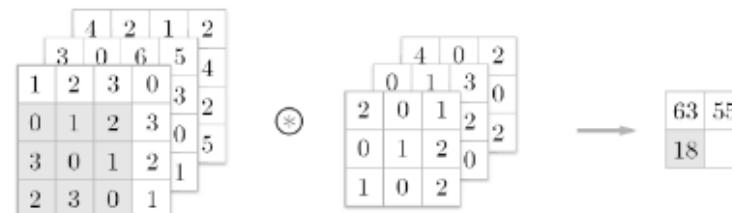
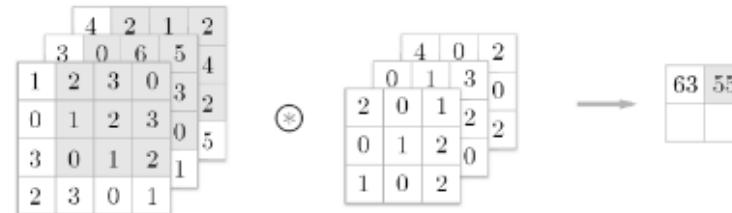
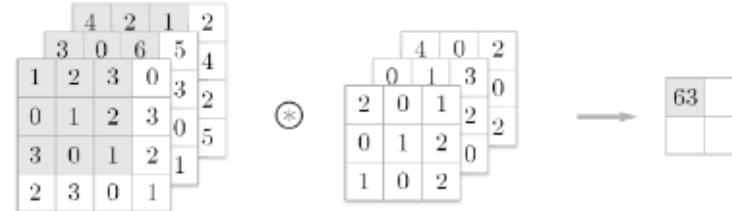
Filter(1x2x2x3)

$$\begin{aligned} & 10 + 20 + 3 + 4 \\ & + (?) + (?) + (?) + (?) \\ & + (?) + (?) + (?) + (?) \\ = & ? \end{aligned}$$

Convolution Layer

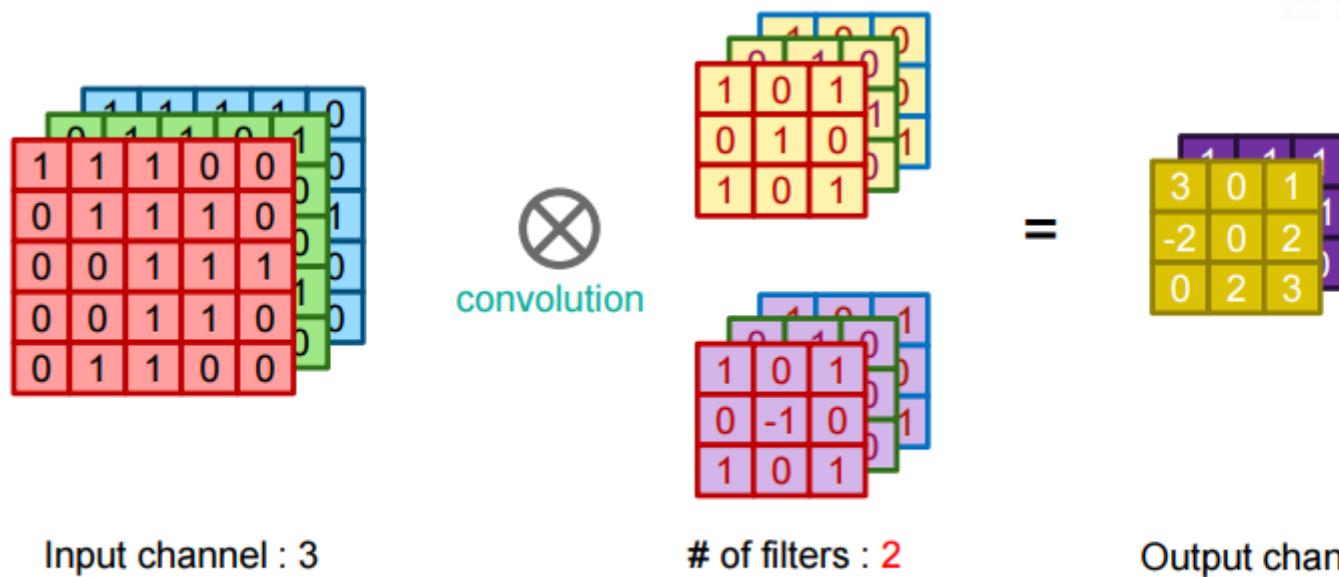
❖ 3차원 데이터의 합성곱

- 입력 데이터와 필터의 합성곱 연산을 깊이마다 수행하고 그 결과를 더해서 출력



Convolution Layer

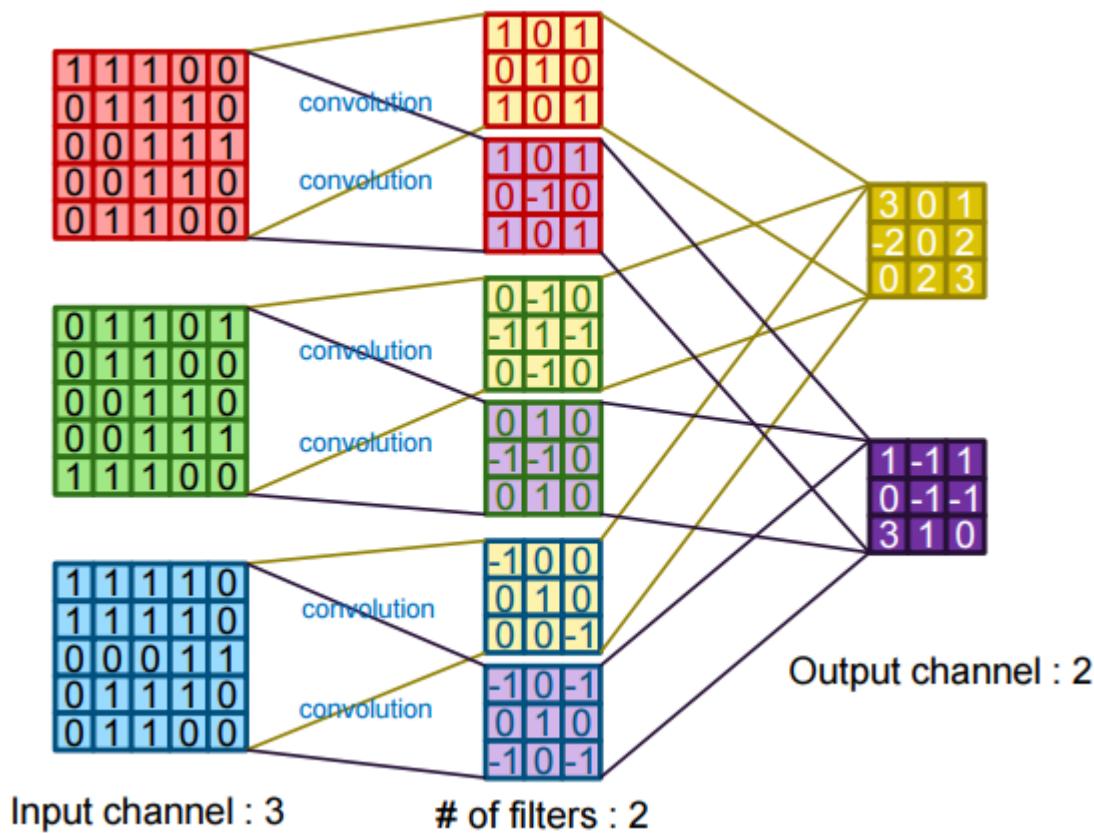
- ❖ Many filters, multi Channel



<https://predictiveprogrammer.com/famous-convolutional-neural-network-architectures-1>

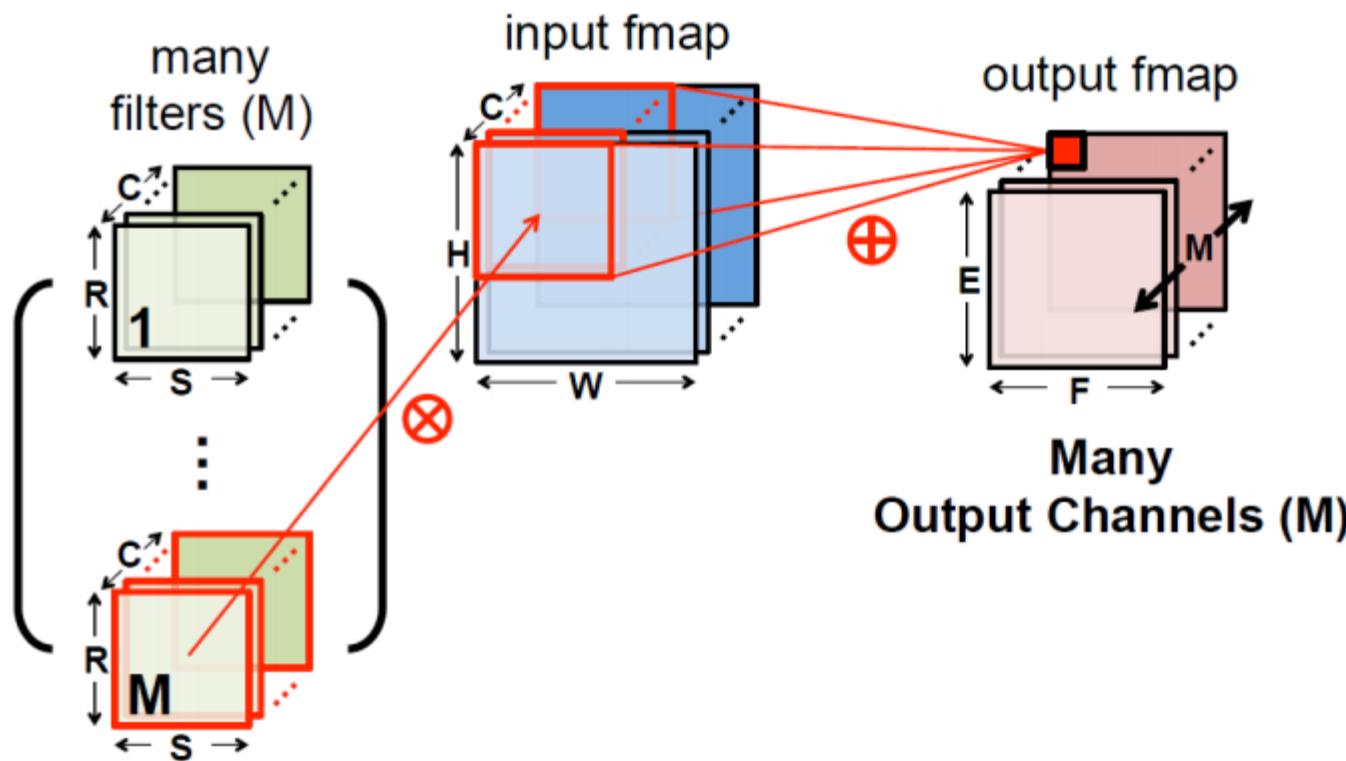
Convolution Layer

- ❖ Many filters, multi Channel



Convolution Layer

❖ Many filters, multi Channel

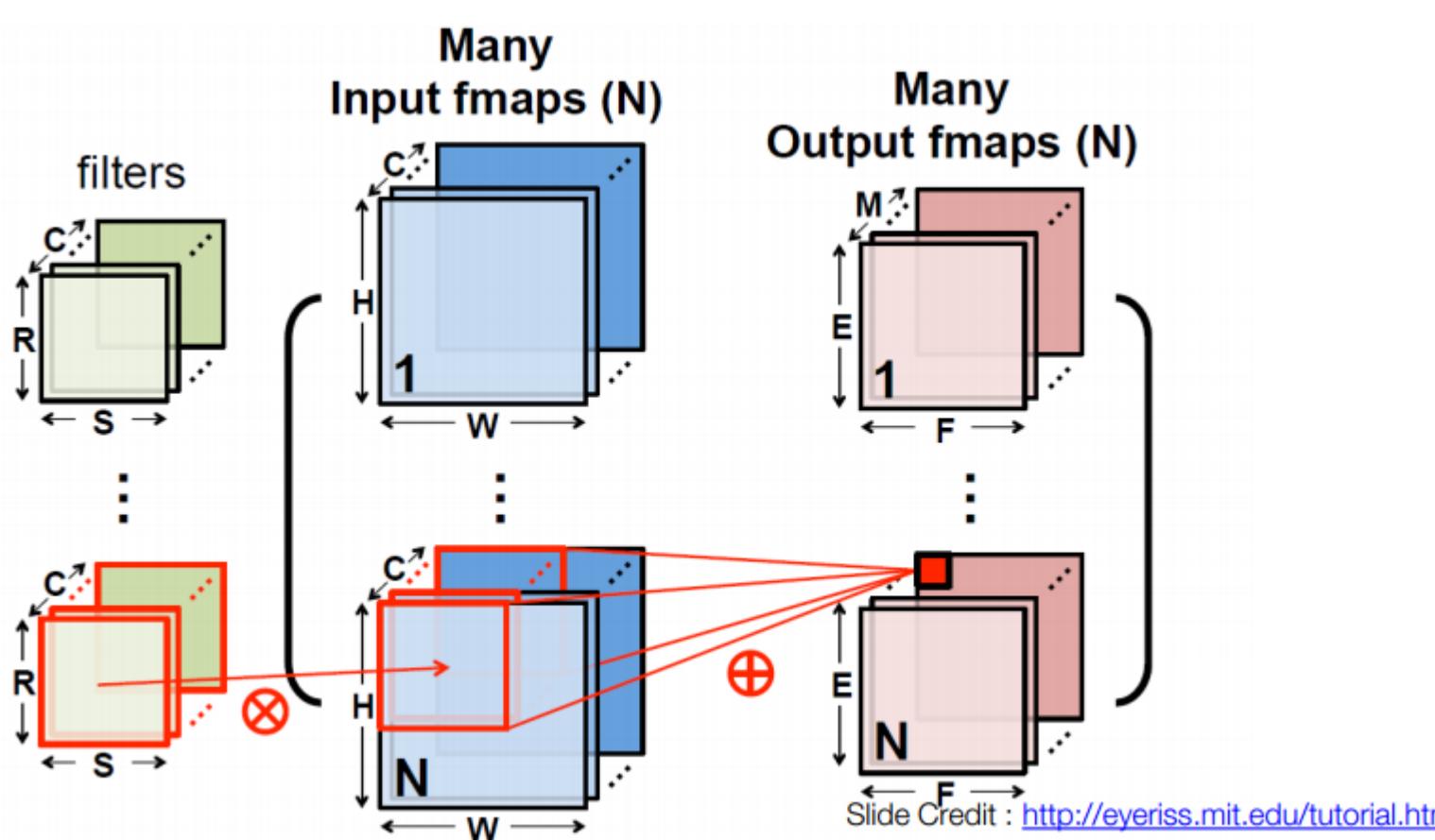


Slide Credit : <http://eyeriss.mit.edu/tutorial.html>

Convolution Layer

❖ Many input(batch size), Many filters, multi Channel

- Input(N, H, W, C), filter(R, S, C, M), Output(N, E, F, M)



Convolution Layer

- ❖ Activation map 이 28×28 이 되려면 어떻게 해야 할까?



Convolution Layer

❖ 쉬운 예

- 7x7 이미지에 3x3 필터를 적용하여 나올 수 있는 Activation map은?

다음 페이지에서 예상해보세요

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

7 x 7 x 1 image

0	0	0
1	1	1
2	2	2

3 x 3 x 1 filter

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

7 x 7 x 1 image

0	0	0
1	1	1
2	2	2

3 x 3 x 1 filter

5 x 5 x 1 activation map

or

3 x 3 x 1 activation map

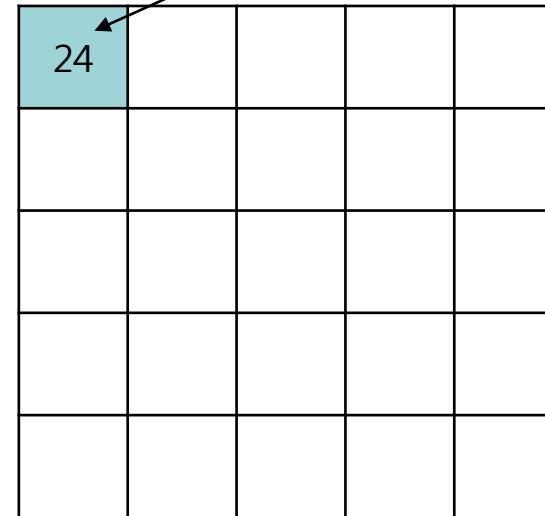
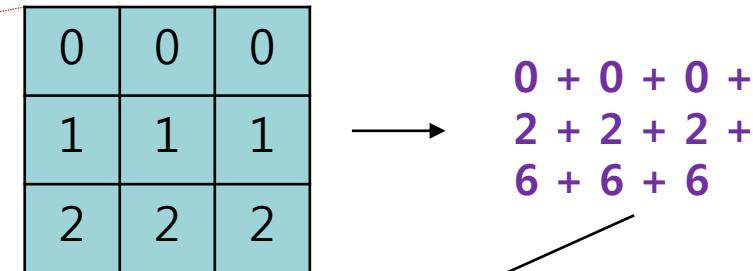
Convolution Layer

❖ Stride

- step당 건너뛰는 크기

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

Stride = 1



Activation map

Convolution Layer

❖ Stride

- step당 건너뛰는 크기

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

Stride = 1

0	0	0
1	1	1
2	2	2

Filter

24	24			

Activation map

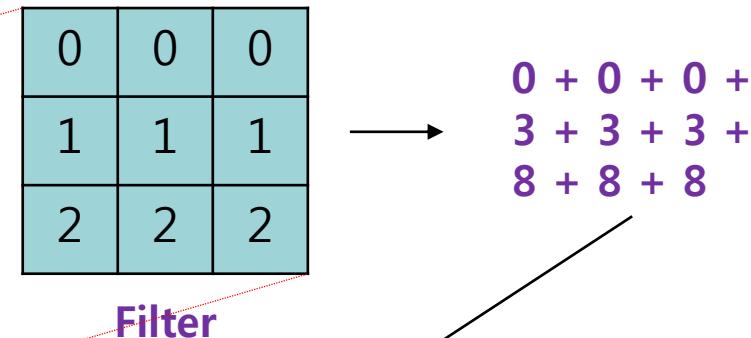
Convolution Layer

❖ Stride

- step당 건너뛰는 크기

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

Stride = 1



24	24	24	24	24
33				

Activation map

Convolution Layer

❖ Stride

- step당 건너뛰는 크기

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

Stride = 2

0	0	0
1	1	1
2	2	2

Filter

24		

$$0 + 0 + 0 + \\ 2 + 2 + 2 + \\ 6 + 6 + 6$$

Activation map

Convolution Layer

❖ Stride

- step당 건너뛰는 크기

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

Stride = 2

0	0	0
1	1	1
2	2	2

Filter

24	24	

Activation map

$$0 + 0 + 0 + \\ 2 + 2 + 2 + \\ 6 + 6 + 6$$

Convolution Layer

❖ Stride

- step당 건너뛰는 크기

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

Stride = 2

0	0	0
1	1	1
2	2	2

Filter

$$0 + 0 + 0 + \\ 4 + 4 + 4 + \\ 10 + 10 + 10$$

24	24	24
42		

Activation map

1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7

7 x 7 x 1 image

0	0	0
1	1	1
2	2	2

3 x 3 x 1 filter

24	24	24	24	24
33	33	33	33	33
42	42	42	42	42
51	51	51	51	51
60	60	60	60	60

5 x 5 x 1 activation map

or

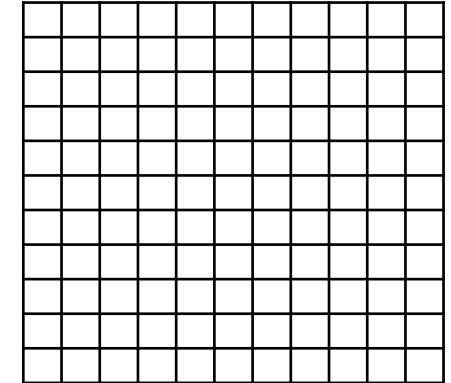
24	24	24
42	42	42
60	60	60

3 x 3 x 1 activation map

Exercise

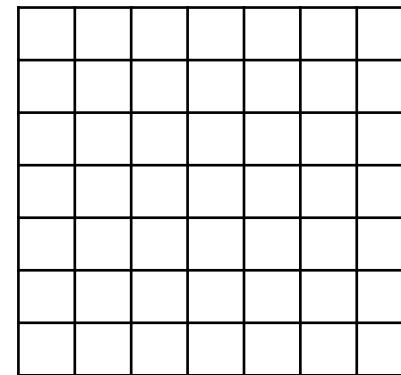
Q. $11 \times 11 \times 1$ Sample, $3 \times 3 \times 1$ Filter

- Stride = 1 일 때 activation map의 크기?
- Stride = 2 일 때 activation map의 크기?



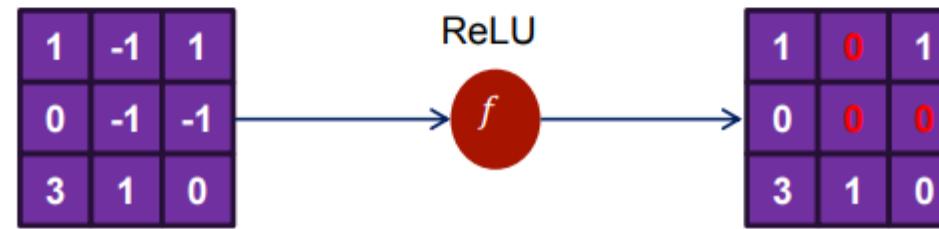
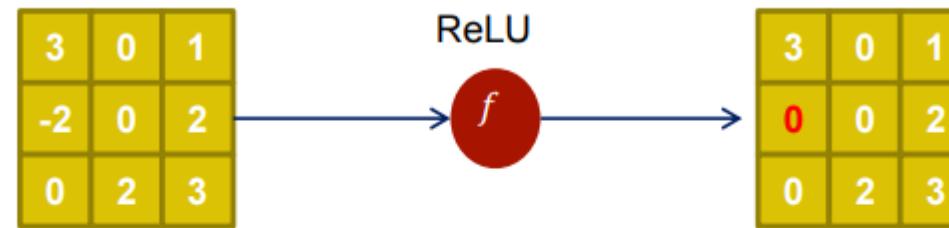
Q. $7 \times 7 \times 3$ Sample에서 $5 \times 5 \times 1$ 의 activation map 생성

- Filter의 크기는?
- Stride의 크기는?

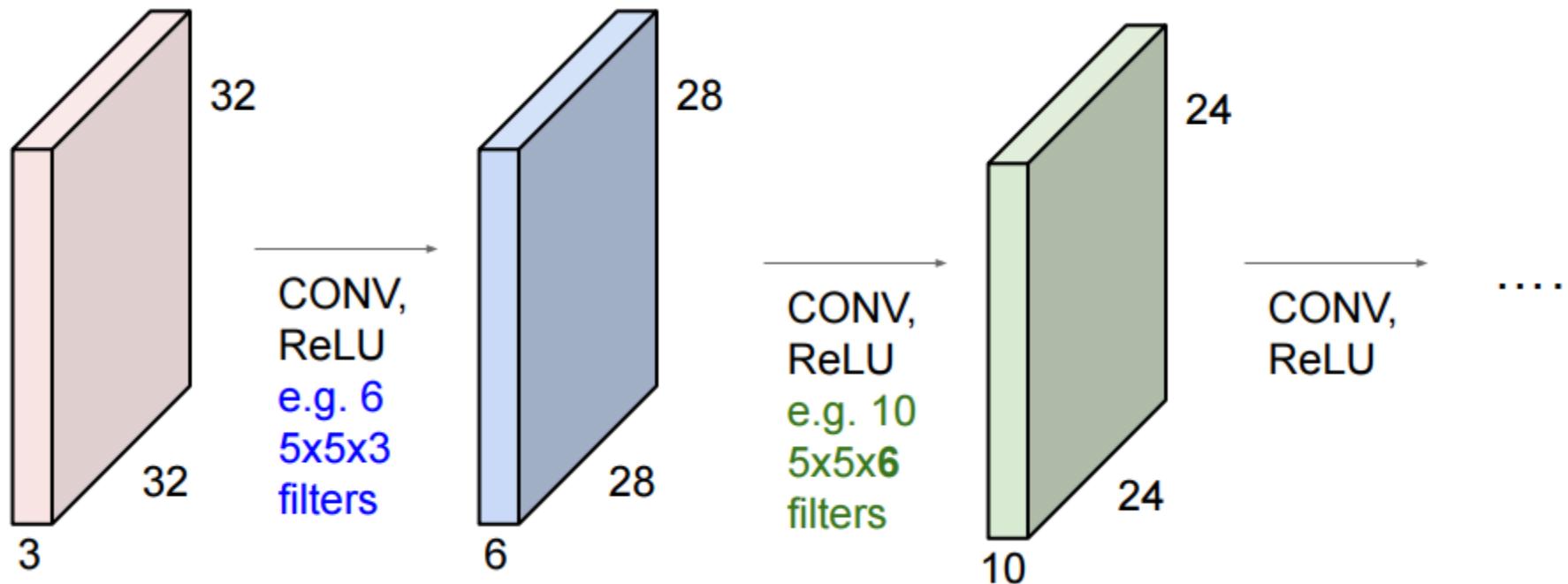


Activation function

- ReLU



Activation function



tf.keras.layers.Conv2D

```
tf.keras.layers.Conv2D(  
    filters, kernel_size, strides=(1, 1), padding='valid',  
    data_format=None, dilation_rate=(1, 1), activation=None,  
    use_bias=True, kernel_initializer='glorot_uniform',  
    bias_initializer='zeros', kernel_regularizer=None,  
    bias_regularizer=None, activity_regularizer=None,  
    kernel_constraint=None, bias_constraint=None, **kwargs  
)
```

filters : 필터개수

kernel_size : 커널 크기

strides=(1, 1) : 폭, 높이로 컨볼루션 보폭 지정

padding='valid' (패딩 안함), 'same' (stride 가 1일 때, 입력과 출력 크기가 같아지도록)

data_format : 입력 데이터 구조의 순서 (batch_size, height, width, channels) (default)

(batch_size, channels, rows, cols)if data_format = 'channels_first'

(batch_size, rows, cols, channels)if data_format = 'channels_last'.

activation: 활성화 함수 지정

https://www.tensorflow.org/api_docs/python/tf/keras/layers/Conv2D

tf.keras.layers.Conv2D

(출력 channel 개수 == 필터 개수)

kernel dimension : {height, width, in_channel, out_channel}
Ex) {5, 5, 3, 2}



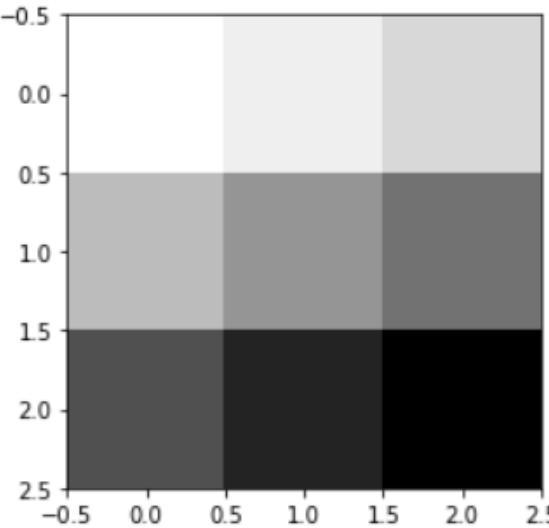
Input

```
import numpy as np
import tensorflow as tf
from tensorflow import keras
import matplotlib.pyplot as plt

print(tf.__version__)
print(keras.__version__)
```

```
image = tf.constant([[[[1],[2],[3]],
                     [[4],[5],[6]],
                     [[7],[8],[9]]]], dtype=np.float32)
print(image.shape)
plt.imshow(image.numpy().reshape(3,3), cmap='Greys')
plt.show()
```

(1, 3, 3, 1)

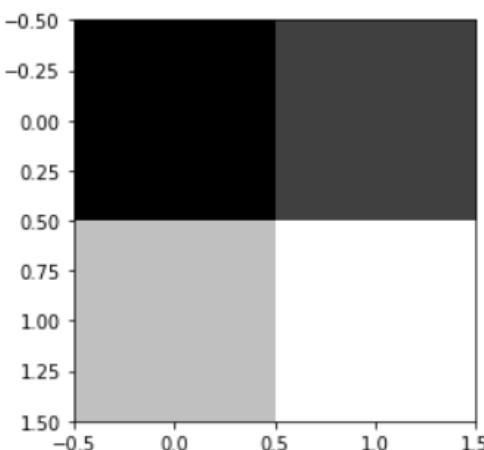


https://github.com/deeplearningzeroall/TensorFlow/blob/master/tf_2.x/lab-11-0-cnn-basics-keras-eager.ipynb

Weight(filter)

```
print("image.shape", image.shape)
weight = np.array([[[[1.],[1.]],
                   [[1.],[1.]]]])
print("weight.shape", weight.shape)
weight_init = tf.constant_initializer(weight)
conv2d = keras.layers.Conv2D(filters=1, kernel_size=2, padding='VALID',
                             kernel_initializer=weight_init)(image)
print("conv2d.shape", conv2d.shape)
print(conv2d.numpy().reshape(2,2))
plt.imshow(conv2d.numpy().reshape(2,2), cmap='gray')
plt.show()
```

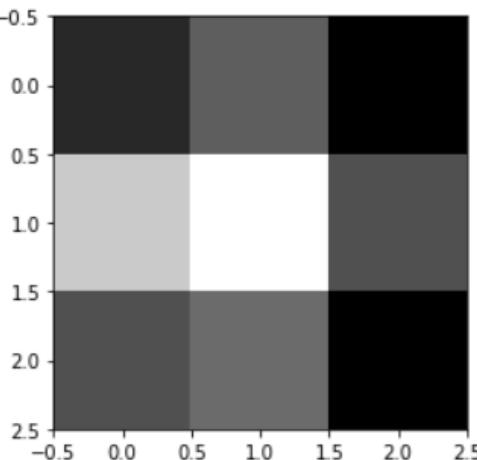
```
image.shape (1, 3, 3, 1)
weight.shape (2, 2, 1, 1)
conv2d.shape (1, 2, 2, 1)
[[12. 16.]
 [24. 28.]]
```



conv2d

```
print("image.shape", image.shape)
weight = np.array([[[[1.],[1.]],
                   [[1.],[1.]]]])
print("weight.shape", weight.shape)
weight_init = tf.constant_initializer(weight)
conv2d = keras.layers.Conv2D(filters=1, kernel_size=2, padding='SAME',
                            kernel_initializer=weight_init)(image)
print("conv2d.shape", conv2d.shape)
print(conv2d.numpy().reshape(3,3))
plt.imshow(conv2d.numpy().reshape(3,3), cmap='gray')
plt.show()
```

```
image.shape (1, 3, 3, 1)
weight.shape (2, 2, 1, 1)
conv2d.shape (1, 3, 3, 1)
[[12. 16.  9.]
 [24. 28. 15.]
 [15. 17.  9.]]
```



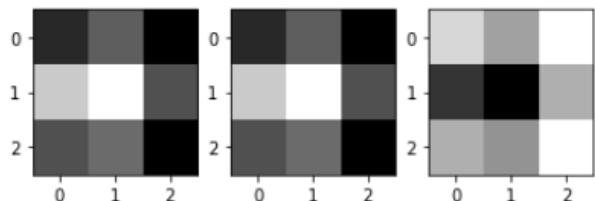
3 filters (2,2,1,3)

```
# print("image:\n", image)
print("image.shape", image.shape)

weight = np.array([[[[1.,10.,-1.]], [[1.,10.,-1.]]],  
                  [[[1.,10.,-1.]], [[1.,10.,-1.]]]])
print("weight.shape", weight.shape)
weight_init = tf.constant_initializer(weight)
conv2d = keras.layers.Conv2D(filters=3, kernel_size=2, padding='SAME',  
                           kernel_initializer=weight_init)(image)
print("conv2d.shape", conv2d.shape)
feature_maps = np.swapaxes(conv2d, 0, 3)
for i, feature_map in enumerate(feature_maps):
    print(feature_map.reshape(3,3))
    plt.subplot(1,3,i+1), plt.imshow(feature_map.reshape(3,3), cmap='gray')
plt.show()
```

```
image.shape (1, 3, 3, 1)
weight.shape (2, 2, 1, 3)
conv2d.shape (1, 3, 3, 3)
```

```
[[12. 16. 9.]  
 [24. 28. 15.]  
 [15. 17. 9.]]  
[[120. 160. 90.]  
 [240. 280. 150.]  
 [150. 170. 90.]]  
[[-12. -16. -9.]  
 [-24. -28. -15.]  
 [-15. -17. -9.]]
```



Padding

❖ Padding

- 이미지의 외각에 지정된 값만큼 특정 값으로 채워 넣는 작업

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

원본 $5 \times 5 \times 1$

Padding

❖ Padding

- 만일 외각 두께 1만큼 0으로 모두 채운다면 아래와 같은 형태가 된다

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

Padding 후 $7 \times 7 \times 1$

모두 0으로 채우는 것을 zero padding 이라고도 한다

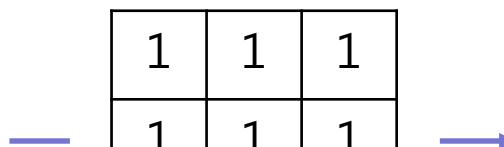
Padding

❖ Padding

- filter = $3 \times 3 \times 1$, stride = 1 을 진행하면 padding 을 하기 전과 크기가 같다

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

Padding 후 $7 \times 7 \times 1$



$3 \times 3 \times 1$ filter

Stride = 1

4	6	6	6	4
6	9	9	9	6
6	9	9	9	6
6	9	9	9	6
4	6	6	6	4

Activation map
 $5 \times 5 \times 1$

Padding

❖ Padding

- Weighted sum 을 데이터의 drop 없이 모두 수행
- Sample 의 크기가 너무 빨리 줄어드는 것을 방지
- 경계면의 정보를 유지
- 출력크기를 조정할 때 사용

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

Padding

- ❖ 입력 크기 (H,W), 필터 크기 (FH, FW), 출력 크기를 (OG, OW), 패딩 P, 스트라이드 S일 때 출력의 크기는 ?

$$OH = (H + 2P - FH) / S + 1$$

$$OW = (W + 2P - FW) / S + 1$$

예>(1) 입력 (4,4) 필터(3,3) 패딩 1, 스트라이드 1

$$OH = (4 + 2*1 - 3) / 1 + 1 = 4$$

$$OW = (4 + 2*1 - 3) / 1 + 1 = 4$$

(2) 입력 (28,32) 필터(5,5) 패딩 2, 스트라이드 2 ??

Padding

❖ Padding 고급

- padding = 'VALID'

원본 $11 \times 11 \times 1$

1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1

하얀색은 쓰이지 않고 버려지는 부분

1	1	1	1	1	1
1	1	1	1	1	1
1	1	1	1	1	1
1	1	1	1	1	1
1	1	1	1	1	1

$6 \times 6 \times 1$ filter

Activation map
 $(2, 2, 1)$

Stride = 4

Padding

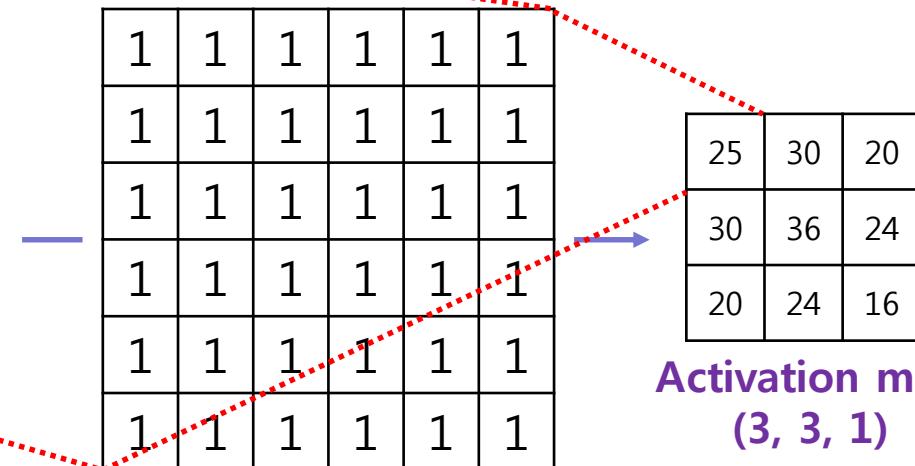
❖ Padding 고급

- padding = 'SAME' -> stride = 4, filter = 6×6 을 완수하려면 3칸이 더 필요

A 11x11 input matrix with padding. The input values are 0 or 1. The input is processed by a 6×6 filter with stride 4. The output is a 3x3 activation map. The input has 3 extra columns of padding (0s) on both sides.

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

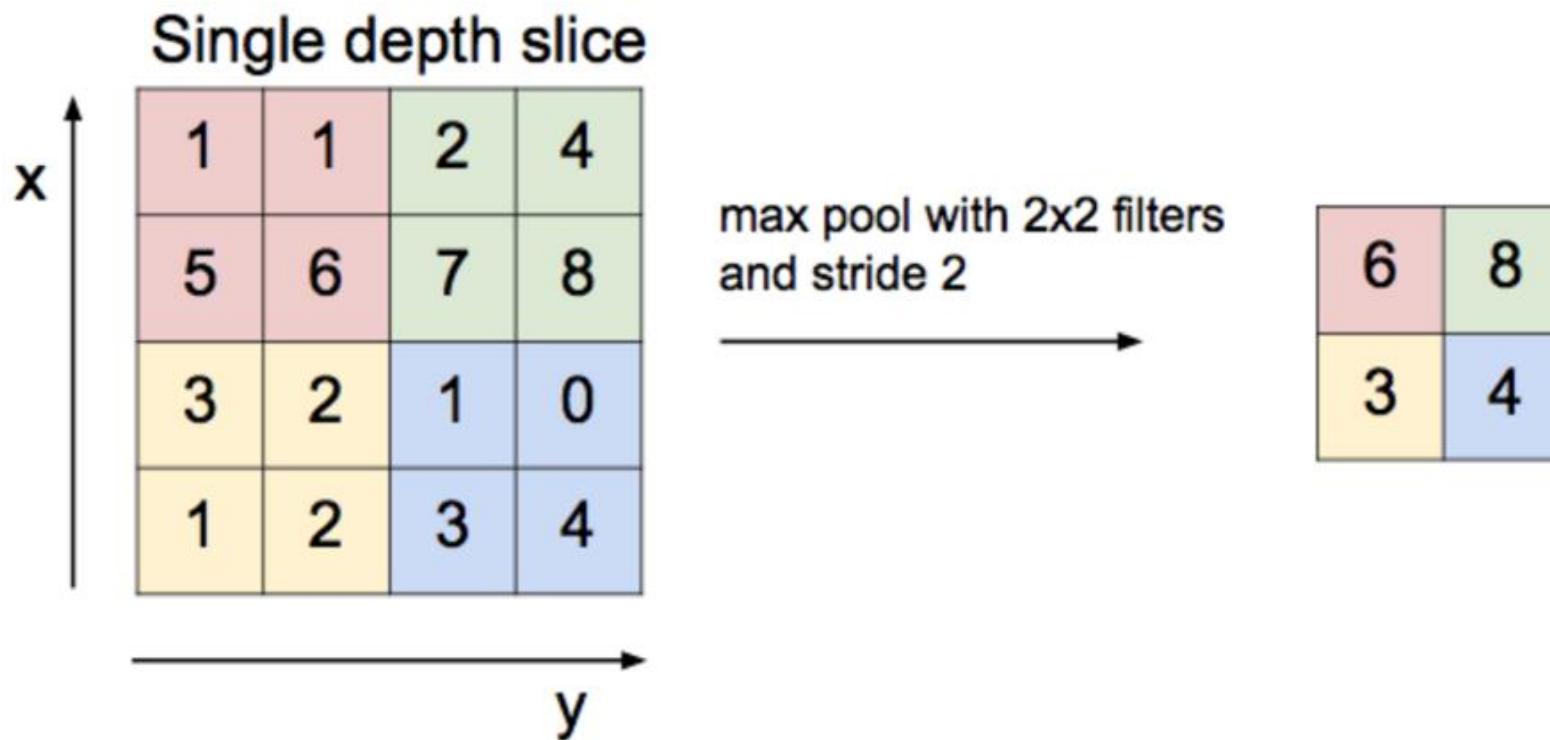
원본 $11 \times 11 \times 1 \rightarrow 14 \times 14 \times 1$



Stride = 4

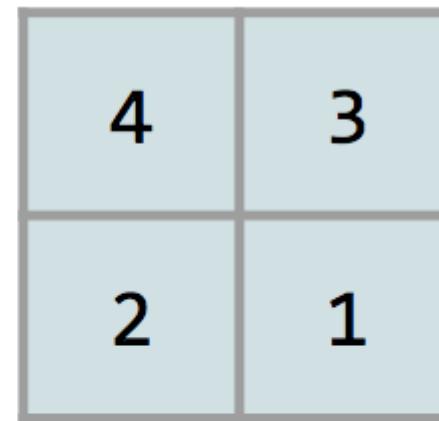
Activation map
(3, 3, 1)

MAX POOLING



Padding

padding='valid'



```
image = tf.constant([[[[4],[3]],
                     [[2],[1]]]], dtype=np.float32)
pool = keras.layers.MaxPool2D(pool_size=(2,2), strides=1, padding='VALID')(image)
print(pool.shape)
print(pool.numpy())
```

(1, 1, 1, 1)
[[[4.]]]

Padding

SAME: Zero paddings

4	3	0
2	1	0
0	0	0

4	3	0
2	1	0
0	0	0

4	3	0
2	1	0
0	0	0

4	3	0
2	1	0
0	0	0

```
image = tf.constant([[[[4],[3]],  
                     [[2],[1]]]], dtype=np.float32)  
pool = keras.layers.MaxPool2D(pool_size=(2,2), strides=1, padding='SAME')(image)  
print(pool.shape)  
print(pool.numpy())
```

```
(1, 2, 2, 1)  
[[[4.,  
   [3.,  
    [2.,  
     [1.]]]]]
```

```
[[[2.,  
   [1.]]]]]
```

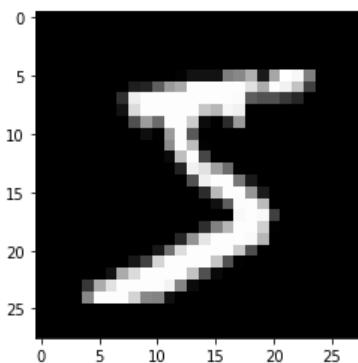
MNIST CNN

```
mnist = keras.datasets.mnist
class_names = ['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']
#mnist = keras.datasets.fashion_mnist
#class_names = ['T-shirt/top', 'Trouser', 'Pullover', 'Dress', 'Coat', 'Sandal', 'Shirt', 'Sneaker', 'Bag', 'Ankle boot']
```

```
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()
```

```
train_images = train_images.astype(np.float32) / 255.
test_images = test_images.astype(np.float32) / 255.
```

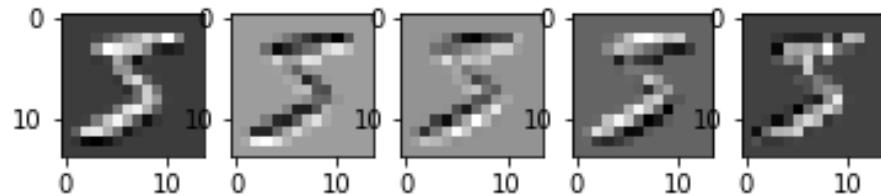
```
img = train_images[0]
plt.imshow(img, cmap='gray')
plt.show()
```



MNIST CNN

```
img = img.reshape(-1,28,28,1)
img = tf.convert_to_tensor(img)
weight_init = keras.initializers.RandomNormal(stddev=0.01)
conv2d = keras.layers.Conv2D(filters=5, kernel_size=3, strides=(2, 2), padding='SAME',
                             kernel_initializer=weight_init)(img)
print(conv2d.shape)
feature_maps = np.swapaxes(conv2d, 0, 3)
for i, feature_map in enumerate(feature_maps):
    plt.subplot(1,5,i+1), plt.imshow(feature_map.reshape(14,14), cmap='gray')
plt.show()
```

(1, 14, 14, 5)



MNIST CNN

```
pool = keras.layers.MaxPool2D(pool_size=(2, 2), strides=(2, 2), padding='SAME')(conv2d)
print(pool.shape)

feature_maps = np.swapaxes(pool, 0, 3)
for i, feature_map in enumerate(feature_maps):
    plt.subplot(1,5,i+1), plt.imshow(feature_map.reshape(7, 7), cmap='gray')
plt.show()
```

(1, 7, 7, 5)

