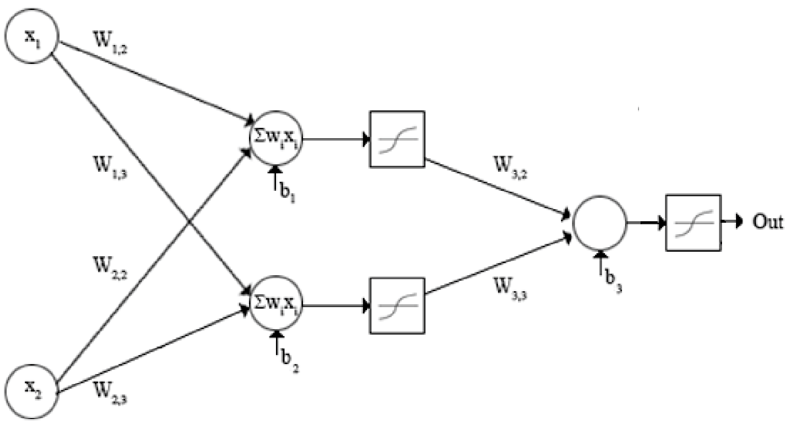
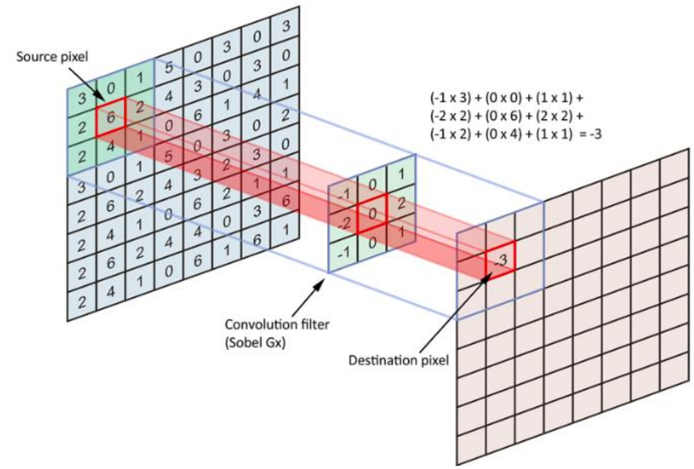
Course Outline

- TOPICS
  1. What is Machine Learning and Image Processing
  2. Traditional Features, K-NN classifier
  3. Linear Classification
  4. Perceptron Algorithm, Sigmoid Activation Function, Gradient Descent
  5. Stochastic Gradient Descent, Back-Propagation
  6. Multi-Layer Neural Network
  7. Convolution and Pooling
  8. Mid-Term Examination
  9. Mid-Term Examination
  10. Convolutional Neural Networks.
  11. Training Convolutional Neural Networks: Hyper-Parameters, Activation functions, initialization, dropout, batch normalization
  12. Recurrent Neural Networks
  13. Applications of Convolutional Neural Networks for Image Segmentation and Object Classification
  14. Project Presentations

Difference Between NN and CNN





NN:

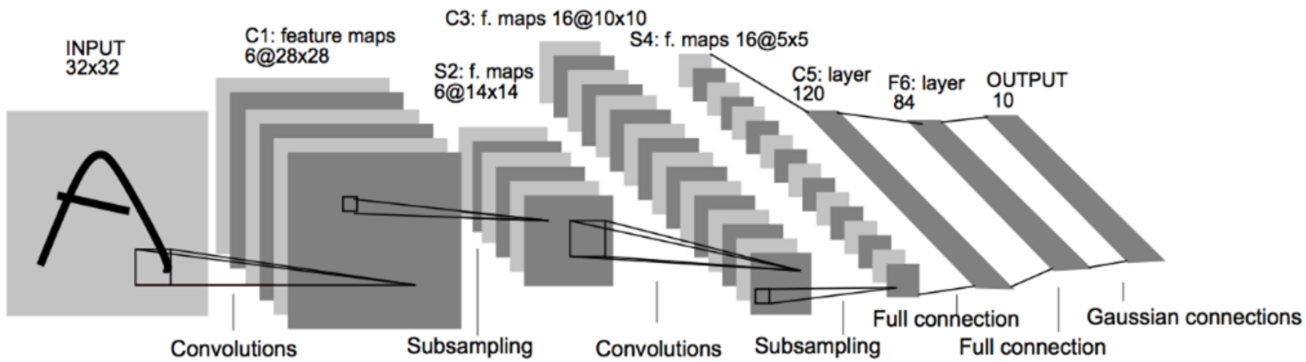
- Resemble to human brain: interconnected neurons, transmit signal.
- Input Layer, Hidden Layers, Output Layer.
- **Inputs** are in the **Array** form.
- **Filters** are in the **Array** form

CNN:

- Similar to NN but convolution exist.
- Convolutional Layer, ReLU Layer (called Activation), Pooling Layer, Fully Connected Layer.
- **Inputs** are in the **Matrix** form.
- **Filters** are in the **Matrix** form

https://medium.freecodecamp.org/an-intuitive-guide-to-convolutional-neural-networks-260c2de0a050

LeNet5

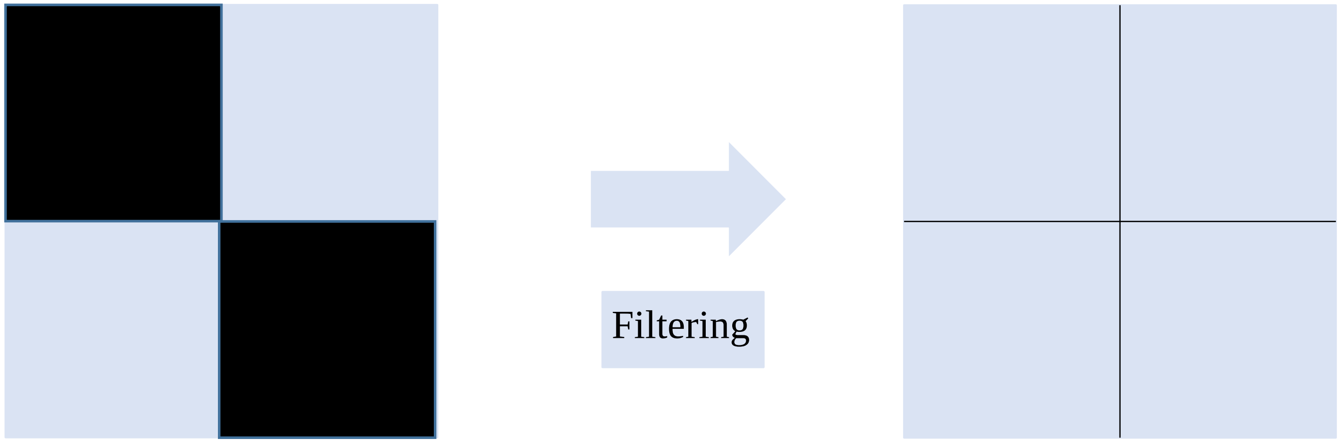


CNN called LeNet by Yann LeCun (1998)

Lenet5: The first CNN structure was proposed by Yann LeCun in 1998.

- Applied on MNIST and ASCII characters for document classification.
- Specifically, characters and digits are segmented and forwarded to CNN to determine its label.

Edge Detection



- How can we find the edges in images?
- Answer: Using derivative operation to remove redundant information (homogenous regions).
- Perform derivative operation through –x axis and –y axis.

Edge Detection

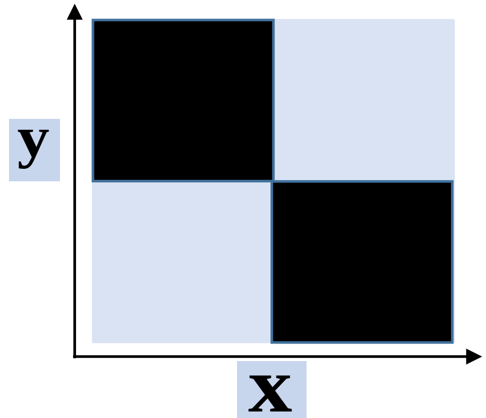


Image: I

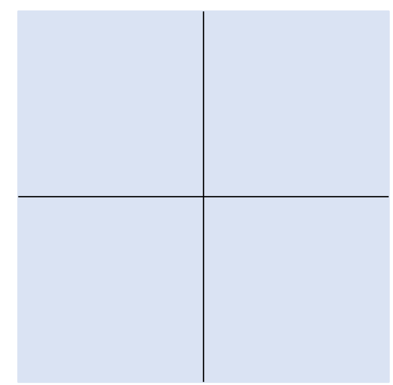
Horizantal Edges: $\frac{dI}{dy} \cong \frac{f(y_i) - f(y_{i-1})}{y_i - y_{i-1}}$

Image: I

Vertical Edges: $\frac{dI}{dx} \cong \frac{f(x_i) - f(x_{i-1})}{x_i - x_{i-1}}$

Image: I

EdgeMap $= \left|\frac{dI}{dx}\right| + \left|\frac{dI}{dy}\right|$



Edge Detection

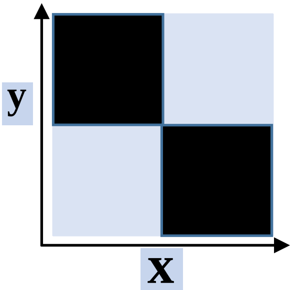


Image: I

As an alternative way,

we can convolve the image with filters.

$$\text{Horizantal Filter}: F_x = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

$$\text{Horizantal Edges}: \frac{dI}{dx} \cong I * F_x \qquad *: \text{refers convolution}$$

$$\text{Vertical Filter}: F_y = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

$$\text{Vertical Edges}: \frac{dI}{dy} \cong I * F_y \qquad *: \text{refers convolution}$$

Edge Detection

1	1	1
0	0	0
–1	–1	–1

convolve

0	0	0	20	20	20
0	0	0	20	20	20
0	0	0	20	20	20
20	20	20	0	0	0
20	20	20	0	0	0
20	20	20	0	0	0

gradient

0	0	0	0
60	20	–20	–60
60	20	–20	–60
0	0	0	0

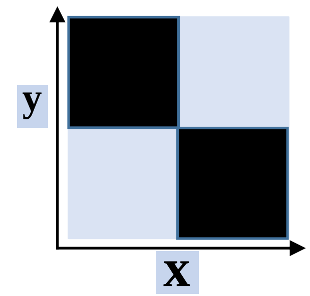
1	0	–1
1	0	–1
1	0	–1

convolve

0	0	0	20	20	20
0	0	0	20	20	20
0	0	0	20	20	20
20	20	20	0	0	0
20	20	20	0	0	0
20	20	20	0	0	0

gradient

0	60	60	0
0	20	20	0
0	–20	–20	0
0	–60	–60	0



0	0	0	20	20	20
0	0	0	20	20	20
0	0	0	20	20	20
20	20	20	0	0	0
20	20	20	0	0	0
20	20	20	0	0	0

Gradient Strengthness $\Delta I \cong \left|\frac{dI}{dx}\right| + \left|\frac{dI}{dy}\right|$

Gradient Direction $\theta = \tan^{-1}\left(\frac{dI}{dy} \Big/ \frac{dI}{dx}\right)$

gradient strength

0	60	60	0
60	40	40	60
60	40	40	60
0	60	60	0

Padding

1	1	1
0	0	0
–1	–1	–1

convolve

0	0	0	20	20	20
0	0	0	20	20	20
0	0	0	20	20	20
20	20	20	0	0	0
20	20	20	0	0	0
20	20	20	0	0	0

output

0	60	60	0
60	40	40	60
60	40	40	60
0	60	60	0

valid

padding : 1

1	1	1
0	0	0
–1	–1	–1

convolve

0	0	0	0	0	0	0	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	0	0	0	0	0	0	0

output

0	0	20	40	60	40
0	0	0	0	0	0
40	60	20	–20	–60	–40
40	60	20	–20	–60	–40
0	0	0	0	0	0
–40	–60	–40	–20	0	0

same

Convolution

$$o = \frac{n + 2p - f}{s} + 1$$

Ex1:

$f = 3 \times 3$

$n = 6, f = 3, \ p = 0, s = 1$

$$out = \frac{6 + 2 \cdot 0 - 3}{1} + 1 = 4$$

$out = 4 \times 4$

Ex2:

$f = 3 \times 3$

$n = 6 \times 6, f = 3, \ p = 1, s = 1$

$$out = \frac{6 + 2 \cdot 1 - 3}{1} + 1 = 6$$

$out = 6 \times 6$

p : padding

h : height

w : width

f : filter, $f \times f$ or $h \times w$

I : image $n \times n$

s : stride

out : output

Ex3:

$f = 3 \times 4 = h \times w$

$I = 6 \times 6$

$n = 6, h = 3, \ p = 1, s = 1$

$$h_{out} = \frac{6 + 2 \cdot 1 - 3}{1} + 1 = 6$$

$$w_{out} = \frac{6 + 2 \cdot 1 - 4}{1} + 1 = 5$$

$I_{new=} 6 \times 5$

Ex4:

$f = 3 \times 5 = h \times w$

$I = 12 \times 8$

$n = 6, h = 3, \ p = 1, s = 1$

$$h_{out} = \frac{12 + 2 \cdot 1 - 3}{1} + 1 = 12$$

$$w_{out} = \frac{8 + 2 \cdot 1 - 5}{1} + 1 = 6$$

$I_{new=} 12 \times 6$

padding 0
stride 1

1	1	1
0	0	0
–1	–1	–1

convolve

0	0	0	20	20	20
0	0	0	20	20	20
0	0	0	20	20	20
20	20	20	0	0	0
20	20	20	0	0	0
20	20	20	0	0	0

output

0	0	0	40
60	20	–20	–20
60	20	–20	–20
40	40	40	0

valid

padding 1
stride 1

1	1	1
0	0	0
–1	–1	–1

convolve

0	0	0	0	0	0	0	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	0	0	0	0	0	0	0

output

0	0	20	40	60	40
0	0	0	0	40	40
40	60	20	–20	–20	0
40	60	20	–20	–20	0
0	20	20	0	0	0
–40	–20	0	20	0	0

same

padding 1
stride 2

1	1	1
0	0	0
–1	–1	–1

convolve

0	0	0	0	0	0	0	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	0	0	0	0	0	0	0

output

?

valid

padding 1, stride 2

wrong padding

1	1	1
0	0	0
−1	−1	−1

convolve

0	0	0	0	0	0	0	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	0	0	0	20	20	20	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	20	20	20	0	0	0	0
0	0	0	0	0	0	0	0

output

0	60	60	0
60	40	40	60
60	40	40	60
0	60	60	0

padding 3, stride 3

true padding

1	1	1
0	0	0
−1	−1	−1

			0	0	0	20	20	20			
			0	0	0	20	20	20			
			0	0	0	20	20	20			
			20	20	20	0	0	0			
			20	20	20	0	0	0			
			20	20	20	0	0	0			

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$$o = \frac{n + 2p - f}{s} + 1$$

$$6 = \frac{6 + 2 \cdot p - 3}{2} + 1$$
$$10 = 6 + 2 \cdot p - 3$$
$$7 = 2 \cdot p$$
$$p = 3.5$$

wrong padding

$$6 = \frac{6 + 2 \cdot p - 3}{3} + 1$$
$$15 = 6 + 2 \cdot p - 3$$
$$12 = 2 \cdot p$$
$$p = 3$$

true padding

$$p = \frac{f - 1}{2}$$

Convolution over Volume