ML/DL for Everyone with PYTORCH

Lecture 3: Gradient Descent

Sung Kim <hunkim+ml@gmail.com> HKUST

Code: https://github.com/hunkim/PyTorchZeroToAll

Slides: http://bit.ly/PyTorchZeroAll

Videos: http://bit.ly/PyTorchVideo

Call for Comments

Please feel free to add comments directly on these slides.

Other slides: http://bit.ly/PyTorchZeroAll

Picture from http://www.tssablog.org/archives/3280

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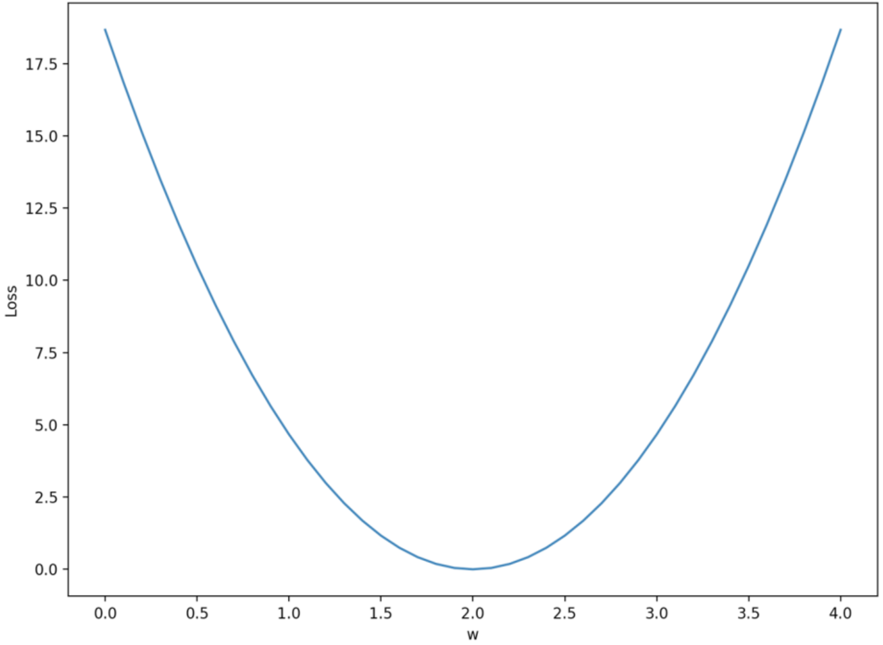
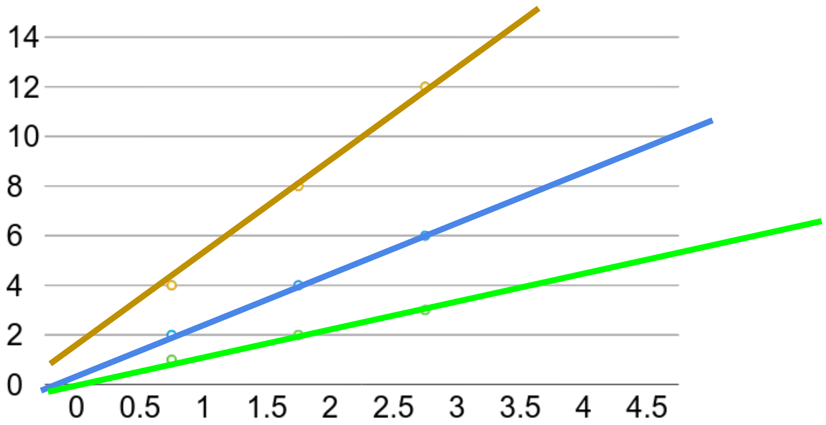
Loss graph

Loss (w=0)	Loss (w=1)	Loss (w=2)	Loss (w=3)	Loss (w=4)
mean=56/3=18.7	mean=14/3=4.7	mean=0	mean=14/3=4.7	mean=56/3=18.7



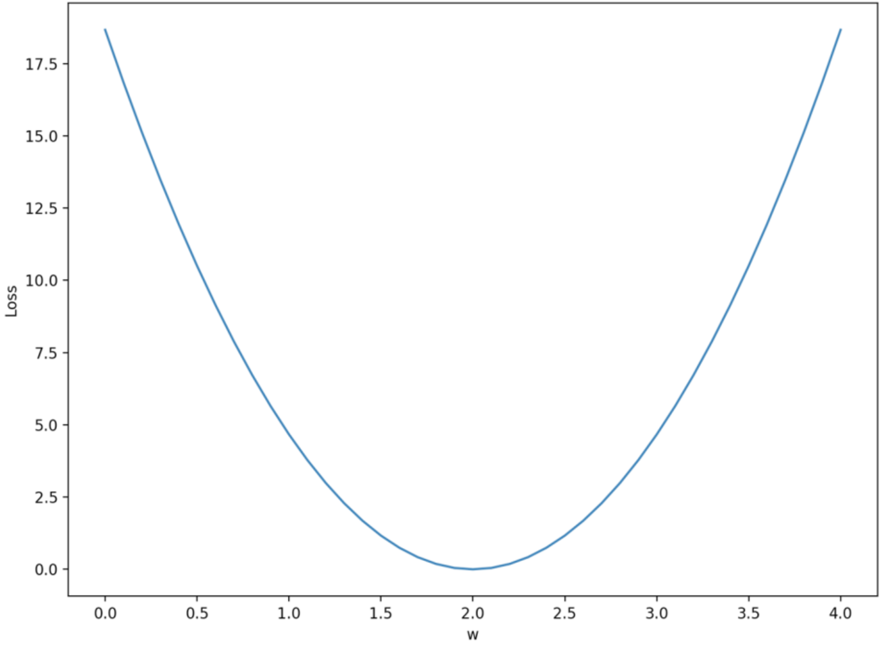
$$loss(w) = \frac{1}{N}\sum_{n=1}^{N}(\hat{y_n} - y_n)^2$$

Linear Regression error?



What is the learning: find **w** that minimizes the loss

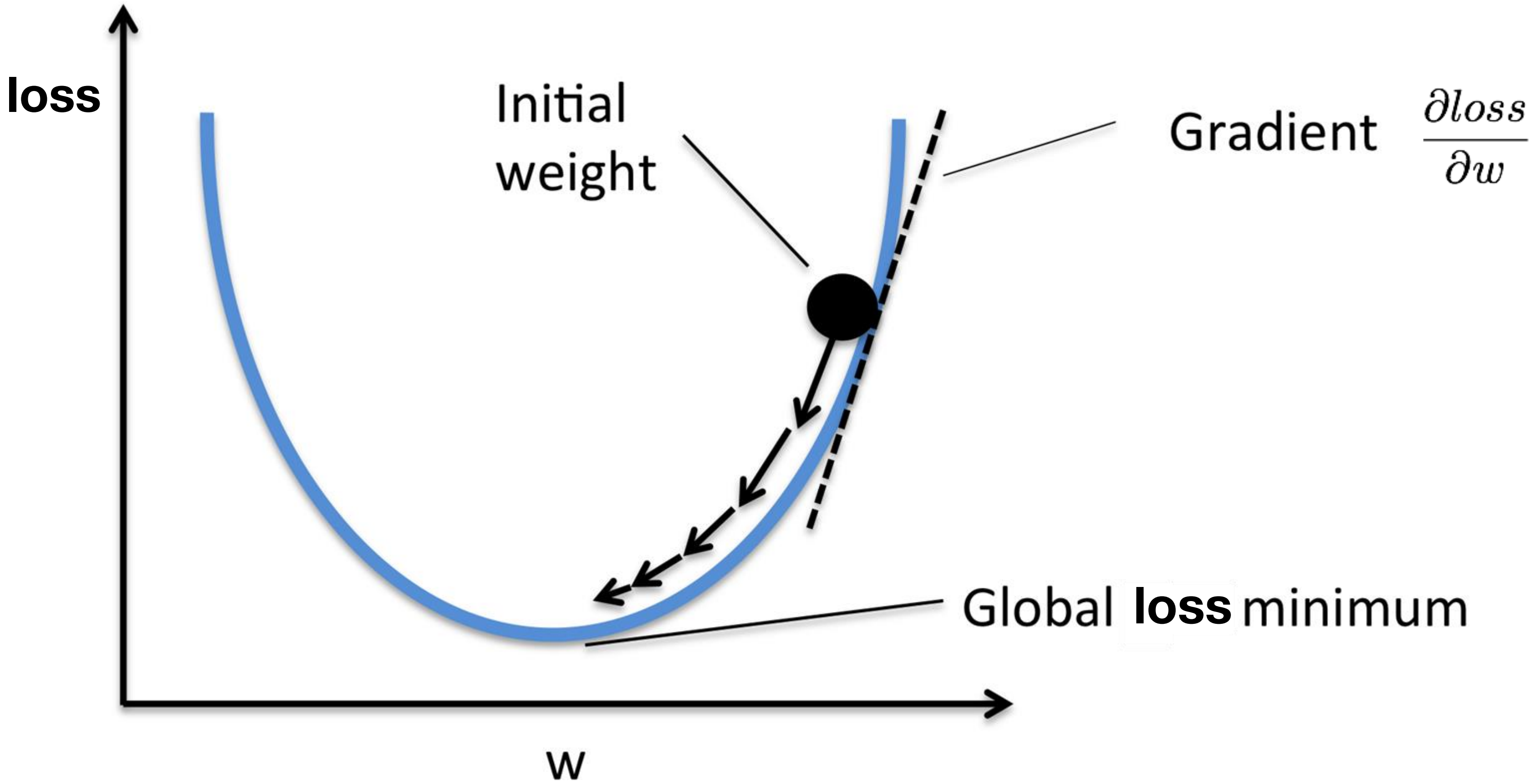
Loss (w=0)	Loss (w=1)	Loss (w=2)	Loss (w=3)	Loss (w=4)
mean=56/3=18.7	mean=14/3=4.7	mean=0	mean=14/3=4.7	mean=56/3=18.7



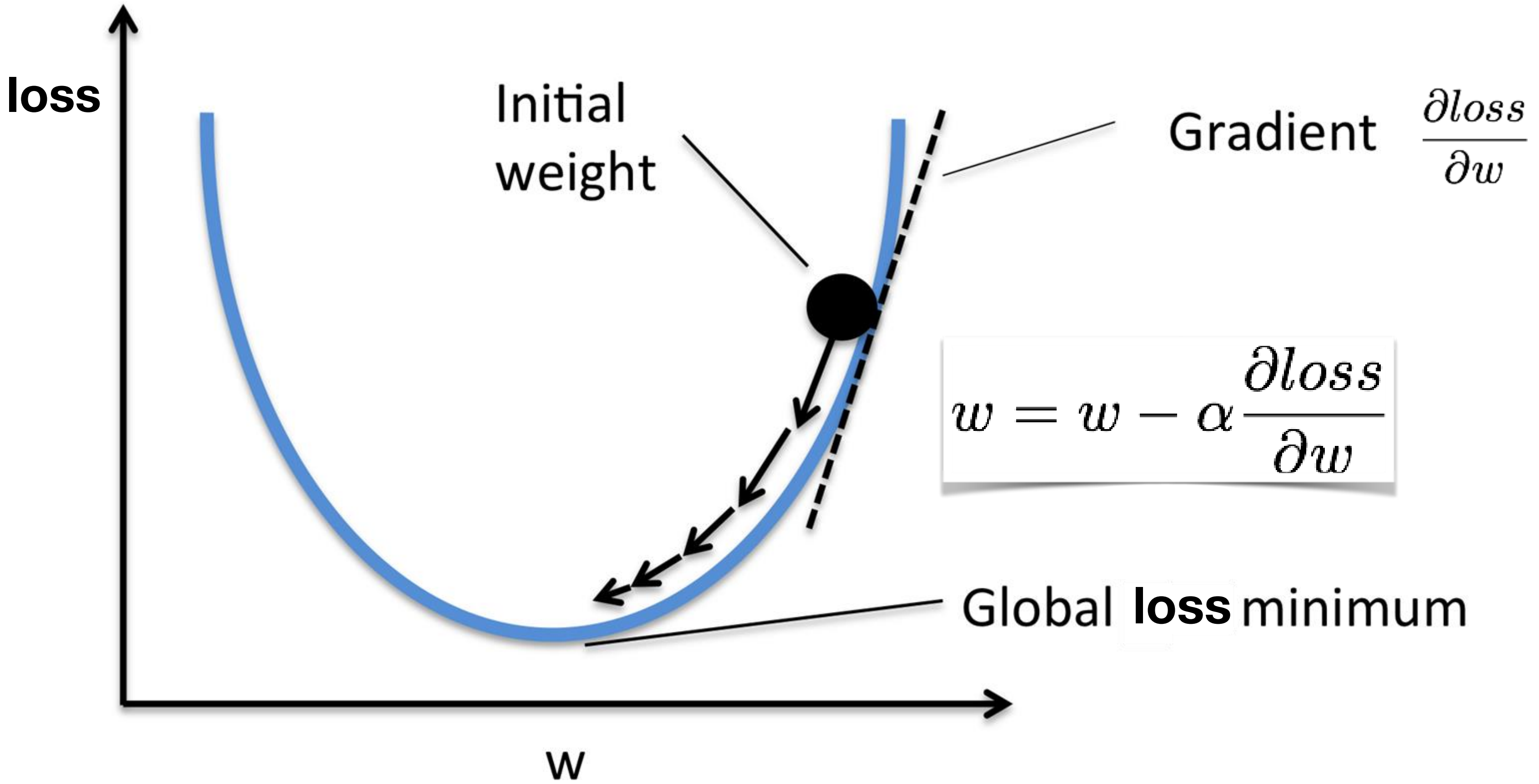
$$loss(w) = \frac{1}{N}\sum_{n=1}^{N}(\hat{y_n} - y_n)^2$$

$$\arg\min_{w} loss(w)$$

Gradient descent algorithm



Gradient descent algorithm



Derivative

$$loss = (\hat{y} - y)^2 = (x * w - y)^2$$

$$w = w - \alpha \frac{\partial loss}{\partial w}$$

Derivative

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$$w = w - \alpha \frac{\partial loss}{\partial w}$$

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

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

YOUR INPUT:

$f(w) =$

$$(xw - y)^2$$

Simplify **Roots/zeros**

FIRST DERIVATIVE:

$\frac{d}{dw}[f(w)] = f'(w) =$

The steps of calculation are displayed.

Move the mouse over a derivative $\frac{d}{dw}[\ldots]$ or tap it in order to show its calculation.

$$\frac{d}{dw}\left[(xw - y)^2\right]$$

$$= 2(xw - y) \cdot \frac{d}{dw}[xw - y]$$

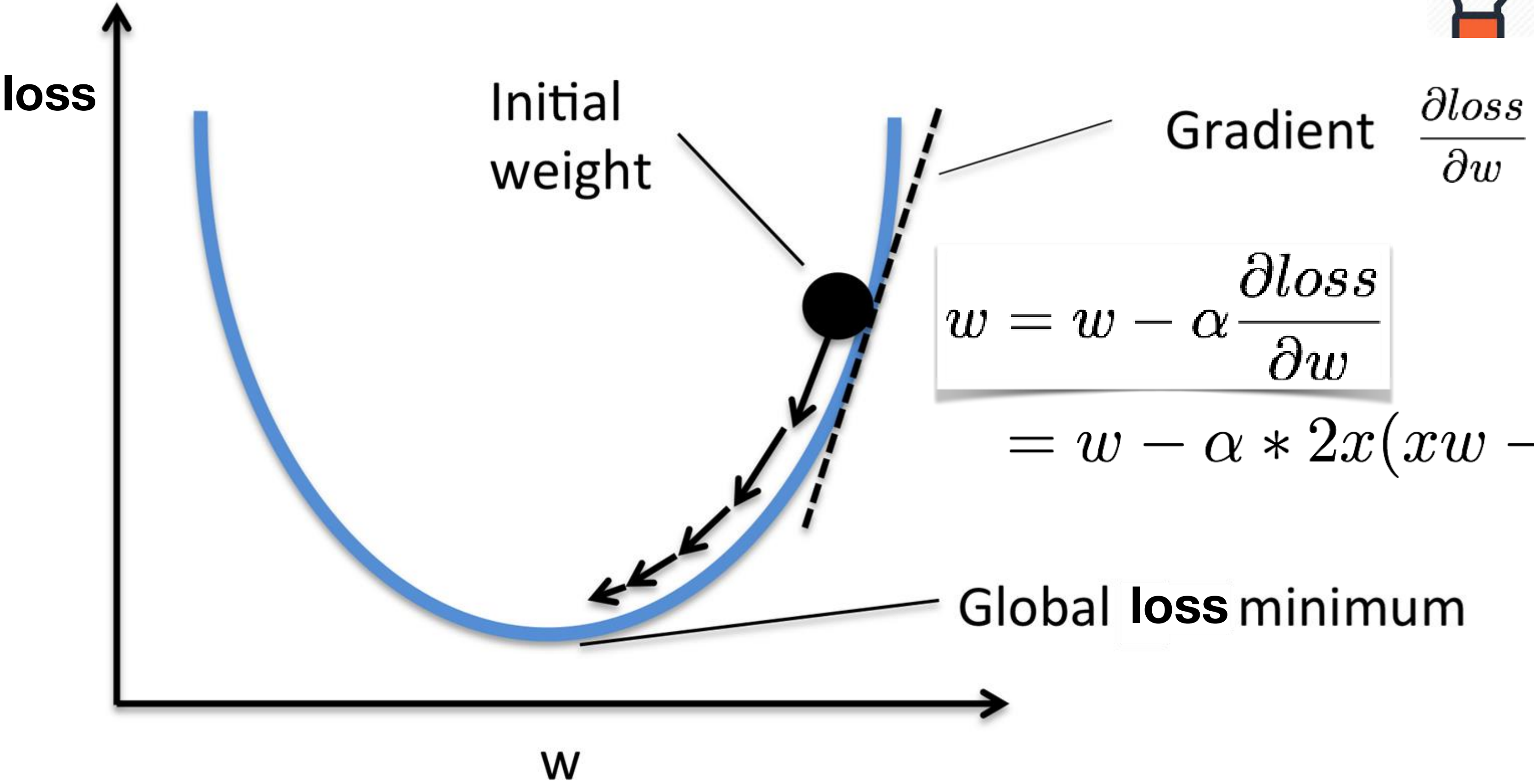
$$= 2\left(x \cdot \frac{d}{dw}[w] + \frac{d}{dw}[-y]\right)(xw - y)$$

$$= 2(1x + 0)(xw - y)$$

$$= 2x(xw - y)$$

https://www.derivative-calculator.net/

Let's implement!



$$\boxed{w = w - \alpha \frac{\partial loss}{\partial w}}$$

$$= w - \alpha * 2x(xw - y)$$

Data, Model, Loss, and Gradient

```python
x_data = [1.0, 2.0, 3.0]
y_data = [2.0, 4.0, 6.0]

w = 1.0  # a random guess: random value

# our model forward pass
def forward(x):
    return x * w


# Loss function
def loss(x, y):
    y_pred = forward(x)
    return (y_pred - y) * (y_pred - y)


# compute gradient
def gradient(x, y):  # d_loss/d_w
    return 2 * x * (x * w - y)
```

$$2x(xw - y)$$

Training: updating weight

```python
x_data = [1.0, 2.0, 3.0]
y_data = [2.0, 4.0, 6.0]

w = 1.0  # a random guess: random value

# our model forward pass
def forward(x):
    return x * w


# Loss function
def loss(x, y):
    y_pred = forward(x)
    return (y_pred - y) * (y_pred - y)


# compute gradient
def gradient(x, y):  # d_loss/d_w
    return 2 * x * (x * w - y)
```

```python
# Before training
print("predict (before training)",  4, forward(4))

# Training loop
for epoch in range(100):
    for x_val, y_val in zip(x_data, y_data):
        grad = gradient(x_val, y_val)
        w = w - 0.01 * grad
        print("\tgrad: ", x_val, y_val, grad)
        l = loss(x_val, y_val)

    print("progress:", epoch, "w=", w, "loss=", l)

# After training
print("predict (after training)",  "4 hours", forward(4))
```

Output
(from gradient numeric computation)

```
predict (before training) 4 4.0
	grad:  1.0 2.0 -2.0
	grad:  2.0 4.0 -7.84
	grad:  3.0 6.0 -16.23
progress: 0 w= 1.26 loss= 4.92
	grad:  1.0 2.0 -1.48
	grad:  2.0 4.0 -5.8
	grad:  3.0 6.0 -12.0
progress: 1 w= 1.45 loss= 2.69
	grad:  1.0 2.0 -1.09
	grad:  2.0 4.0 -4.29
	grad:  3.0 6.0 -8.87
progress: 2 w= 1.6 loss= 1.47
	grad:  1.0 2.0 -0.81
	grad:  2.0 4.0 -3.17
	grad:  3.0 6.0 -6.56
..
progress: 7 w= 1.91 loss= 0.07
	grad:  1.0 2.0 -0.18
	grad:  2.0 4.0 -0.7
	grad:  3.0 6.0 -1.45
progress: 8 w= 1.93 loss= 0.04
	grad:  1.0 2.0 -0.13
	grad:  2.0 4.0 -0.52
	grad:  3.0 6.0 -1.07
progress: 9 w= 1.95 loss= 0.02
predict (after training) 4 hours 7.80
```

```python
# Before training
print("predict (before training)",  4, forward(4))

# Training loop
for epoch in range(100):
   for x_val, y_val in zip(x_data, y_data):
       grad = gradient(x_val, y_val)
       w = w - 0.01 * grad
       print("\tgrad: ", x_val, y_val, grad)
       l = loss(x_val, y_val)

   print("progress:", epoch, "w=", w, "loss=", l)

# After training
print("predict (after training)",  "4 hours", forward(4))
```

Exercise 3-1: compute gradient

$$\hat{y} = x^2 w_2 + x w_1 + b$$
$$loss = (\hat{y} - y)^2$$

$$\frac{\partial loss}{\partial w_1} = ?$$

$$\frac{\partial loss}{\partial w_2} = ?$$

Exercise 3-2: implement

$$\hat{y} = x^2 w_2 + x w_1 + b$$
$$loss = (\hat{y} - y)^2$$

$$\frac{\partial loss}{\partial w_1} = ?$$

$$\frac{\partial loss}{\partial w_2} = ?$$

WHAT NEXT

Lecture 4:
Back-propagation