(순한맛) Neural Network

임경태

본 슬라이드는 (최건호) 연구원의 자료를 2차 가공함
https://github.com/GunhoChoi/PyTorch-FastCampus

실습 설정방법

본 강의에서 사용하는 Visdom을 실행하기 위해서는 Jupyter notebook을 개인 PC에 설치해서 실습 해야함

Colab에서 실행하고자 하는 경우 Visdom으로 시각화 하는 부분 주석 처리하면 됨

Jupyter, Visdom설치 관련 참조 https://github.com/jujbob/NLPApps

Linear Regression

Hard cases for a linear classifier

Class 1:
number of pixels > 0 odd

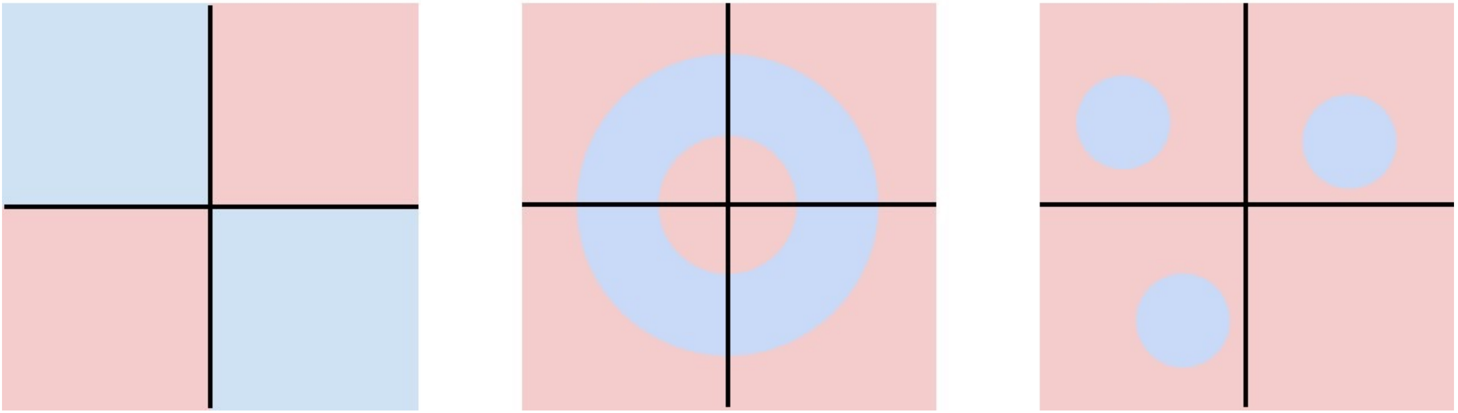
Class 2:
number of pixels > 0 even

Class 1:
1 <= L2 norm <= 2

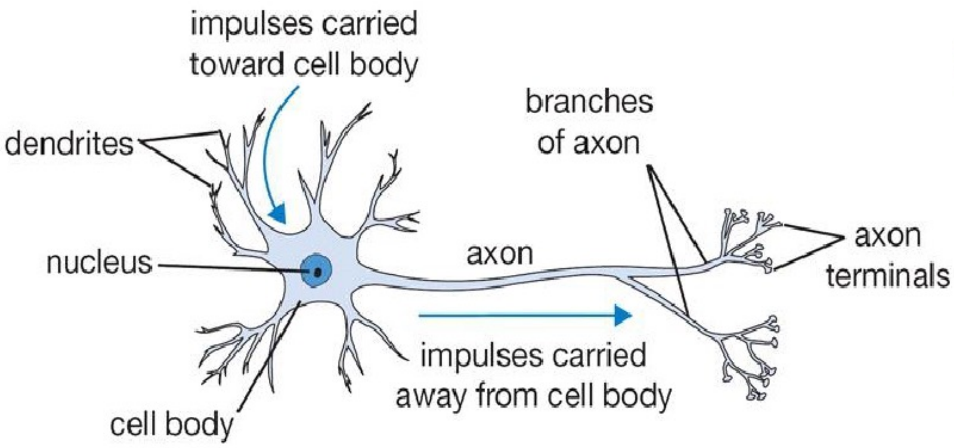
Class 2:
Everything else

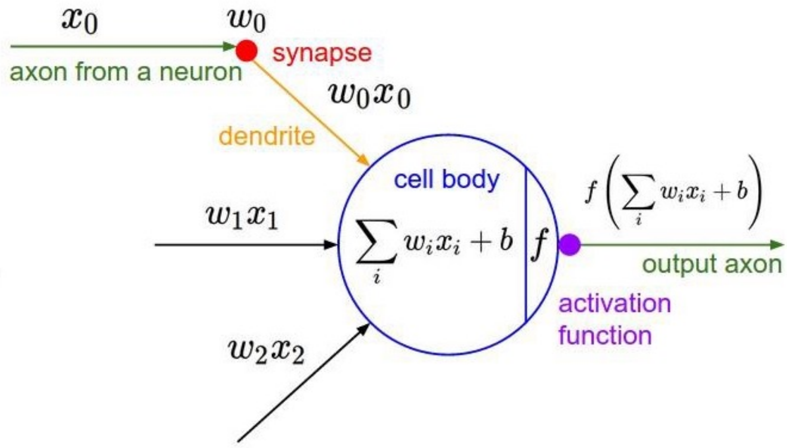
Class 1:
Three modes

Class 2:
Everything else



Neural Network

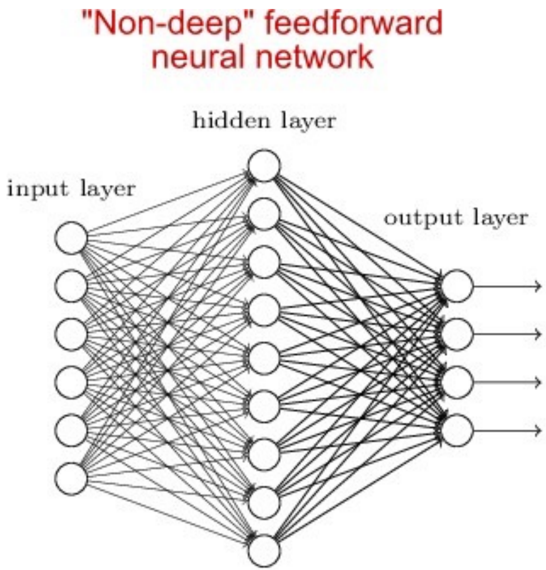




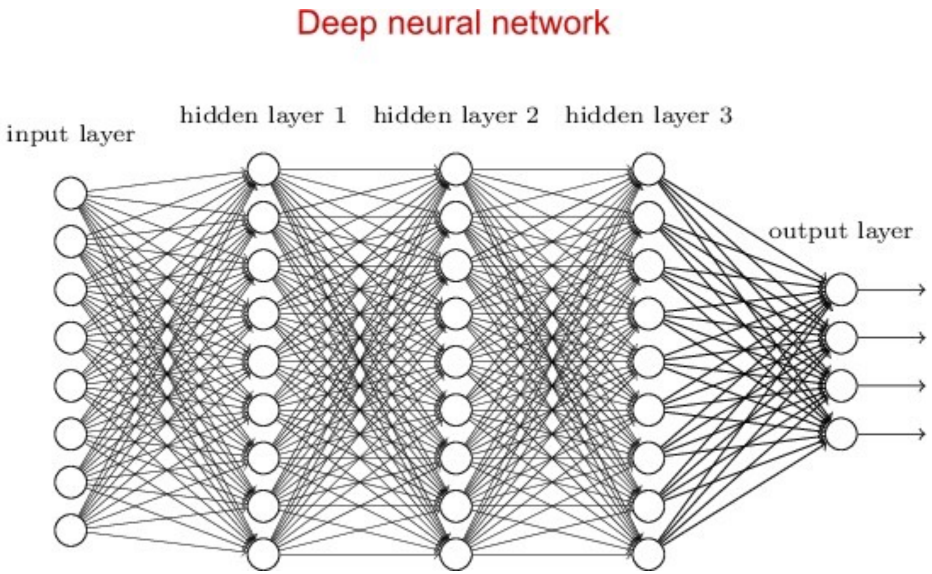
여러 자극이 들어오고 일정 기준을 넘으면 이를 다른 뉴런에 전달하는 구조

(출처: http://cs231n.github.io/neural-networks-1/)

Neural Network



$$y = w2\big(act(w1 * input + b1)\big) + b2$$



$$y = w4\Big(act\Big(w3\Big(act\big(w2\big(act(w1 * input + b1)\big) + b2\big)\Big) + b3\Big)\Big) + b4$$

(출처: http://neuralnetworksanddeeplearning.com/chap5.html)

Neural Network

$$y = W \cdot x + b$$

$$
= \underset{m \times n}{\overset{x}{\begin{bmatrix} x_{00} & x_{01} & \cdots & \cdots \\ x_{10} & x_{11} & & \\ \vdots & & \ddots & \\ \vdots & & & x_{mn} \end{bmatrix}}}
\underset{n \times l}{\overset{W}{\begin{bmatrix} W_{00} & W_{01} & W_{02} & \cdots \\ W_{10} & W_{11} & & \\ W_{20} & & \ddots & \\ \vdots & & & W_{nl} \end{bmatrix}}}
+ \underset{m \times 1}{\overset{b}{\begin{bmatrix} b_0 \\ b_1 \\ \vdots \\ b_m \end{bmatrix}}}
$$

Neural Network

$$y = W \cdot x + b$$

$$= \begin{array}{c} x \\ \begin{bmatrix} x_{00} & x_{01} & \cdots & \cdots \\ x_{10} & x_{11} & & \\ \vdots & & \ddots & \\ \vdots & & & x_{mn} \end{bmatrix} \\ m \times n \end{array} \begin{array}{c} W \\ \begin{bmatrix} w_{00} & w_{01} & w_{02} & \cdots \\ w_{10} & w_{11} & & \\ w_{20} & & \ddots & \\ \vdots & & & w_{nl} \end{bmatrix} \\ n \times l \end{array} + \begin{array}{c} b \\ \begin{bmatrix} b_0 \\ b_1 \\ \vdots \\ b_m \end{bmatrix} \\ m \times 1 \end{array}$$

Neural Network

$y = act(wx+b)$

$$= \underset{\sim\sim\sim}{\text{activation}} \left(\underset{m \times 1}{\left[\quad wx + b \quad \right]} \right)$$

Neural Network

만약 activation function이 없다면 아래의 식은 결국 linear function.

$$y = w4(act\left(w3\left(act\left(w2\left(act(w1 * input + b1)\right) + b2\right)\right) + b3\right)) + b4$$

Neural Network

만약 activation function이 없다면 아래의 식은 결국 linear function.

$$y = w4(act\left(w3\left(act(w2(act(w1 * input + b1)) + b2)\right) + b3)\right) + b4$$

activation function으로 non-linearity를 추가해야 함

Neural Network

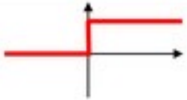
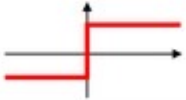
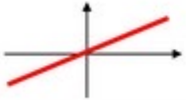
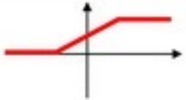
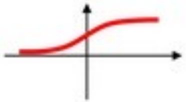
만약 activation function이 없다면 아래의 식은 결국 linear function.

$$y = w4(act\left(w3\left(act\left(w2\left(act\left(w1 * input + b1\right)\right) + b2\right)\right) + b3\right)\right) + b4$$

activation function으로 non-linearity를 추가해야 함

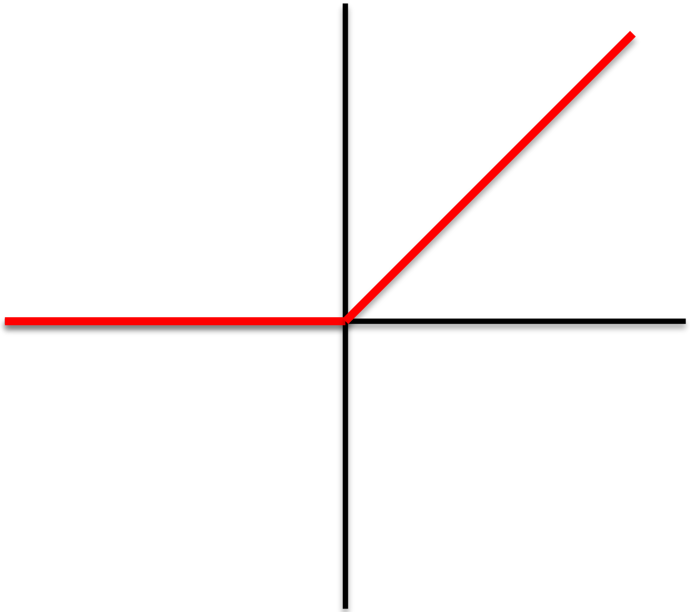
그렇다면 어떤 activation function을 써야 할까?

Neural Network

Activation function	Equation	Example	1D Graph
Unit step (Heaviside)	$\phi(z) = \begin{cases} 0, & z < 0, \\ 0.5, & z = 0, \\ 1, & z > 0, \end{cases}$	Perceptron variant	
Sign (Signum)	$\phi(z) = \begin{cases} -1, & z < 0, \\ 0, & z = 0, \\ 1, & z > 0, \end{cases}$	Perceptron variant	
Linear	$\phi(z) = z$	Adaline, linear regression	
Piece-wise linear	$\phi(z) = \begin{cases} 1, & z \geq \frac{1}{2}, \\ z + \frac{1}{2}, & -\frac{1}{2} < z < \frac{1}{2}, \\ 0, & z \leq -\frac{1}{2}, \end{cases}$	Support vector machine	
Logistic (sigmoid)	$\phi(z) = \frac{1}{1 + e^{-z}}$	Logistic regression, Multi-layer NN	
Hyperbolic tangent	$\phi(z) = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}}$	Multi-layer NN	

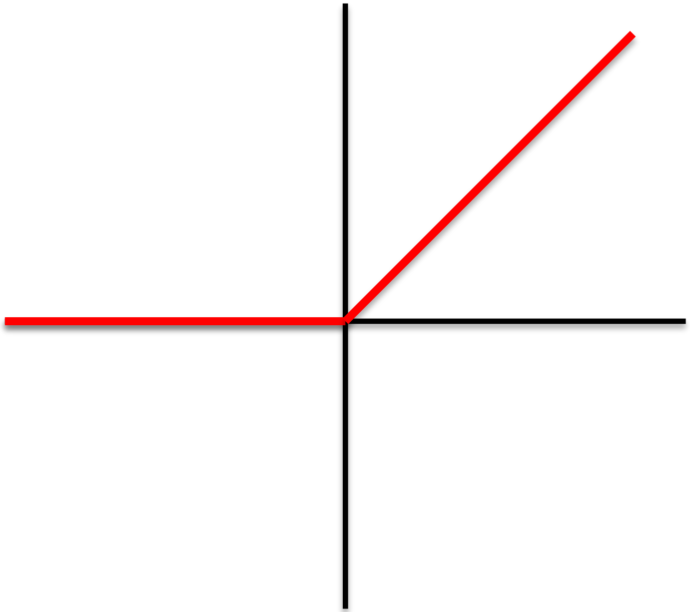
(출처: http://www.kdnuggets.com/2016/08/role-activation-function-neural-network.html)

Neural Network



(출처: http://www.kdnuggets.com/2016/08/role-activation-function-neural-network.html)

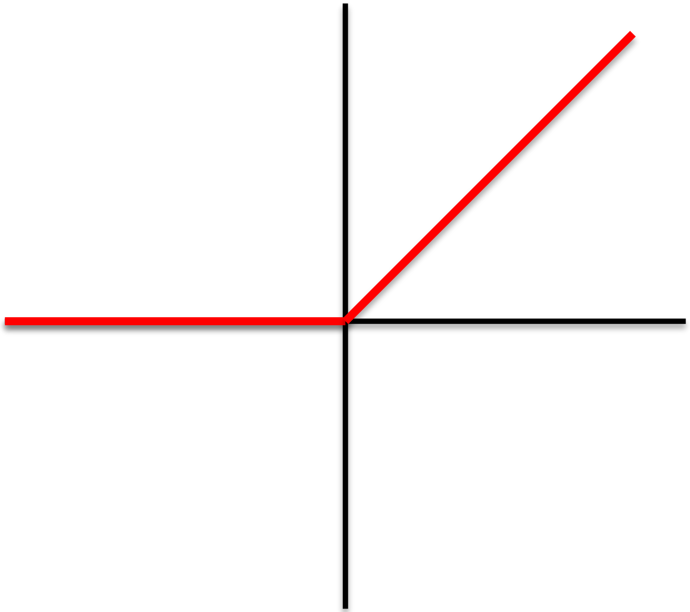
Neural Network



Rectified Linear Unit (ReLU)

(출처: http://www.kdnuggets.com/2016/08/role-activation-function-neural-network.html)

Neural Network

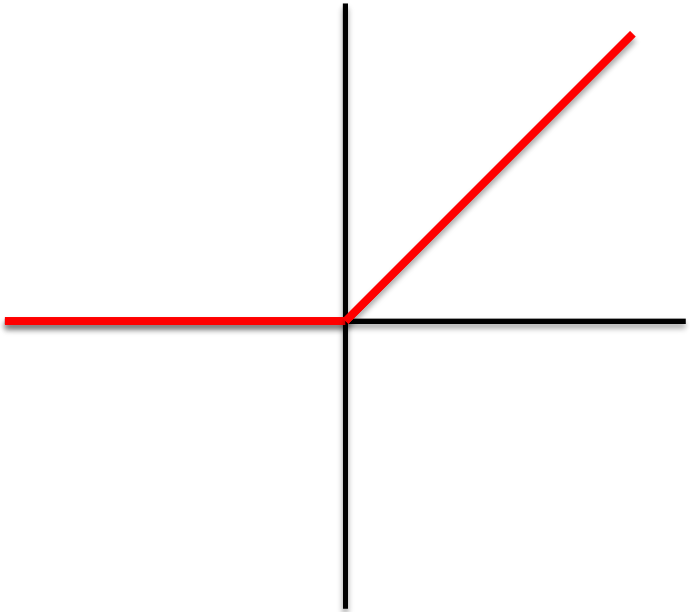


Rectified Linear Unit (ReLU)

$$f(x) = \max(0,x)$$

(출처: http://www.kdnuggets.com/2016/08/role-activation-function-neural-network.html)

Neural Network



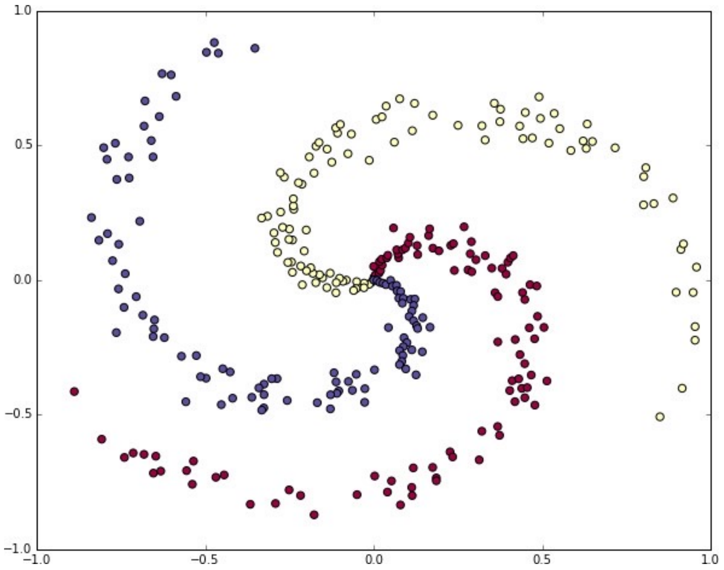
Rectified Linear Unit (ReLU)

f(x) = max(0,x)

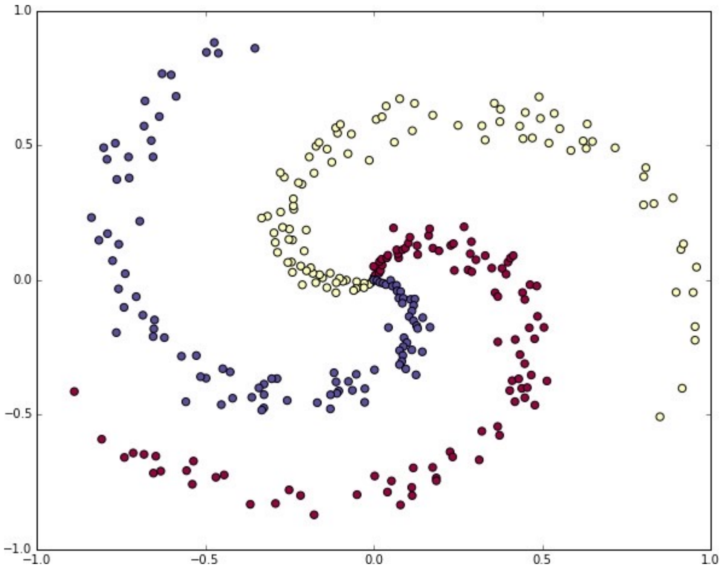
기존의 sigmoid와 tanh로는 학습이 잘 안됐었는데 relu는 gradient의 전달이 좋아서 default로 사용되고 있음

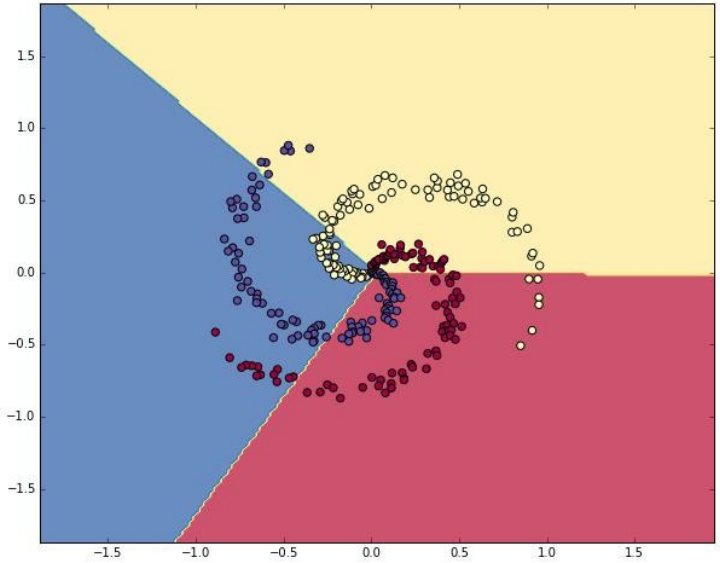
(출처: http://www.kdnuggets.com/2016/08/role-activation-function-neural-network.html)

Neural Network

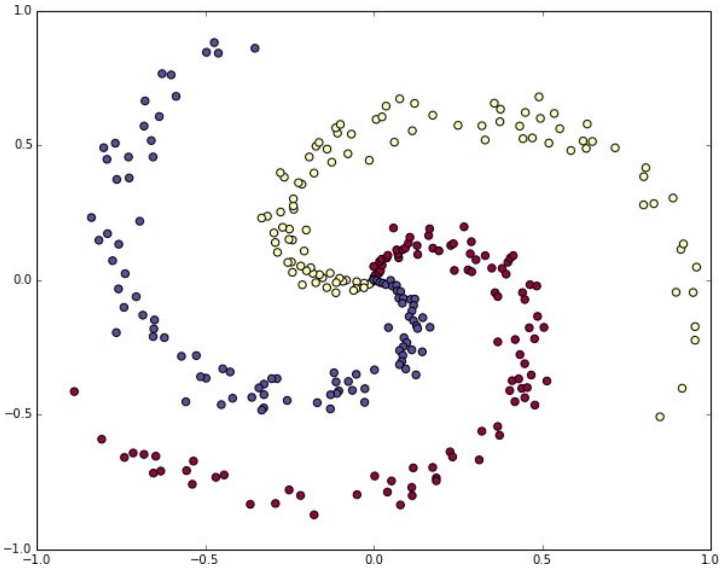


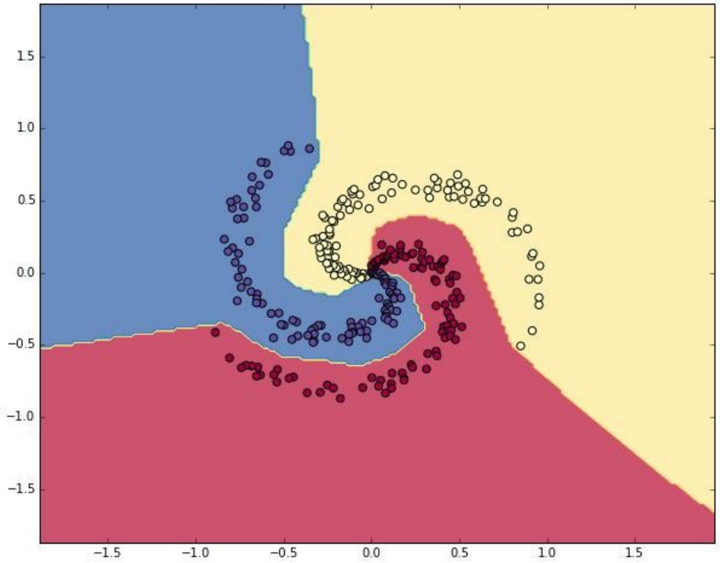
Neural Network



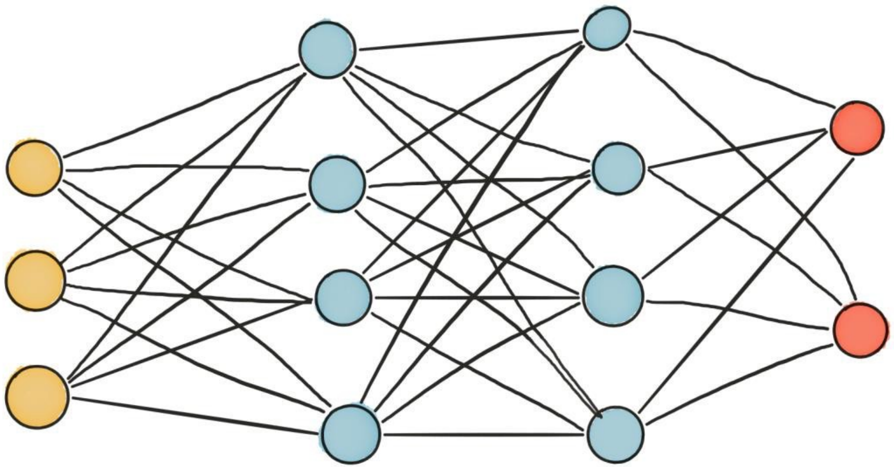


Neural Network

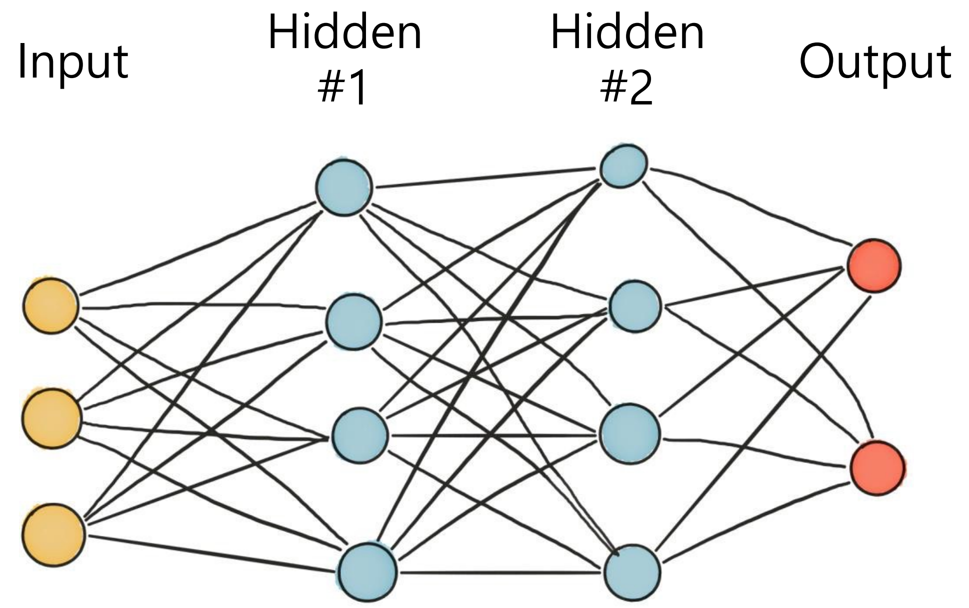




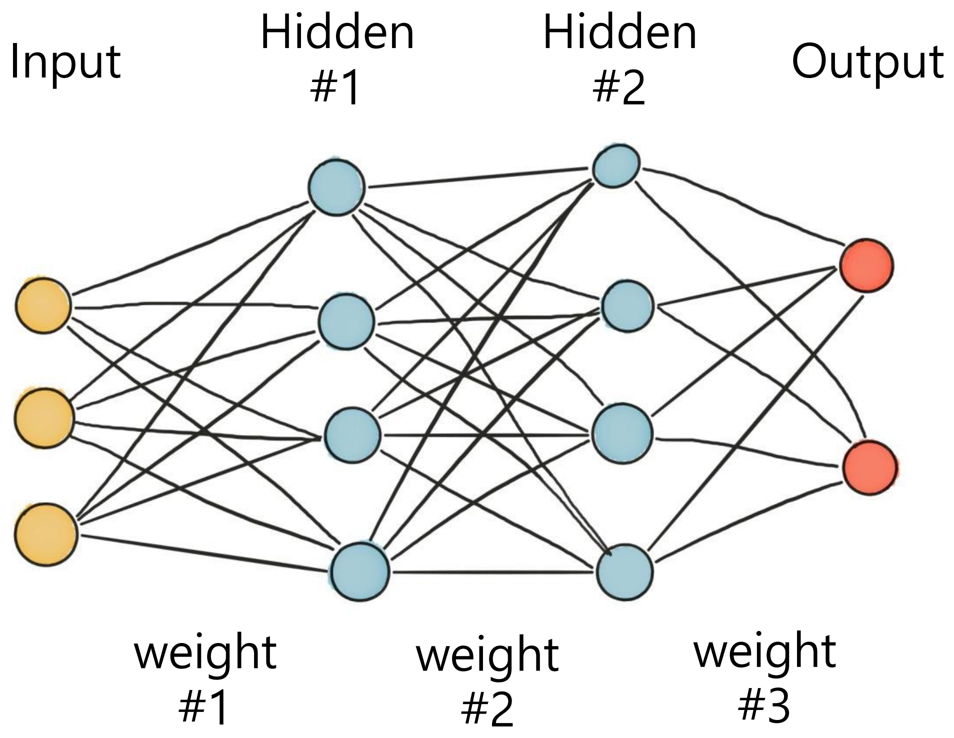
Forward & Back Prop.



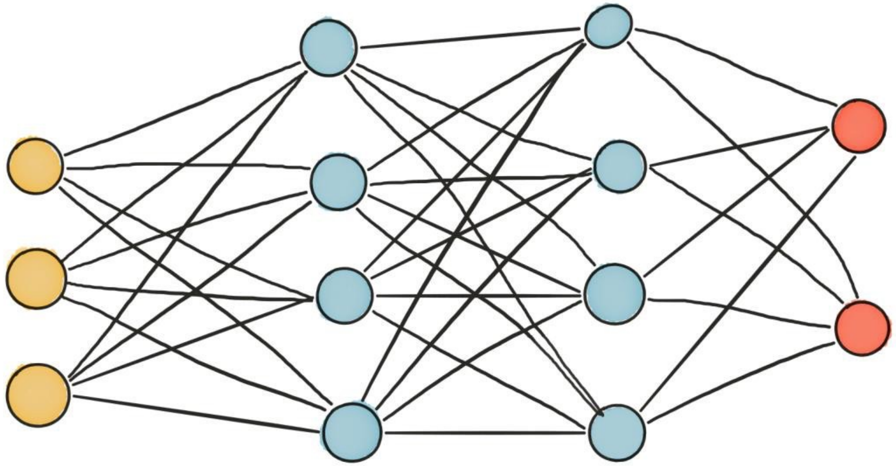
Forward & Back Prop.



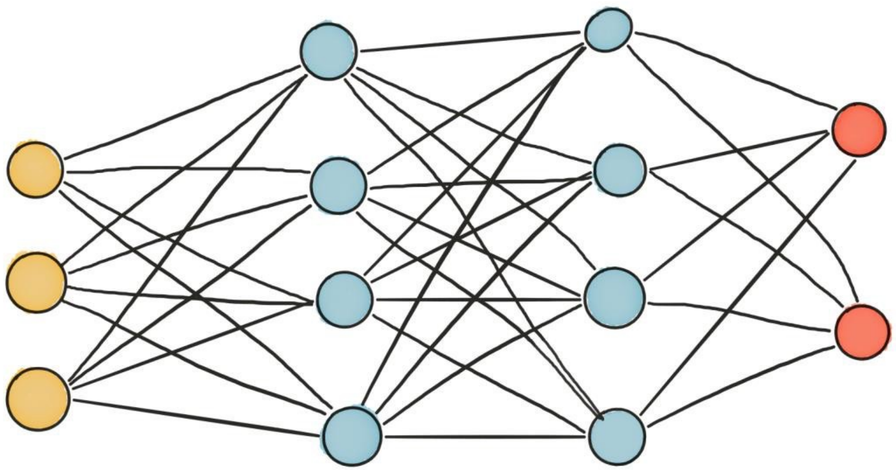
Forward & Back Prop.



Forward & Back Prop.

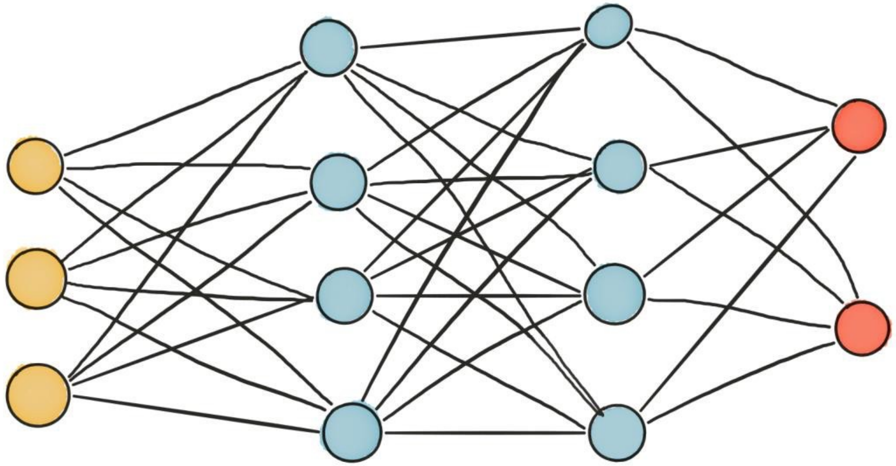


Forward & Back Prop.



$$\begin{bmatrix} w_{oo} & w_{01} & w_{02} & w_{03} \\ w_{10} & w_{11} & w_{12} & w_{13} \\ w_{20} & w_{21} & w_{22} & w_{23} \end{bmatrix} \text{ X } \begin{bmatrix} w_{oo} & w_{01} & w_{02} & w_{03} \\ w_{10} & w_{11} & w_{12} & w_{13} \\ w_{20} & w_{21} & w_{22} & w_{23} \\ w_{30} & w_{31} & w_{32} & w_{33} \end{bmatrix} \text{ X } \begin{bmatrix} w_{00} & w_{01} \\ w_{10} & w_{11} \\ w_{20} & w_{21} \\ w_{30} & w_{31} \end{bmatrix}$$

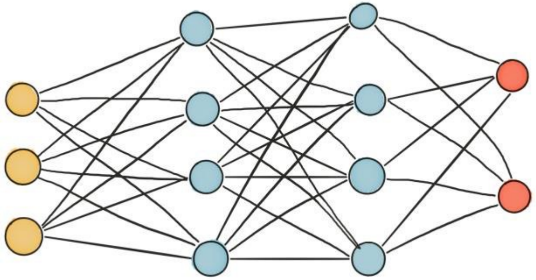
Forward & Back Prop.



$$\begin{bmatrix} w_{oo} & w_{01} & w_{02} & w_{03} \\ w_{10} & w_{11} & w_{12} & w_{13} \\ w_{20} & w_{21} & w_{22} & w_{23} \end{bmatrix} \times \begin{bmatrix} w_{oo} & w_{01} & w_{02} & w_{03} \\ w_{10} & w_{11} & w_{12} & w_{13} \\ w_{20} & w_{21} & w_{22} & w_{23} \\ w_{30} & w_{31} & w_{32} & w_{33} \end{bmatrix} \times \begin{bmatrix} w_{00} & w_{01} \\ w_{10} & w_{11} \\ w_{20} & w_{21} \\ w_{30} & w_{31} \end{bmatrix}$$

3x4 4x4 4x2

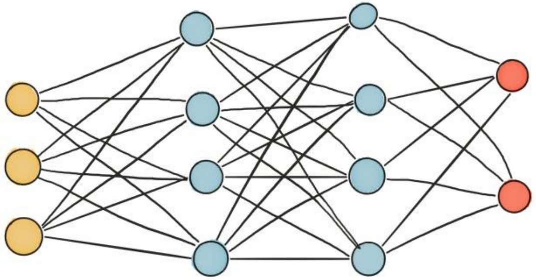
Forward & Back Prop.



쉽게 이해되도록
loss = 예측값-실제로 설정

$$y^* = w3 * sig(w2 * sig(w1 * x + b1) + b2) + b3$$

Forward & Back Prop.



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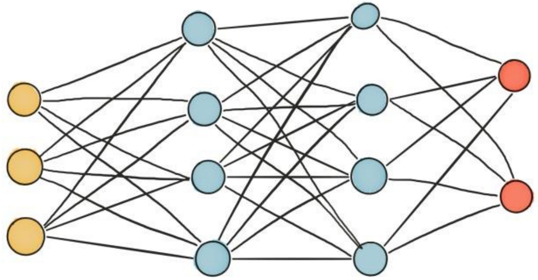
loss = 예측값-실제로 설정

$$y^* = w3 * sig(w2 * sig(w1 * x + b1) + b2) + b3$$

$$\begin{aligned} loss &= y^* - y \\ &= w3 * sig(w2 * sig(w1 * x + b1) + b2) + b3 - y \end{aligned}$$

Forward & Back Prop.



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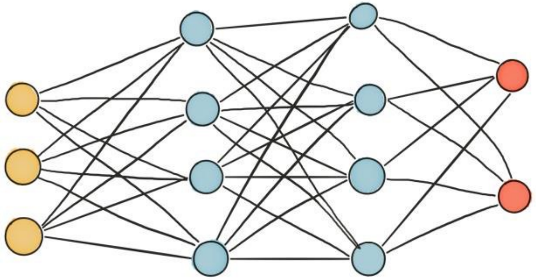
$$\frac{\partial loss}{\partial w3} = sig(w2 * sig(w1 * x + b1) + b2)$$

Forward & Back Prop.



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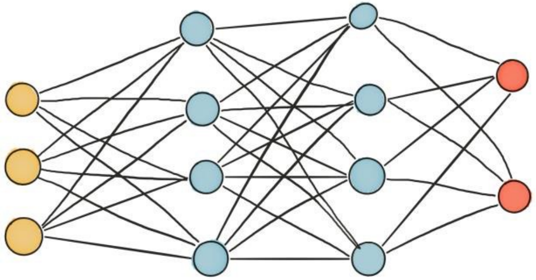
$$\begin{aligned} loss &= y^* - y \\ &= w3 * sig(w2 * sig(w1 * x + b1) + b2) + b3 - y \end{aligned}$$

$$\frac{\partial loss}{\partial w3} = sig(w2 * sig(w1 * x + b1) + b2)$$

$$\frac{\partial loss}{\partial b3} = 1$$

Forward & Back Prop.



쉽게 이해되도록
loss = 예측값-실제로 설정

$$y^* = w3 * sig(w2 * sig(w1 * x + b1) + b2) + b3$$

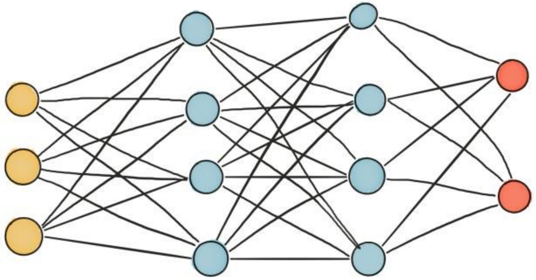
$$\begin{aligned} loss &= y^* - y \\ &= w3 * sig(w2 * sig(w1 * x + b1) + b2) + b3 - y \end{aligned}$$

$$\frac{\partial loss}{\partial w3} = sig(w2 * sig(w1 * x + b1) + b2)$$

$$\frac{\partial loss}{\partial b3} = 1$$

$$\frac{\partial loss}{\partial w2} = ??$$

Forward & Back Prop.



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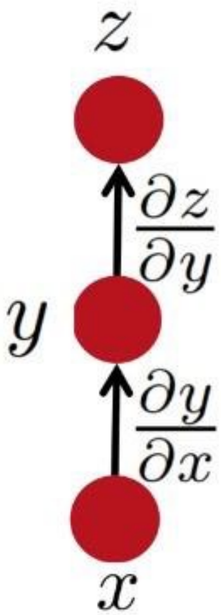
$$\frac{\partial loss}{\partial w3} = sig\big(w2 * sig\big(w1 * x + b1\big) + b2\big)$$

$$\frac{\partial loss}{\partial b3} = 1$$

$$\frac{\partial loss}{\partial w2} = chain\ rule!!$$

Forward & Back Prop.

Simple Chain Rule



$$\Delta z = \frac{\partial z}{\partial y} \Delta y$$

$$\Delta y = \frac{\partial y}{\partial x} \Delta x$$

$$\Delta z = \frac{\partial z}{\partial y} \frac{\partial y}{\partial x} \Delta x$$

$$\frac{\partial z}{\partial x} = \frac{\partial z}{\partial y} \frac{\partial y}{\partial x}$$

(출처:https://www.slideshare.net/roelofp/041114-dl-nlpwordembeddings)

Forward & Back Prop.

Backpropagation: a simple example

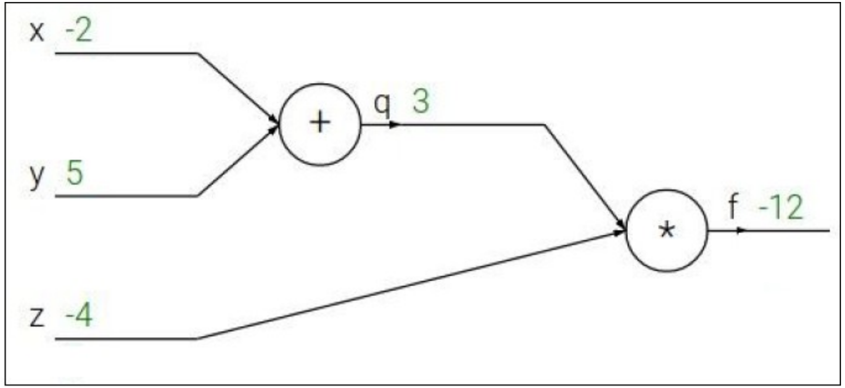
$$f(x, y, z) = (x + y)z$$

e.g. x = -2, y = 5, z = -4

$$q = x + y \qquad \frac{\partial q}{\partial x} = 1, \frac{\partial q}{\partial y} = 1$$

$$f = qz \qquad \frac{\partial f}{\partial q} = z, \frac{\partial f}{\partial z} = q$$

Want: $\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z}$



(출처: cs231n_lecture4 p.13)

Forward & Back Prop.

Backpropagation: a simple example

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e.g. x = -2, y = 5, z = -4

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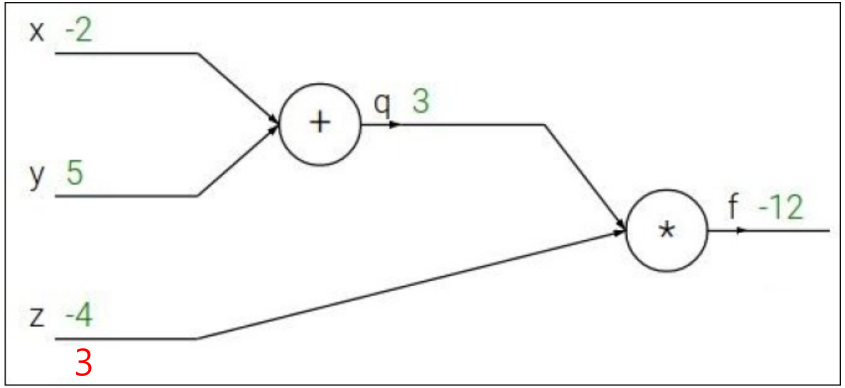
$$f = qz \qquad \frac{\partial f}{\partial q} = z, \frac{\partial f}{\partial z} = q$$

Want: $\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \boxed{\frac{\partial f}{\partial z}}$



$$\frac{\partial f}{\partial z} = q = x + y = -2 + 5 = 3$$

Forward & Back Prop.

Backpropagation: a simple example

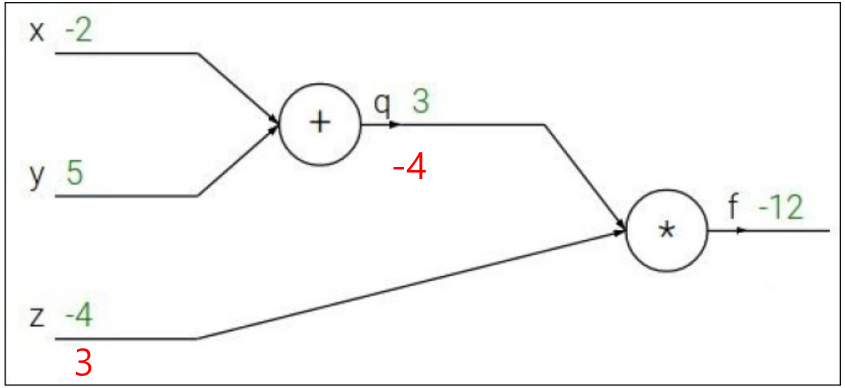
$$f(x, y, z) = (x + y)z$$

e.g. x = -2, y = 5, z = -4

$$q = x + y \qquad \frac{\partial q}{\partial x} = 1, \frac{\partial q}{\partial y} = 1$$

$$f = qz \qquad \frac{\partial f}{\partial q} = z, \frac{\partial f}{\partial z} = q$$

Want: $\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z}$



$$\frac{\partial f}{\partial z} = q = x + y = -2 + 5 = 3$$

$$\frac{\partial f}{\partial q} = z = -4$$

(출처: cs231n_lecture4 p.13)

Forward & Back Prop.

Backpropagation: a simple example

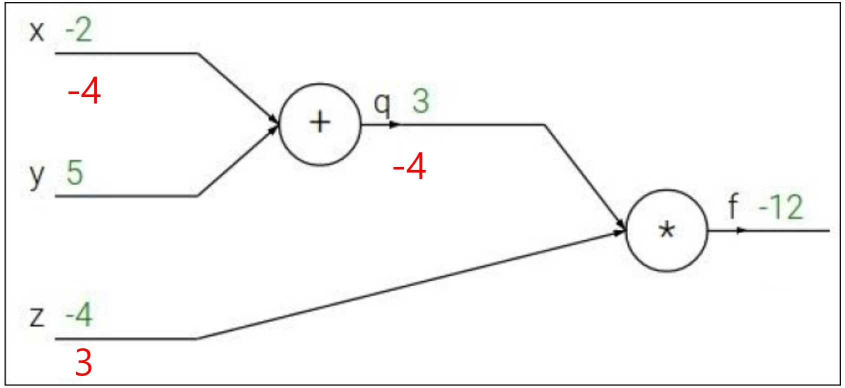
$$f(x,y,z) = (x+y)z$$

e.g. x = -2, y = 5, z = -4

$$q = x + y \qquad \frac{\partial q}{\partial x} = 1, \frac{\partial q}{\partial y} = 1$$

$$f = qz \qquad \frac{\partial f}{\partial q} = z, \frac{\partial f}{\partial z} = q$$

Want: $\boxed{\frac{\partial f}{\partial x}}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z}$



$$\frac{\partial f}{\partial z} = q = x + y = -2 + 5 = 3$$

$$\frac{\partial f}{\partial q} = z = -4 \qquad \frac{\partial f}{\partial x} = \frac{\partial f}{\partial q}\frac{\partial q}{\partial x} = -4 * 1 = -4$$

(출처: cs231n_lecture4 p.13)

Forward & Back Prop.

Backpropagation: a simple example

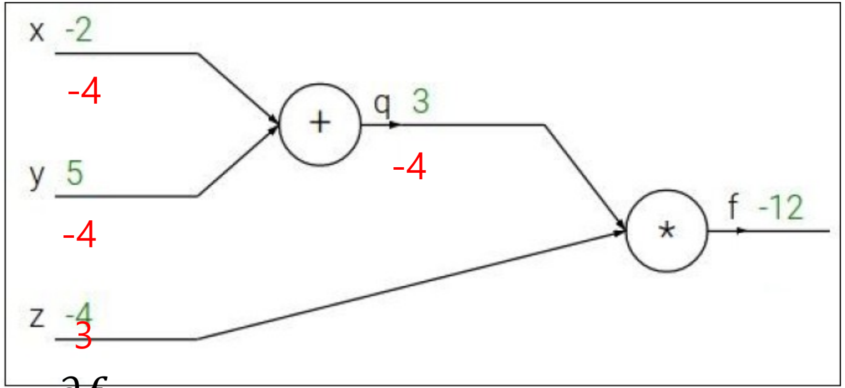
$$f(x,y,z) = (x+y)z$$

e.g. x = -2, y = 5, z = -4

$$q = x + y \qquad \frac{\partial q}{\partial x} = 1, \frac{\partial q}{\partial y} = 1$$

$$f = qz \qquad \frac{\partial f}{\partial q} = z, \frac{\partial f}{\partial z} = q$$

Want: $\frac{\partial f}{\partial x}, \boxed{\frac{\partial f}{\partial y}}, \frac{\partial f}{\partial z}$



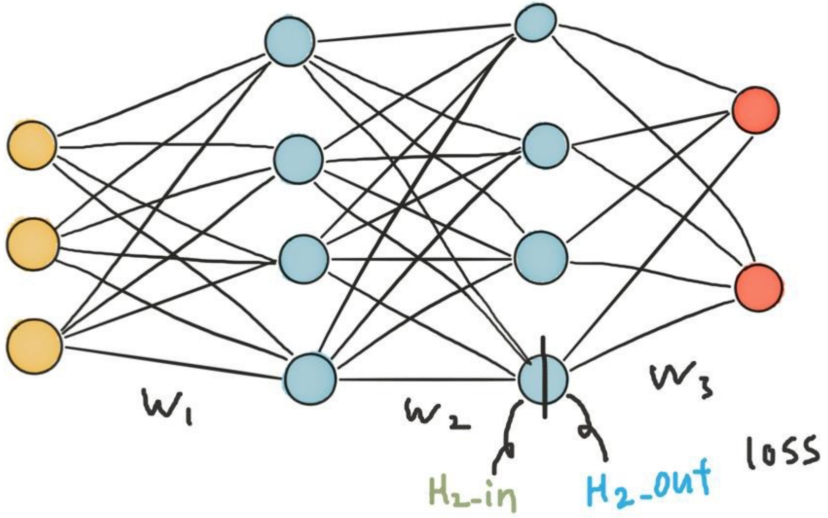
$$\frac{\partial f}{\partial z} = q = x + y = -2 + 5 = 3$$

$$\frac{\partial f}{\partial q} = z = -4 \qquad \frac{\partial f}{\partial x} = \frac{\partial f}{\partial q}\frac{\partial q}{\partial x} = -4 * 1 = -4$$

$$\frac{\partial f}{\partial y} = \frac{\partial f}{\partial q}\frac{\partial q}{\partial y} = -4 * 1 = -4$$

(출처: cs231n_lecture4 p.13)

Forward & Back Prop.



$$loss = W_3 \times \underbrace{sig(\underbrace{w_2 \times sig(w_1 x + b_1) + b_2}_{H_2\_in})}_{H_2\_out} + b_3 - y$$

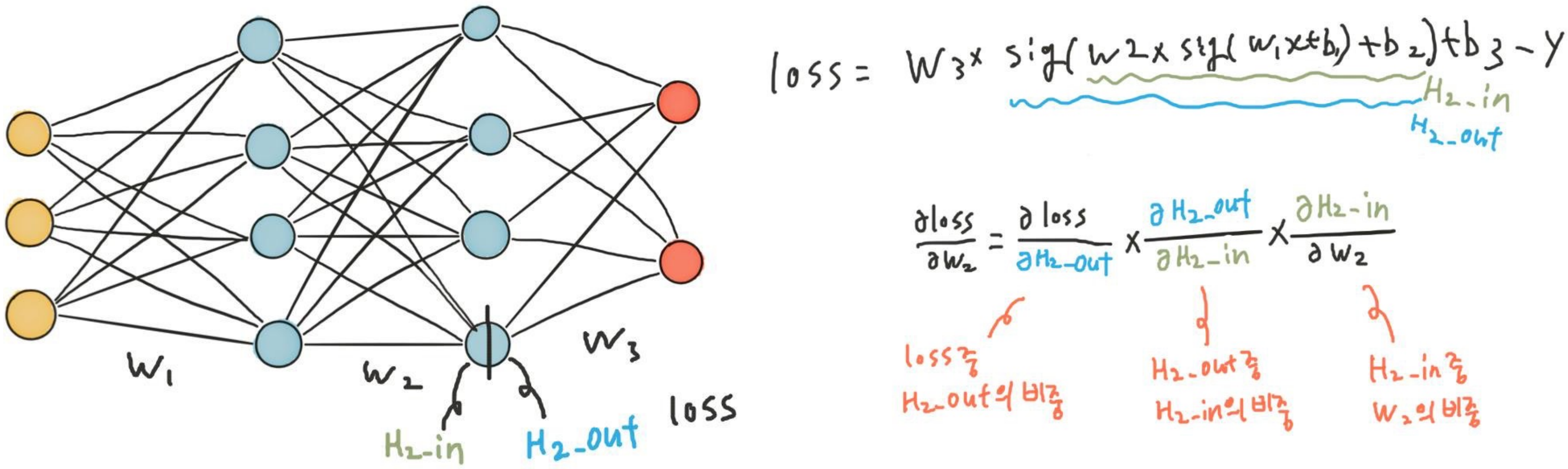
$$\frac{\partial loss}{\partial w_2} = \frac{\partial loss}{\partial H_2\_out} \times \frac{\partial H_2\_out}{\partial H_2\_in} \times \frac{\partial H_2\_in}{\partial w_2}$$

loss중 H2_out의 비중

H2_out중 H2_in의 비중

H2_in중 W2의 비중

Forward & Back Prop.



$$\frac{\partial loss}{\partial w2} = w3 * sigmoid'(h2\_in) * sigmoid(w1 * x + b)$$

Forward & Back Prop.

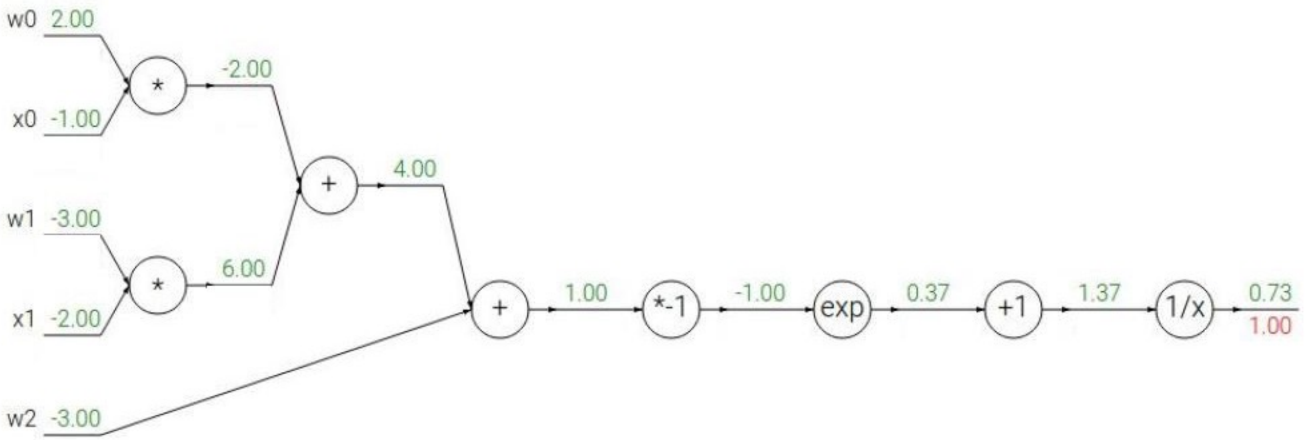
(참고) sigmoid 함수의 미분

$$\sigma(x)' = \frac{\delta\{1+e^{-x}\}^{-1}}{\delta x} = -(1+e^{-x})^{-2}-e^{-x} = \frac{e^{-x}}{(1+e^{-x})^2}$$

$$\sigma(x)(1-\sigma(x)) = \frac{1}{1+e^{-x}}\left(1-\frac{1}{1+e^{-x}}\right) = \frac{1}{1+e^{-x}}\left(\frac{e^{-x}}{1+e^{-x}}\right) = \frac{e^{-x}}{(1+e^{-x})^2}$$

Forward & Back Prop.

Another example: $$f(w,x) = \frac{1}{1+e^{-(w_0x_0+w_1x_1+w_2)}}$$



$$f(x) = e^x \quad \rightarrow \quad \frac{df}{dx} = e^x$$

$$f_a(x) = ax \quad \rightarrow \quad \frac{df}{dx} = a$$

$$f(x) = \frac{1}{x} \quad \rightarrow \quad \frac{df}{dx} = -1/x^2$$

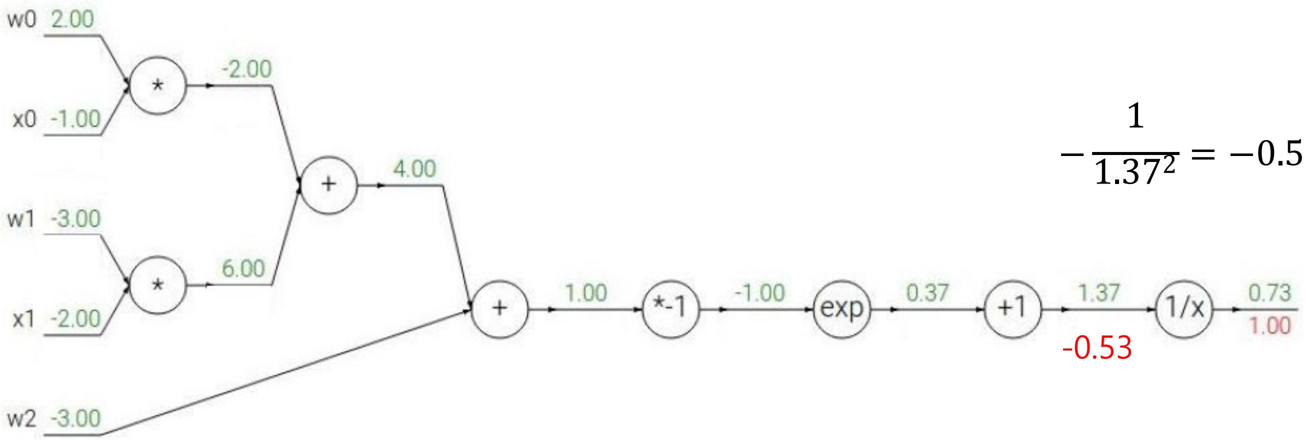
$$f_c(x) = c + x \quad \rightarrow \quad \frac{df}{dx} = 1$$

(출처: cs231n_lecture4 p.31)

Forward & Back Prop.

Another example: $$f(w,x) = \frac{1}{1+e^{-(w_0x_0+w_1x_1+w_2)}}$$

$$-\frac{1}{1.37^2} = -0.53$$



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Forward & Back Prop.

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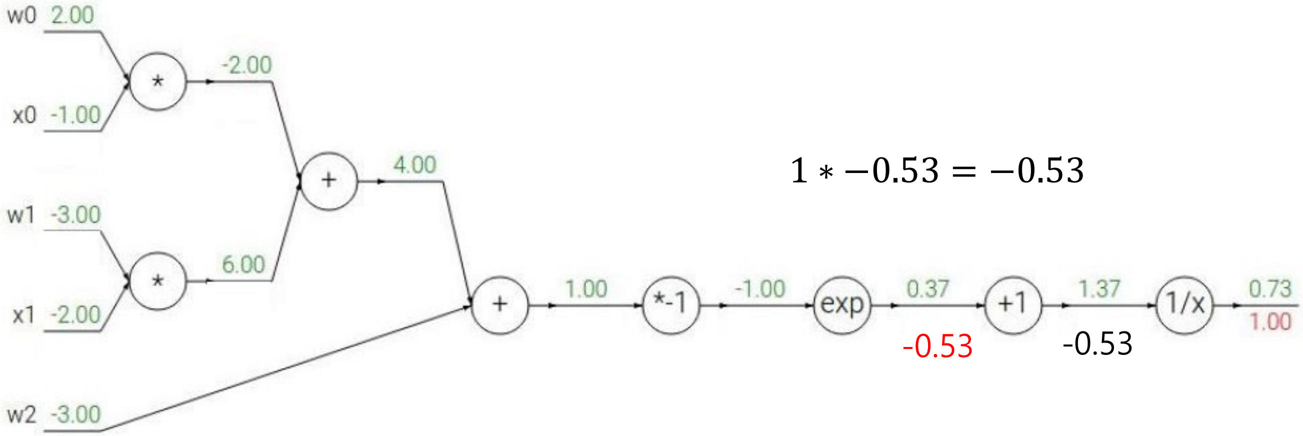
$$1 * -0.53 = -0.53$$



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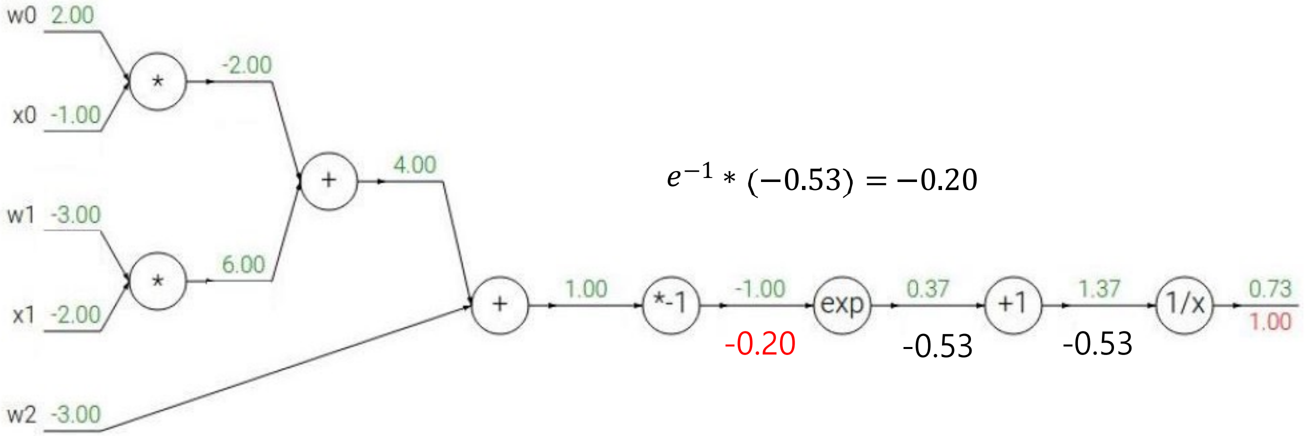

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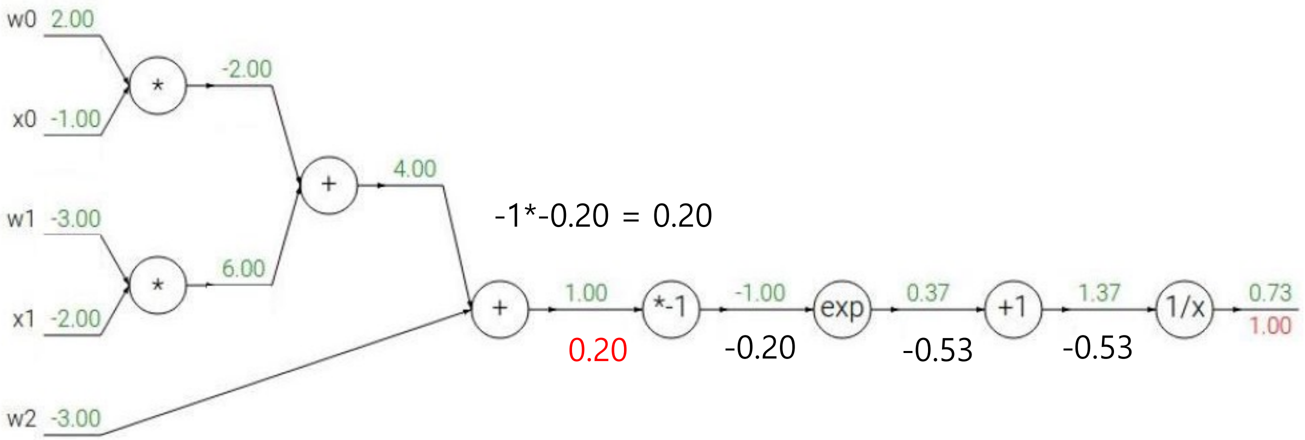

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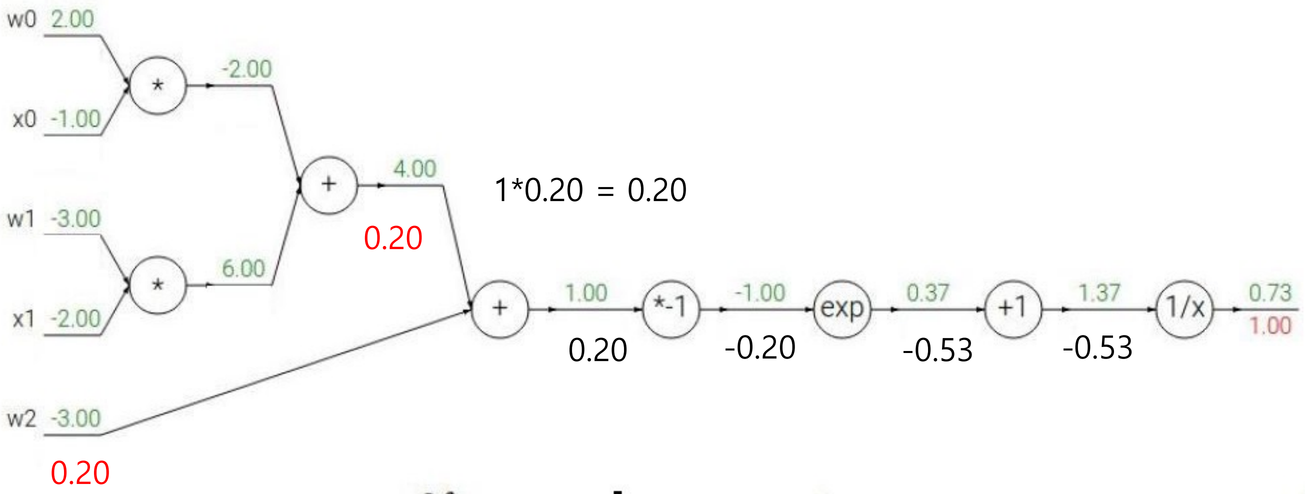

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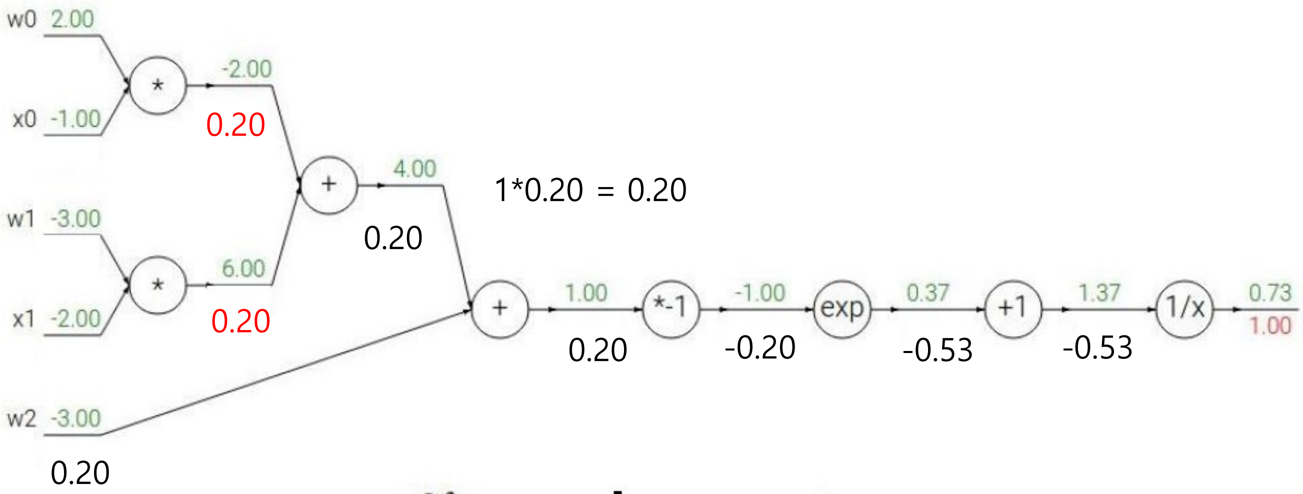

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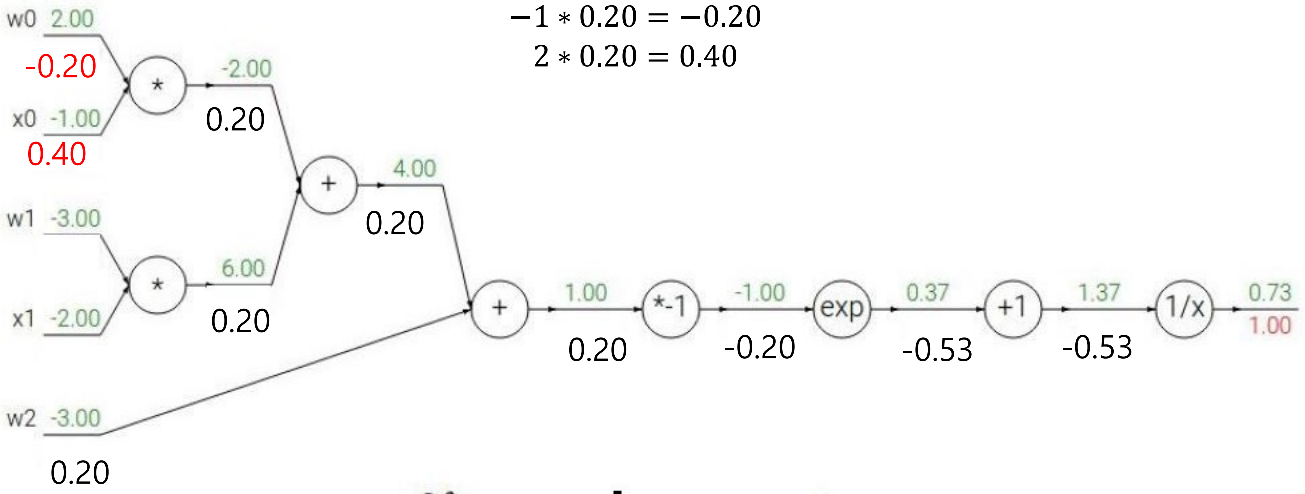
(출처: cs231n_lecture4 p.31)

Forward & Back Prop.

Another example: $$f(w,x) = \frac{1}{1+e^{-(w_0x_0+w_1x_1+w_2)}}$$

$$-1 * 0.20 = -0.20$$
$$2 * 0.20 = 0.40$$



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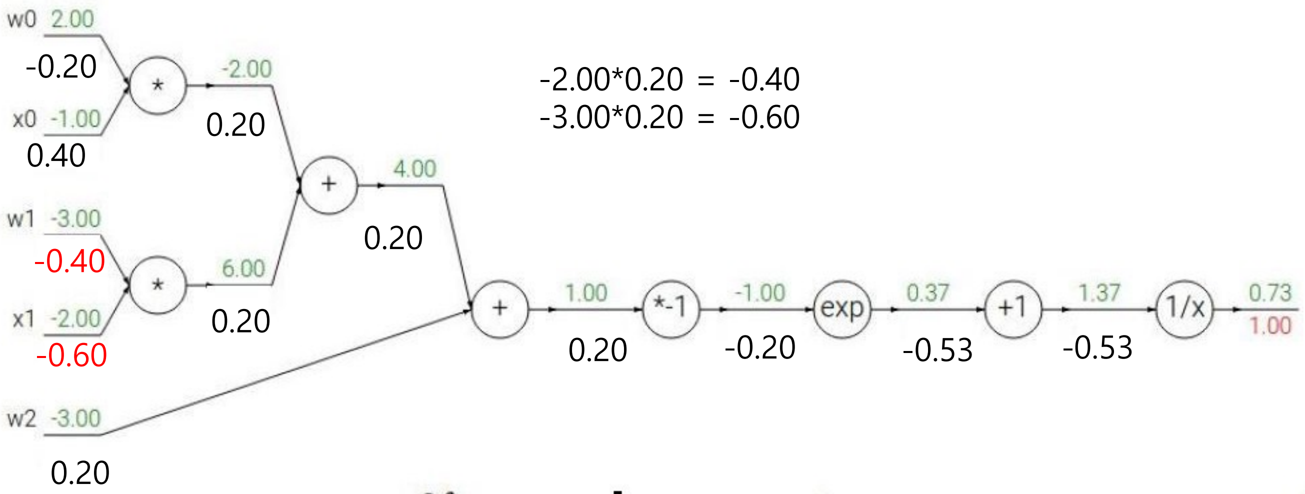

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(출처: cs231n_lecture4 p.31)

Forward & Back Prop.

$$y = \frac{1}{1 + e^{-(w_0x_0 + w_1x_1 + w_2)}} = [1 + e^{-(w_0x_0 + w_1x_1 + w_2)}]^{-1}$$

$w_0 = 2$

$w_1 = -3$

$w_2 = -3$

$x_0 = -1$

$x_1 = -2$

$$loss = \overset{\gamma\,0.73}{\hat{y}} - y$$

$$= [\underbrace{1 + \underbrace{e^{\underbrace{-(w_0x_0 + w_1x_1 + w_2)}_{\alpha = -1}}}_{\beta = 0.37}}_{\gamma = 1.37}]^{-1} - y$$

$loss = \gamma^{-1} - y$

$\gamma = 1 + \beta$

$\beta = e^{\alpha}$

$$\frac{\partial loss}{\partial r} = (r^{-1})' = -\frac{1}{r^2} = -0.5327$$

$$\frac{\partial r}{\partial \beta} = 1$$

$$\frac{\partial \beta}{\partial \alpha} = (e^{\alpha})' = e^{-1} = 0.3678$$

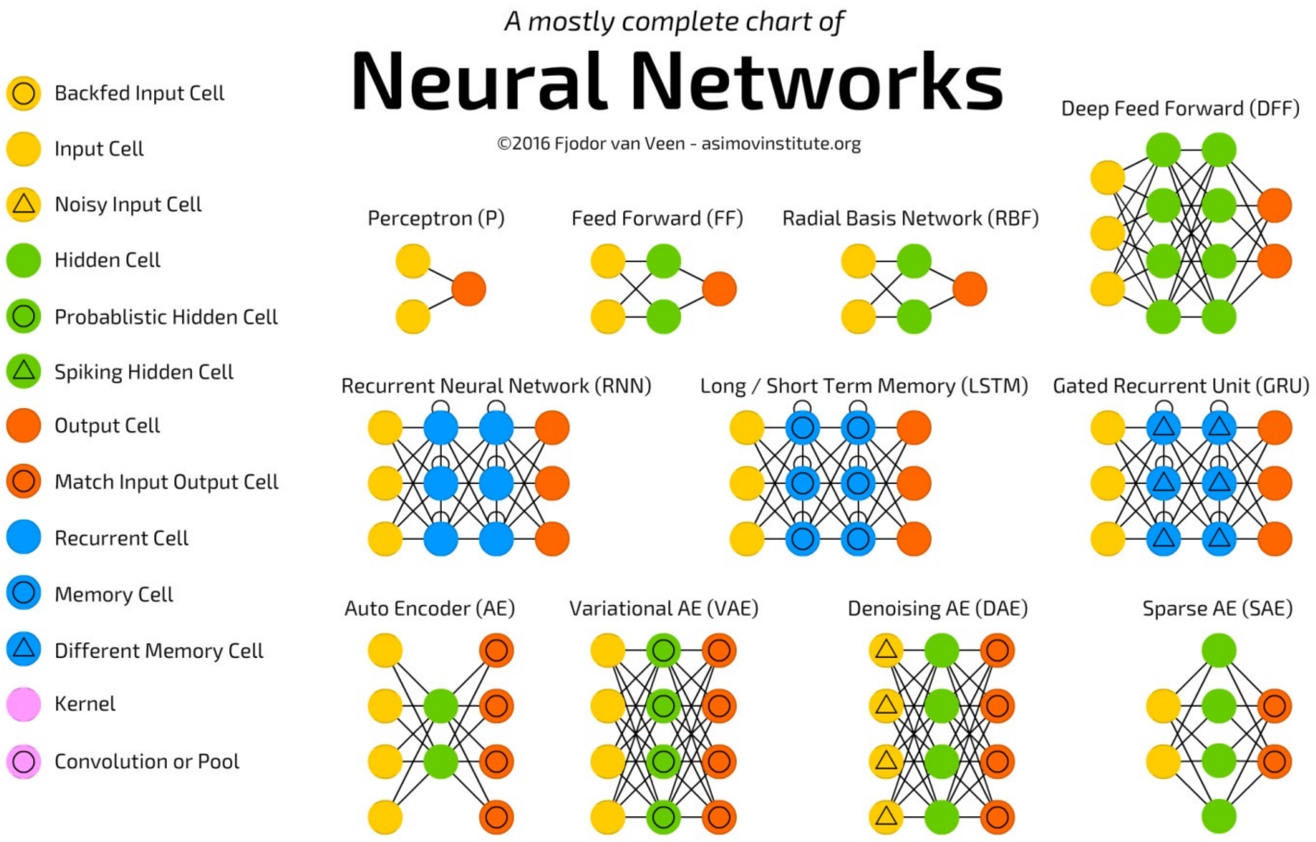
$$\frac{\partial \alpha}{\partial w_0} = -x_0 = 1$$

$$\frac{\partial loss}{\partial w_0} = \frac{\partial loss}{\partial r} \times \frac{\partial r}{\partial \beta} \times \frac{\partial \beta}{\partial \alpha} \times \frac{\partial \alpha}{\partial w_0}$$

$$= -0.5327 \times 1 \times 0.3678 \times 1$$

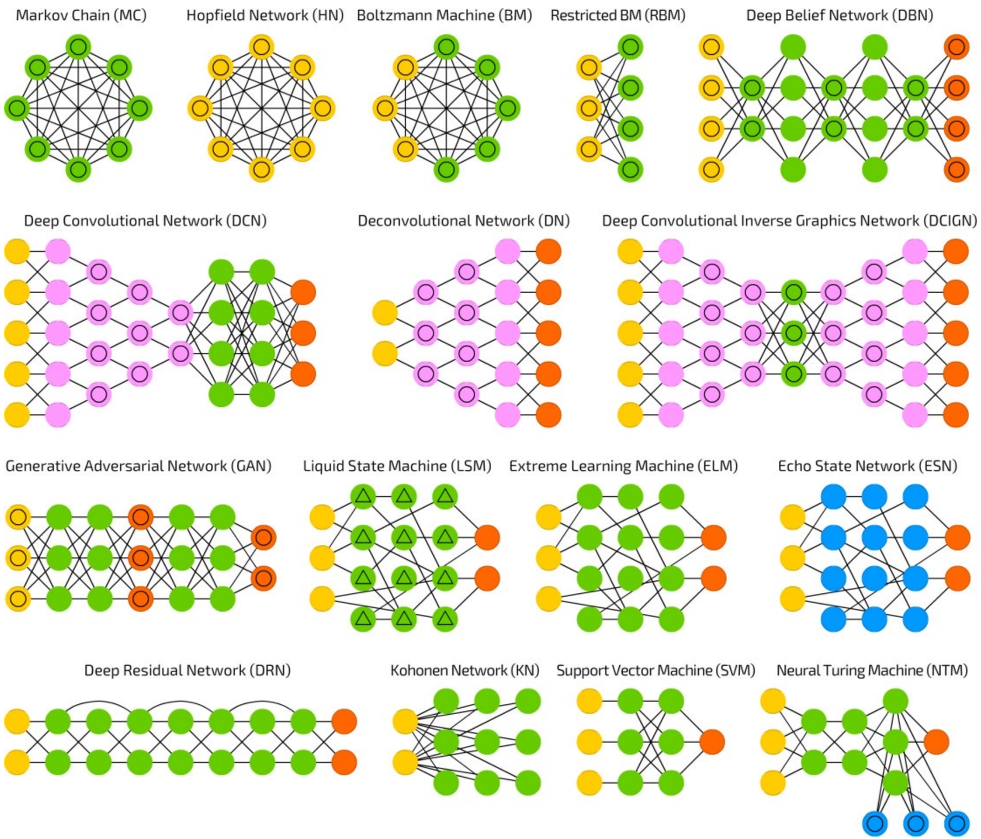
$$= -0.1959 \approx -0.2$$

Neural Network



(출처: http://www.asimovinstitute.org/neural-network-zoo/)

Neural Network



(출처: http://www.asimovinstitute.org/neural-network-zoo/)

Forward & Back Prop.

test.py

```python
import numpy as np
import torch
import torch.nn as nn
import torch.optim as optim
import torch.nn.init as init
from torch.autograd import Variable
from visdom import Visdom
viz = Visdom()

num_data = 1000
num_epoch = 5000

x = init.uniform(torch.Tensor(num_data,1),-15,15)
y = 8*(x**2) + 7*x + 3

noise = init.normal(torch.FloatTensor(num_data,1),std=1)
y_noise = y + noise
```

Forward & Back Prop.

필요한 라이브러리

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Forward & Back Prop.

필요한 라이브러리

데이터 생성

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Forward & Back Prop.

```
model = nn.Sequential(
            nn.Linear(1,10),
            nn.ReLU(),
            nn.Linear(10,6),
            nn.ReLU(),
            nn.Linear(6,1),
        ).cuda()

loss_func = nn.L1Loss()
optimizer = optim.SGD(model.parameters(),lr=0.001)

loss_arr =[]
label = Variable(y_noise.cuda())
for i in range(num_epoch):
    output = model(Variable(x.cuda()))
    optimizer.zero_grad()

    loss = loss_func(output,label)
    loss.backward()
    optimizer.step()
    if i % 100 ==0:
        print(loss)
    loss_arr.append(loss.cpu().data.numpy()[0])

param_list = list(model.parameters())
print(param_list)
```

Forward & Back Prop.

Neural Network 모델 생성

loss function 및
gradient descent
optimizer 생성

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Forward & Back Prop.

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<training 단계>
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2. loss 및 gradient 계산
3. 모델 업데이트

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Forward & Back Prop.

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training 이후 파라미터 값 확인

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Q&A