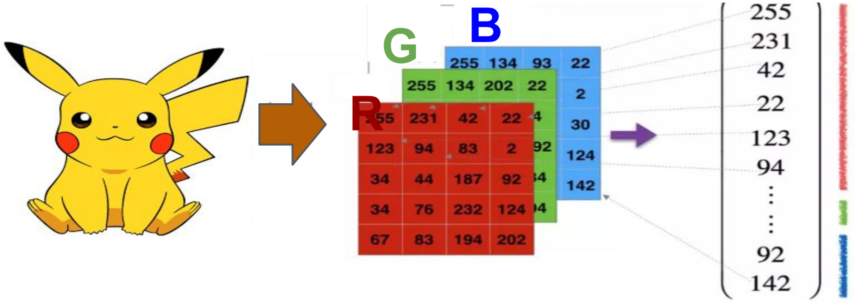
Convolutional Neural Network

How it “understand” Image and Text

Before CNN

Computers See Image

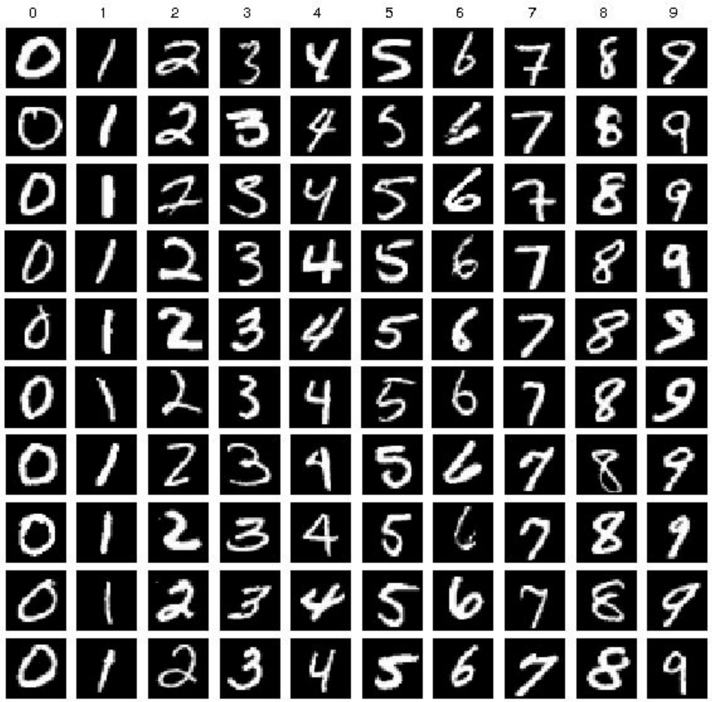


Softmax Classifier
SVM
….

Fully-Connected
Neural Network

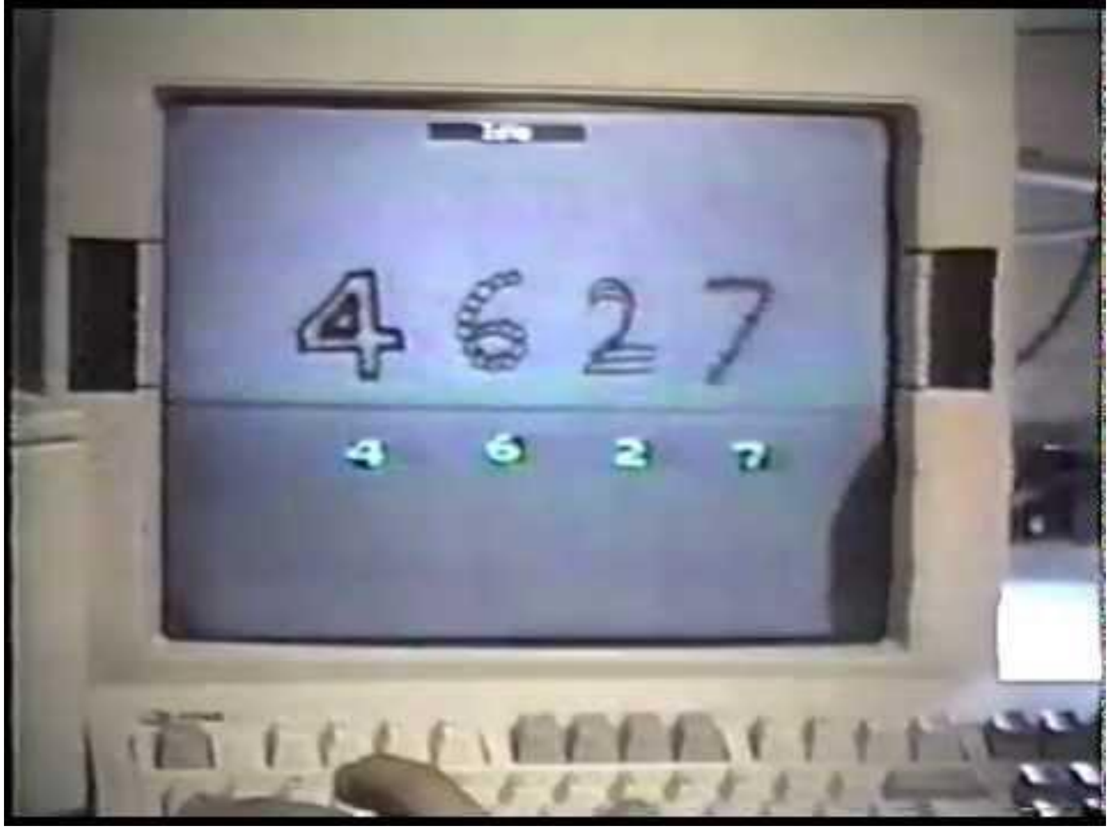
Labels

Think about MNIST Dataset



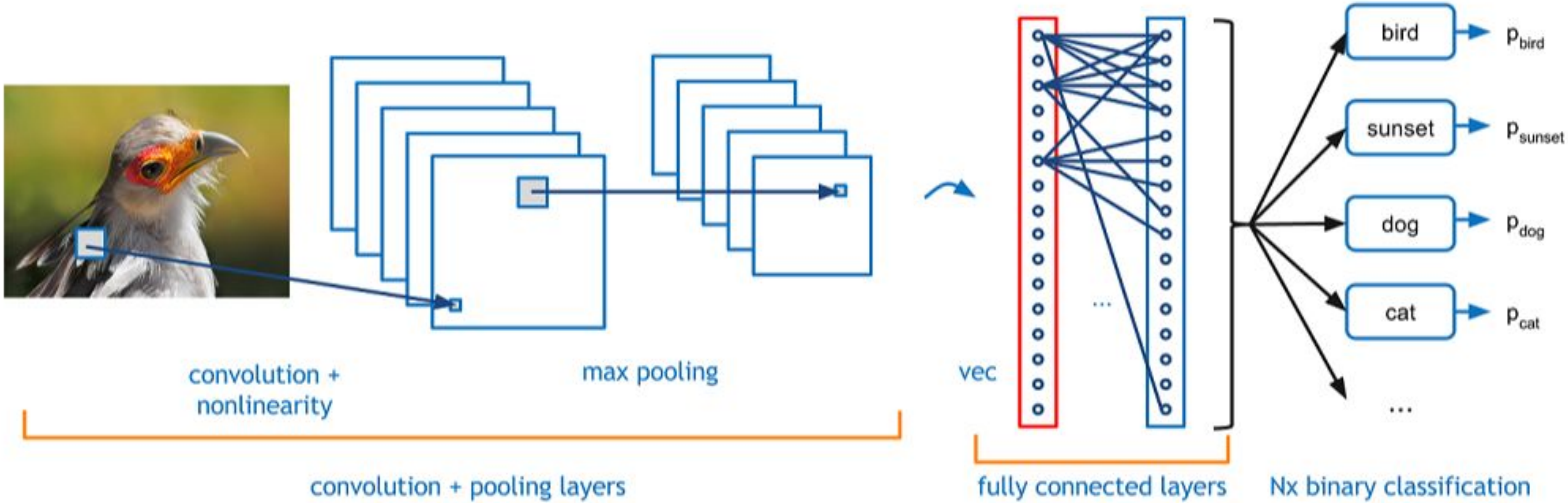
The above model requires the digit should be in the center of the image and it had to be the only thing in the image.

Intro to CNN



https://www.youtube.com/watch?v=FwFduRA_L6Q

Convolutional Neural Network

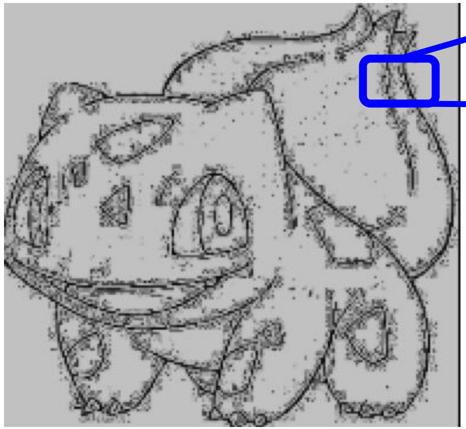


Extracting useful features of data

Perform a ML task (like classification based on the vectorized data)

Filter Operation

Consider neighbor values



0	32	35
34	$\boxed{203}$	122
132	223	163

Current Pixel Value is 203

Dot Product

-1	**0**	**-2**
.5	**4.5**	**-1.5**
1.5	**2**	**-3**

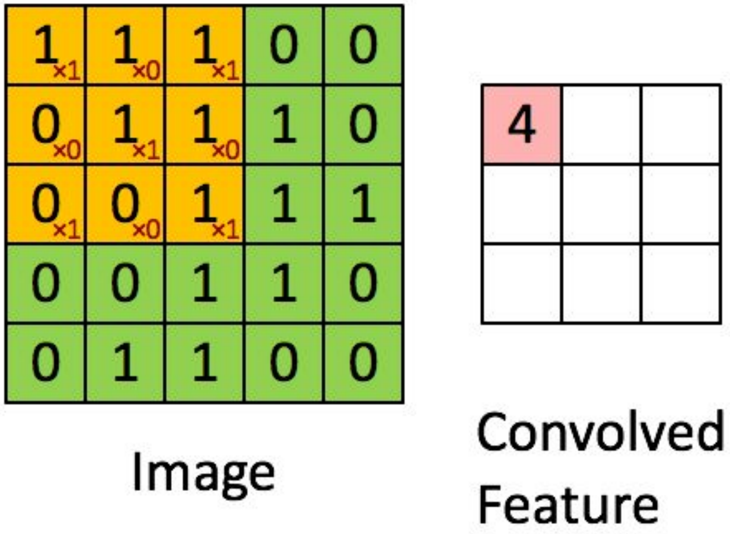
Filter (3 by 3)

New Pixel Value

(-1 * 0) + (0 * 32) + (-2 * 35) +
(.5 * 34) + (4.5 * 203) + (-1.5 * 122) +
(1.5 * 132) + (2 * 223) + (-3 * 163)

Convolutional Operation

- Apply the **same** filter for every pixel in the original image
- Filter Size is the shape of the filter matrix (yellow one)



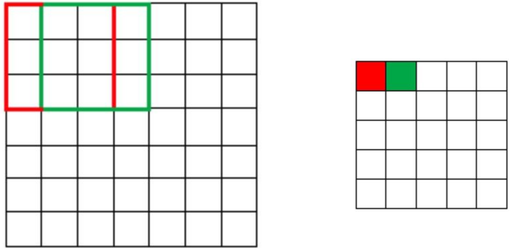
Feature Map

Stanford UFLDL

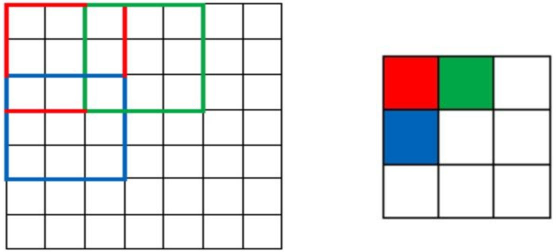
Stride

- Controls how the filter move around the image
- It is the amount by which the filter shifts

Stride is 1

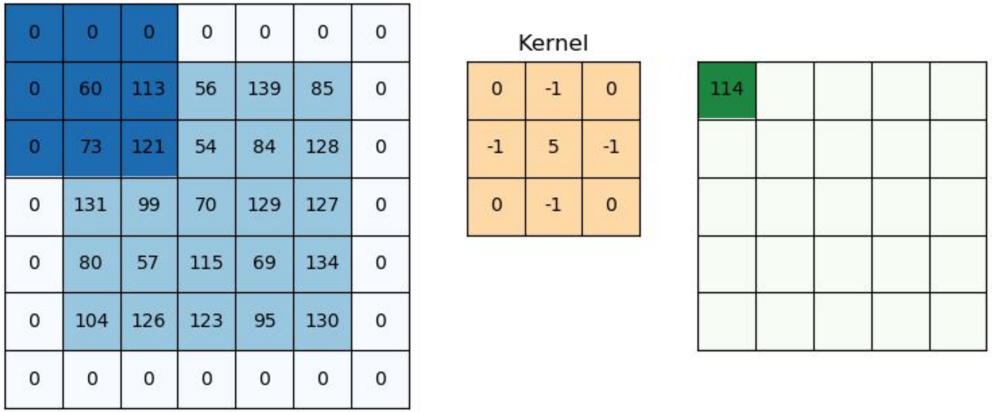


Stride is 2



Zero Padding

- Pads the image with zeros around the **border**
- Make the input image and feature map have the same spatial dimensions



Stride: 1
Size of zero padding:
(k-1)/2

https://stackoverflow.com/questions/52067833/how-to-plot-an-animated-matrix-in-matplotlib

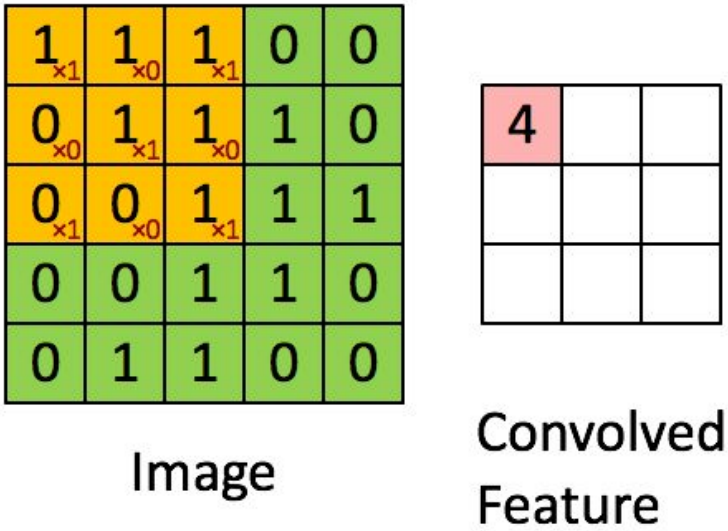
Convolutional Operation

- Filter Size: K
- Stride Size: S
- Padding Size: P

Input size

$$o = \frac{W-K+2P}{S} + 1$$

Output size



Stanford UFLDL

Multi-Channel CNN

- A color image is a 3-D tensor
- 400 (height) 630 (width) 3 (R,G,B channels)

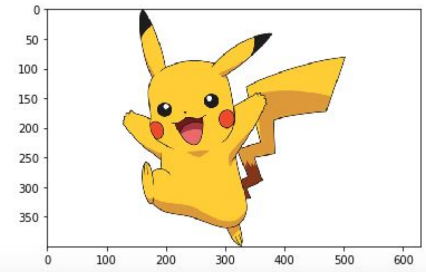
```python
from matplotlib.image import imread
import numpy as np
img = imread('pikka_3.jpg')
```

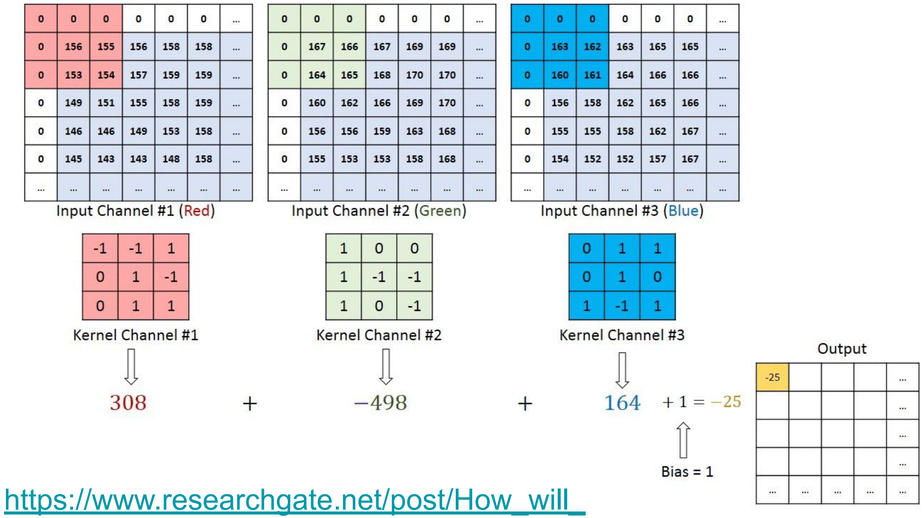
```python
print(img.shape)
```

```
(400, 630, 3)
```

```python
plt.imshow(img, interpolation='nearest')
```

```
<matplotlib.image.AxesImage at 0x11b404278>
```





https://www.researchgate.net/post/How_will_channels_RGB_effect_convolutional_neural_network

From Keras Layers Conv2D

Input shape

4D tensor with shape: `(batch, channels, rows, cols)` if `data_format` is `"channels_first"` or 4D tensor with shape: `(batch, rows, cols, channels)` if `data_format` is `"channels_last"`.

Output shape

4D tensor with shape: `(batch, filters, new_rows, new_cols)` if `data_format` is `"channels_first"` or 4D tensor with shape: `(batch, new_rows, new_cols, filters)` if `data_format` is `"channels_last"`. `rows` and `cols` values might have changed due to padding.

How Filter Works

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

Image

Convolved Features

Only Keep Vertical Lines

How Filter Works

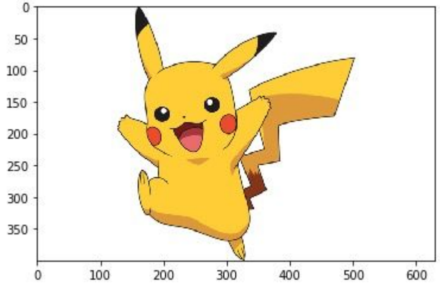
-1	-2	-1
0	0	0
-1	2	1

Image

Convolved Features

Only Keep Horizontal Lines

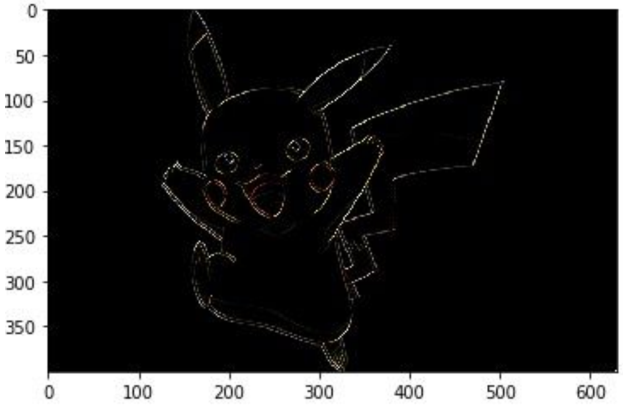
Filter comes from “Image Processing”



Image

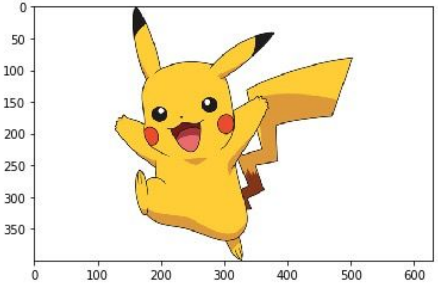
```
print(kernel)

[[ 1  0 -1]
 [ 0  0  0]
 [-1  0  1]]
```

Edge Detection



Convolved Features

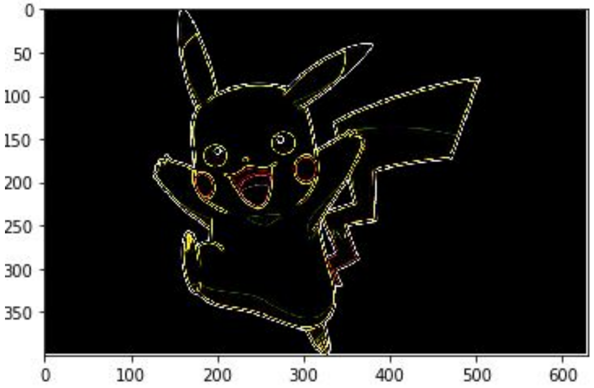
Filter comes from “Image Processing”



Image

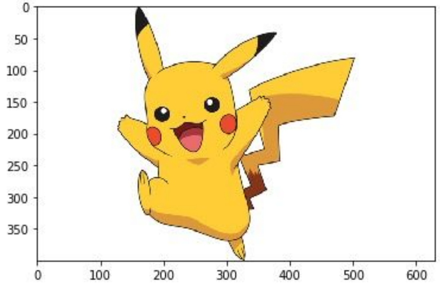
```
print(kernel)

[[-1 -1 -1]
 [-1  8 -1]
 [-1 -1 -1]]
```

Edge Detection



Convolved Features

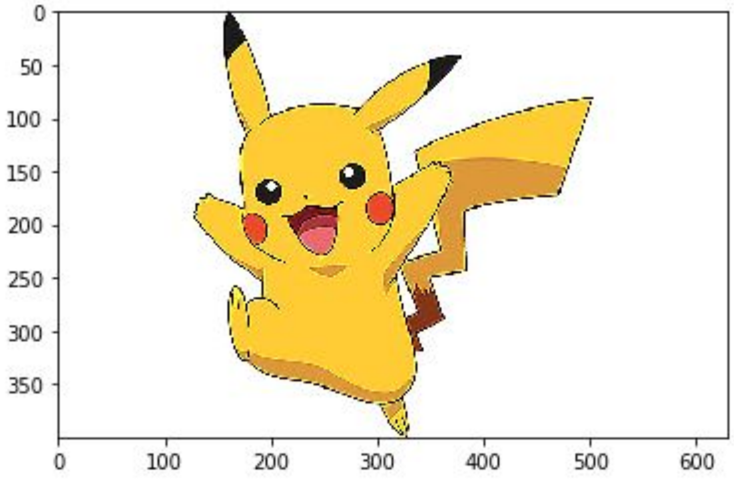
Filter comes from “Image Processing”



Image

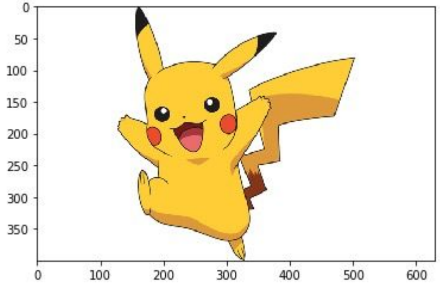
```
print(kernel)
[[ 0 -1  0]
 [-1  5 -1]
 [ 0 -1  0]]
```

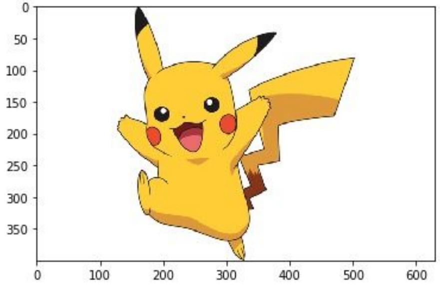
Sharpen



Convolved
Features

Filter comes from “Image Processing”





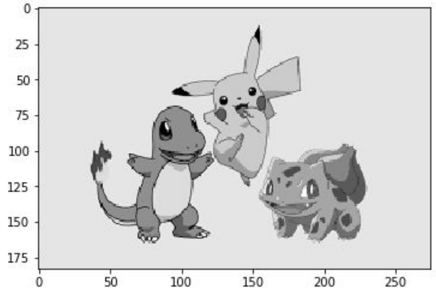
Image

Identity

Convolved Features

Non-linear Activation

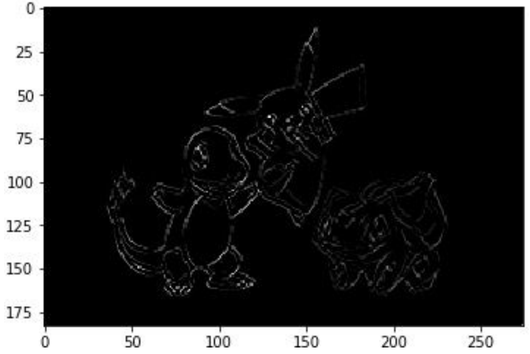
- In nature, filter operation is dot product.
- In deep learning, we need to have non-linear transformation.
- Add non-linear activation



Image

```
print(kernel)
[[ 1  0 -1]
 [ 0  0  0]
 [-1  0  1]]
```

non-linear

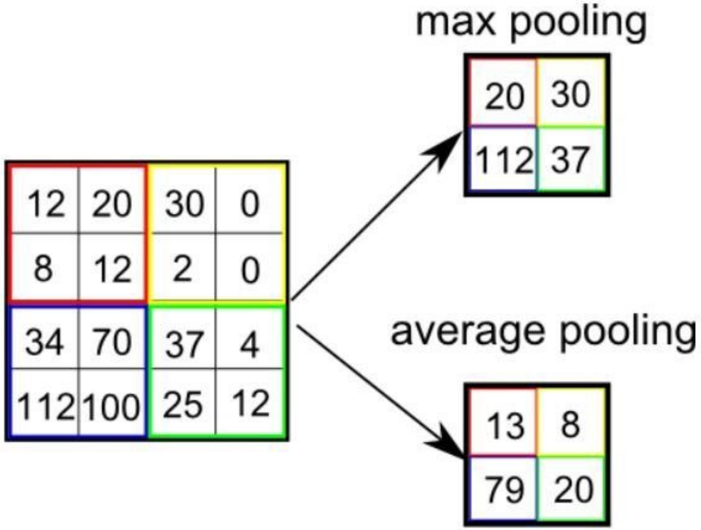


The First Task in Assignment II

Pooling Operation

- Pooling Size: the box size. Here is 2 * 2
- Stride Size: how much pixel the window move

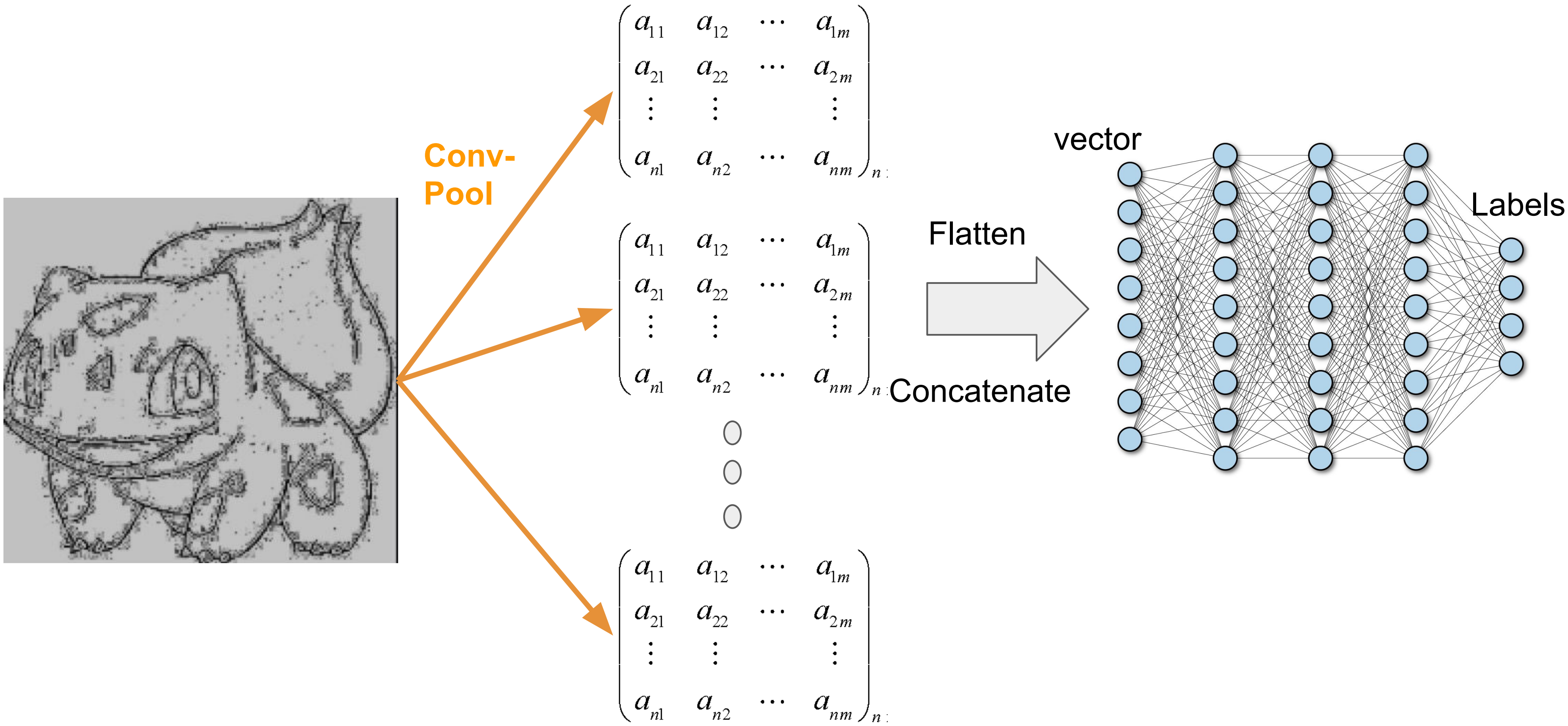
What is stride size here？



Filter then Pool

1. The size is **one quarter** the original size
2. The **vertical line** features are **enhanced**.

Conv-Pool



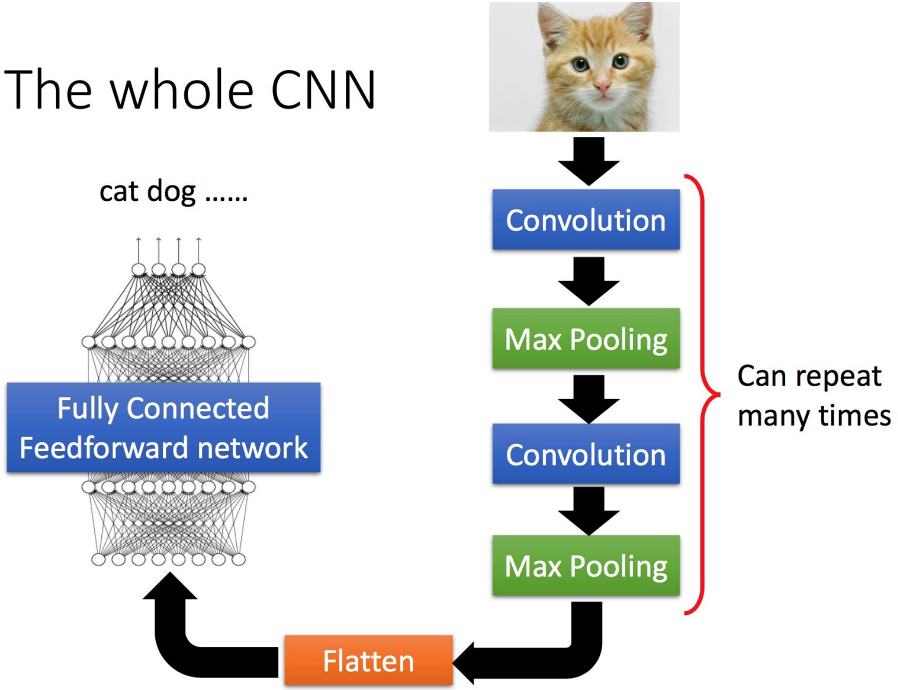
Where are these filters from?

- Filters, in nature, are model parameters, which can be **learned** by backpropagation.
- These filters weights are firstly randomly initialized, and then updated during training process.
- End-to-End optimization: Backpropagation.
- More details: https://towardsdatascience.com/training-a-convolutional-neural-network-from-scratch-2235c2a25754

CNN Can be Deep

- Convolution-Pooling can be followed by another Convolution-Pooling

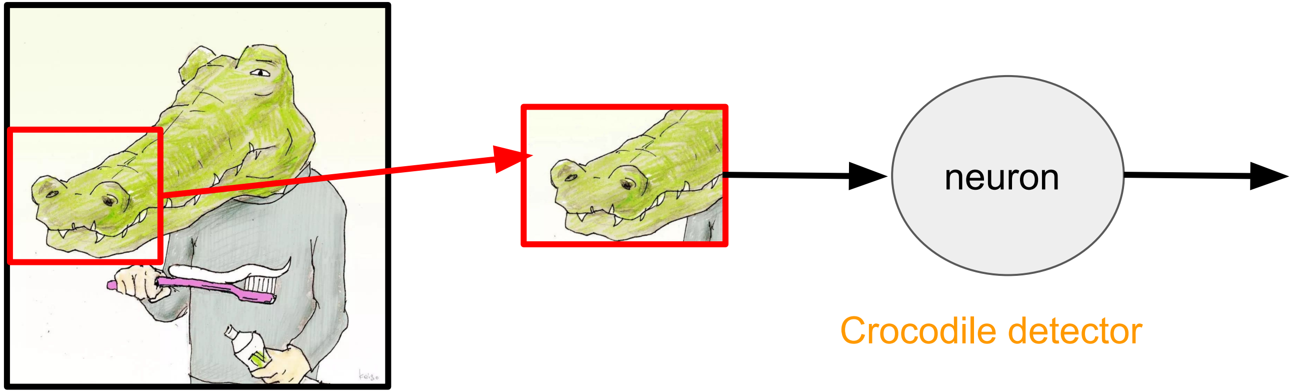
- At the end, after flatten operation, fully connected layers are used to map the outputs.



Why CNN is Suitable for Images

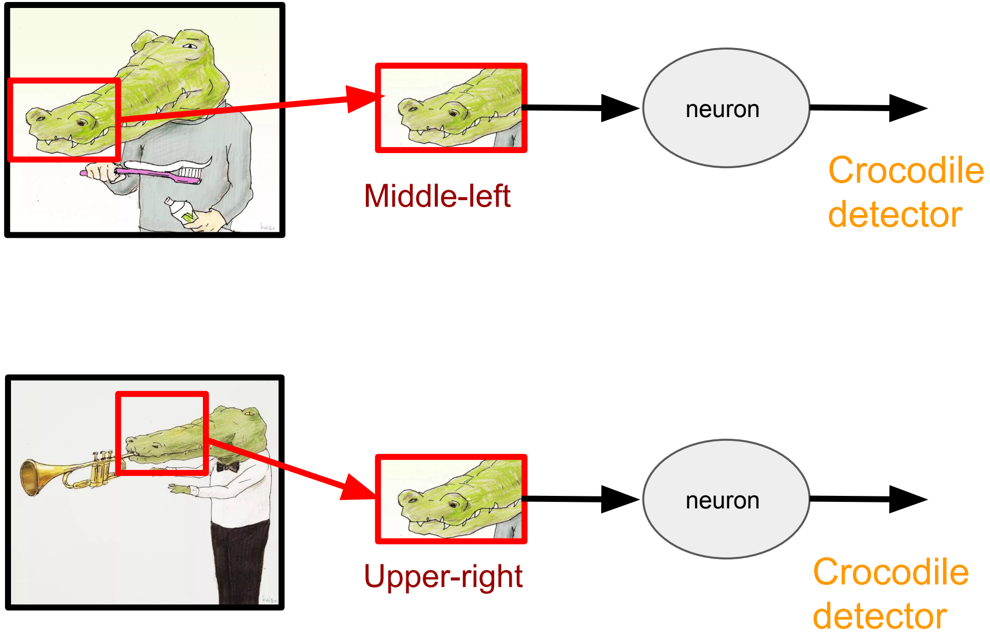
Local Features Matter

- Discriminative patterns are much smaller than the whole image
- A neuron does not have to see the whole image
- Less parameters required



Location Insensitive

- The same patterns appear in different regions
- A neuron should be location insensitive.



Subsampling Works

- Subsampling the pixels will not change the object
- We can subsample the pixels to make images smaller -> less parameters required

Crocodile

subsampling

Crocodile

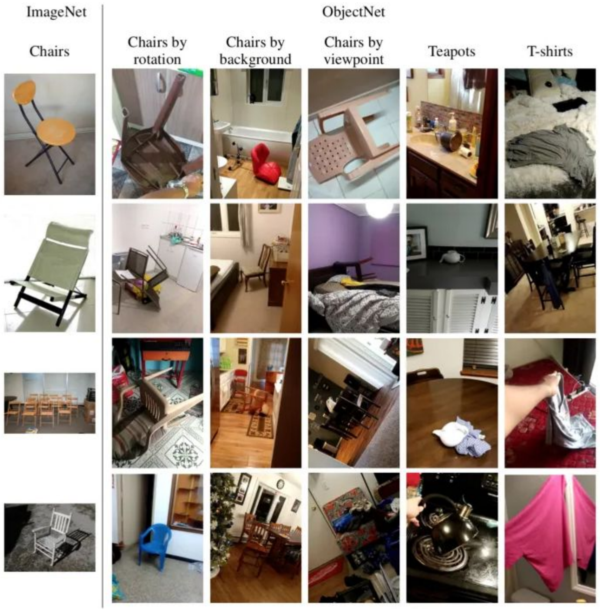
Limitations of CNN

CNN is different human vision

- CNN can handle translations. But they can not cope with the effects of **changing viewpoints such as rotation and scaling**

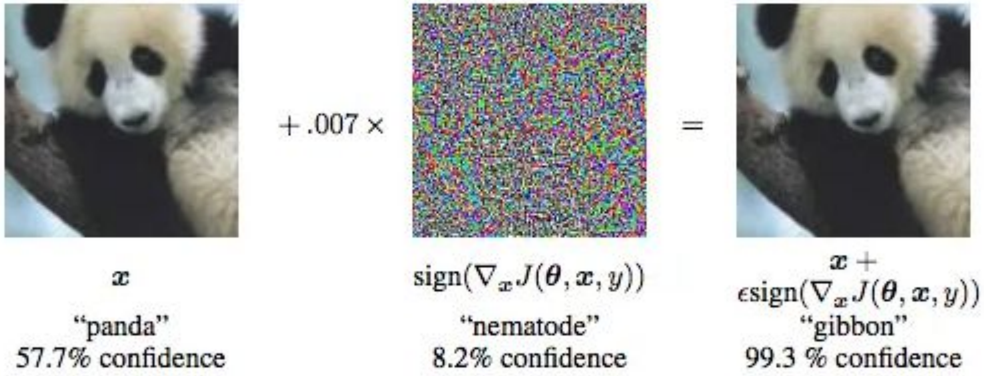
- Human is able to generalize knowledge.

neatly positioned **Real world**



From: objectnet.dev

CNN is different human vision



Adversarial examples can cause neural networks to misclassify images while appearing unchanged to the human eye

Solutions

- Use 4D or 6D maps to train machine learning model
  - Too expensive

- Get huge-size training data that cover all positions of objects.
  - Data augmentation: flip the image or rotate it by some angle. Then, CNN will be trained on multiple copies of every image, each being slightly different.
  - It will never cover all of corner cases.

https://www.kdnuggets.com/2018/05/data-augmentation-deep-learning-limited-data.html

CNN is different human vision

- CNN may get confused by seeing this bizarre teapot, since they can not understand images in terms of objects and their parts.

- Human is able to decompose an object into parts and then we can understand its nature.

CNN for Text

CNN works for Text

Images

- Local Features Matter
- Locations Insensitive
- Subsampling Works

Texts

- Key n-grams define semantics

  Pulp fiction's director is Quentin. I ***am obsessed of*** *it.*

- Locations of key n-grams Insensitive?

  I ***am obsessed of*** *Pulp fiction, whose director is Quentin.*

  Pulp fiction's director is Quentin. I ***am obsessed of*** *it.*

  I owe you ten dollars
  You owe me ten dollars.

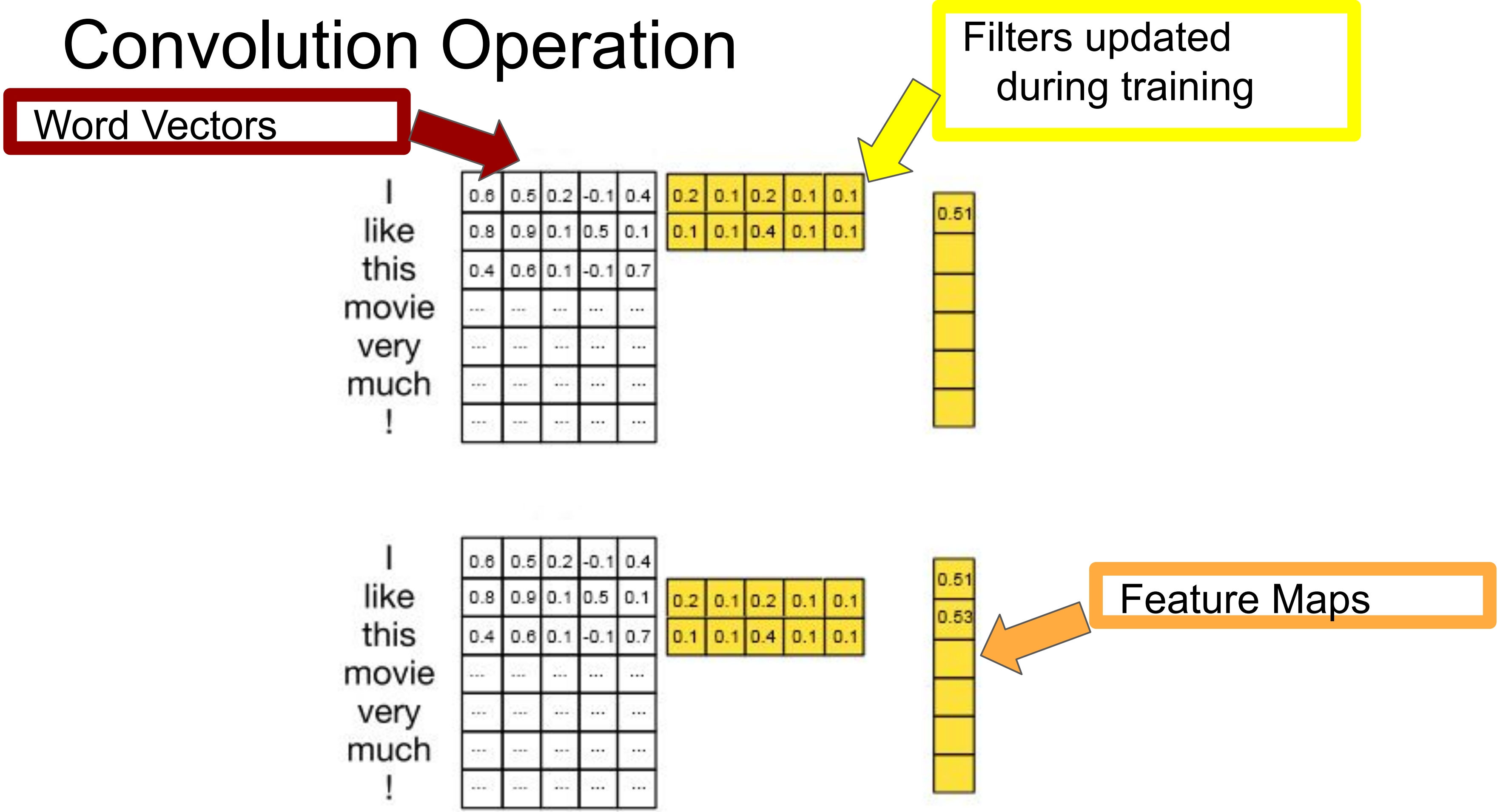
- Doc. Summarization

Combinations

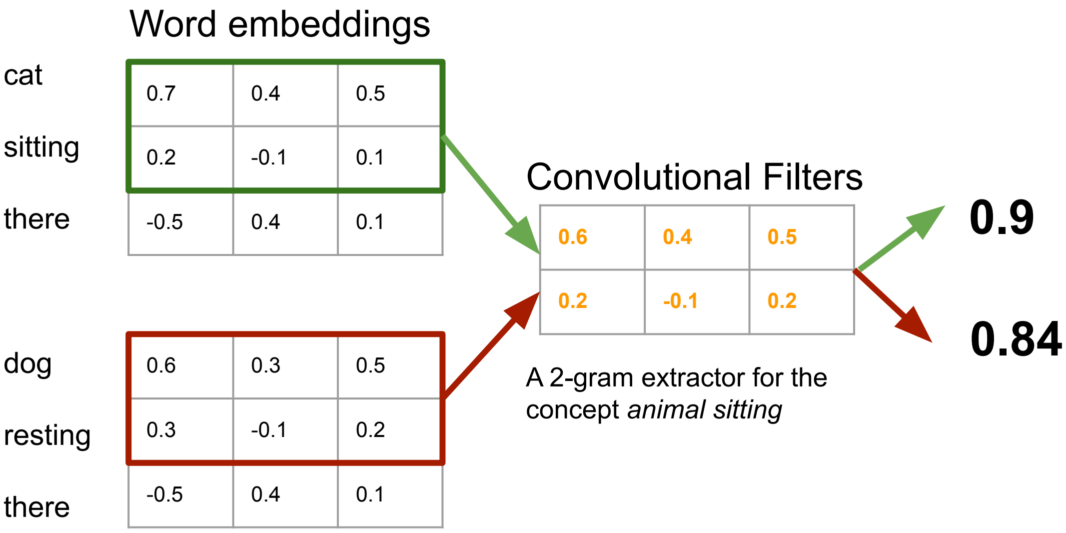
E.g., *I hate this movie*

- Compute vectors for every possible phrase
    - *I hate this movie* ----> I hate; hate this; this movie
- Compute these vectors for these phrases

Convolution Operation



Toy Example

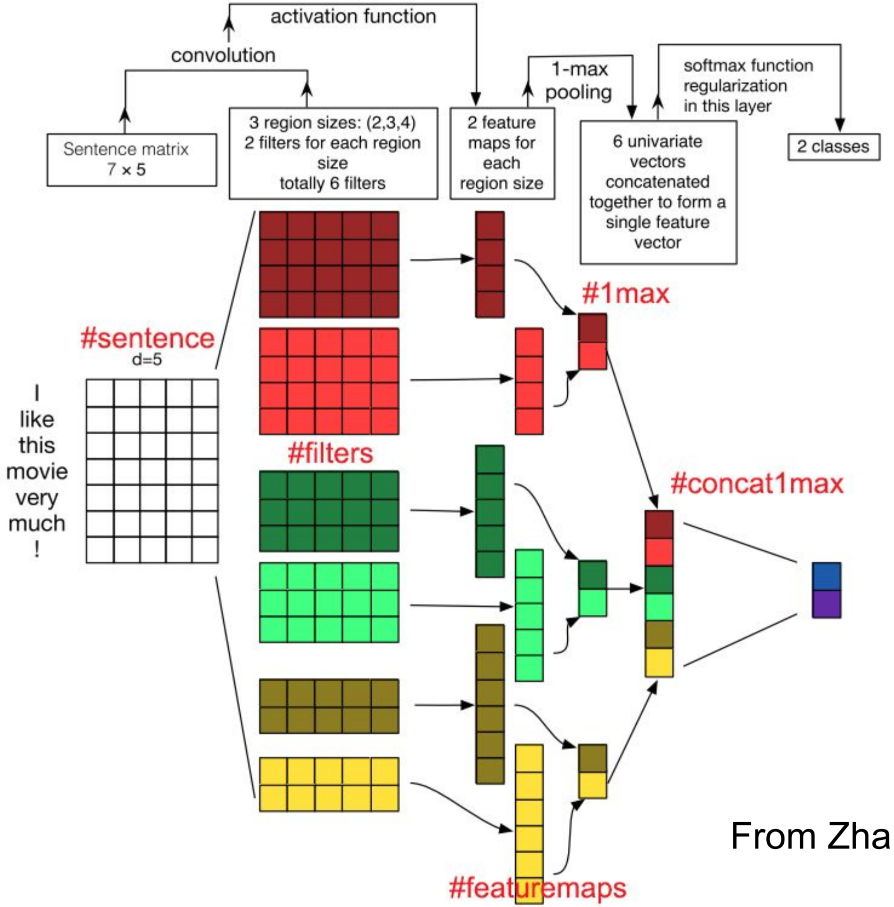


A 2-gram extractor for the concept *animal sitting*

- This convolution provides high activations for 2-grams with certain meaning
- Can be extended to 3-grams, 4-grams, etc.
- Can have various filters, need to track many n-grams.
- They are called 1D since we only slice the windows only in one direction

Why is it better than BoW?

CNN Framework



From Zhang 2015

Multiple Channels

- Like image, CNN is applied on R-G-B channels
- For NLP, different word embeddings can be regarded as different channels

CNN for NLP

1. n-grams features are important (window size)

2. Location of key n-grams are trivial (pooling)

3. Stack of Convolutional layer or large window size can also capture long-range information