Deep Learning 101

How to train a neural network

Schedule

week	Date	Topic
9	10.27	Environment setup, python, Jupyter, PyCharm, TensorFlow, & regression
10	11.03	Training and testing
11	11.11	CNN
12	11.18	RNN
13	11.24	Autoencoder & GAN

Today’s Class

- Recap
- How to train a neural network
  - Feature
  - Hypothesis
  - Activation functions
  - Cost functions
  - Gradient descent and Backpropagation
- Lab time

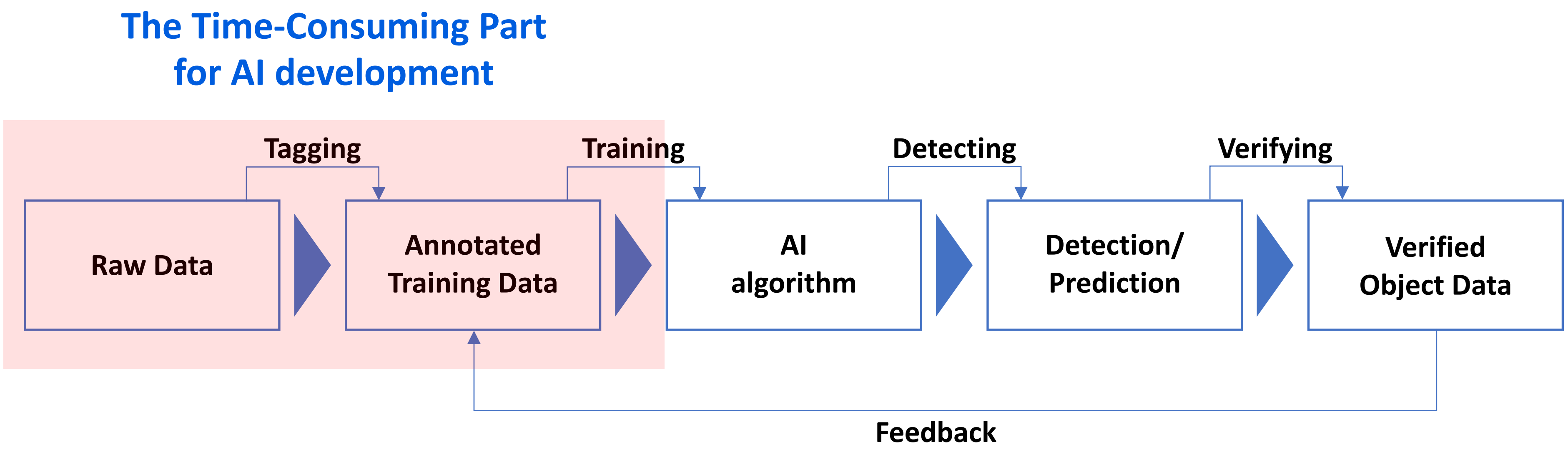
Recap

- Neural network as a function
  - y = f(x)
- Perceptron
  - Y = WX + b
  - Two inputs: x1, x2
  - One output: y
  - Linear regression
- XOR problem
  - Linear regression can’t solve the XOR problem
  - Require multivariate regression

What

- Dataset: data for training and testing
  - Requires preprocessing
- Model: What the network learns
  - Training, validation, and testing
- Inference: Model in action
  - Predicting based on the learned model

The Challenge



Training data is the most important part of AI development, but it is also the most difficult and time-consuming part

How to train a model

- Define input and output
- Decide on the input features
- Build layers of the network: hyperparameters
  - Number of layers
  - Learning rate
  - Number of epochs
  - Etc.
- Train the model: parameters
  - Weights and biases
  - Variables in TensorFlow
- Verify the model:
  - Using verification data

Models and Functions

- Hypothesis:

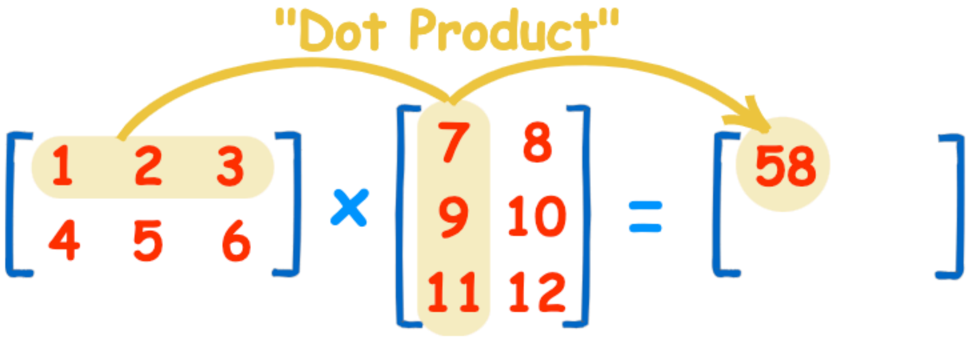
$$H(x_1, x_2, x_3) = w_1x_1 + w_2x_2 + w_3x_3 + b$$

- Activation:
  - Sigmoid, ReLU, LeakyReLU, etc.

- Cost:

$$cost(W, b) = \frac{1}{m}\sum_{I=1}^{m}(H(x_1^{(i)}, x_2^{(i)}, x_3^{(i)}) - y^{(i)})^2$$

Matrix multiplication



The "Dot Product" is where we **multiply matching members**, then sum up:

$$(1, 2, 3) \bullet (7, 9, 11) = 1\times7 + 2\times9 + 3\times11$$
$$= 58$$

https://www.mathsisfun.com/algebra/matrix-multiplying.html

Functions using matrix

- Hypothesis
  - Y = WX + b

$$\begin{pmatrix} x_1 & x_2 & x_3 \end{pmatrix} \cdot \begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix} = \begin{pmatrix} x_1 w_1 + x_2 w_2 + x_3 w_3 \end{pmatrix}$$

- Activation function
- Cost function

$$cost(W, b) = \frac{1}{m} \sum_{I=1}^{m} (H(x_1^{(i)}, x_2^{(i)}, x_3^{(i)}) - y^{(i)})^2$$

Activation functions

- Introduces non-linearity
- Normalizes the output: activation functions are also called Normalization functions
- Different kinds
  - Step function: $f(\mathbf{x}) = \begin{cases} 1 & \text{if } \mathbf{w} \cdot \mathbf{x} + b > 0, \\ 0 & \text{otherwise} \end{cases}$
  - Sigmoid:

$$S(x) = \frac{1}{1 + e^{-x}}$$

$S(x)$ = sigmoid function

e = Euler's number

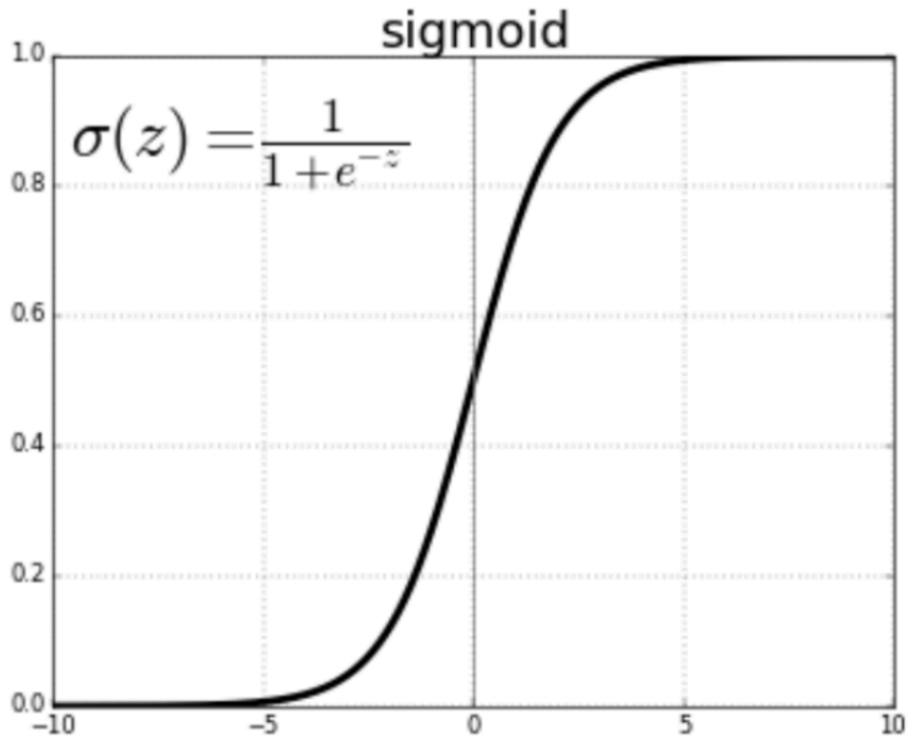
Activation function: Sigmoid

- Sigmoid:

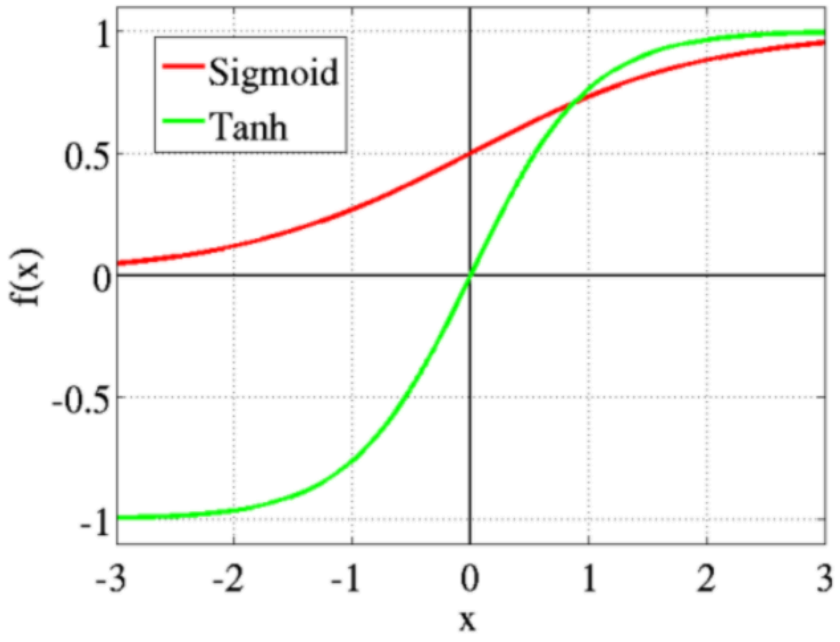
$$S(x) = \frac{1}{1 + e^{-x}}$$

$S(x)$ = sigmoid function

e = Euler's number



Activation functions: Sigmoid and Tanh



https://www.neuronactivator.com/blog/what-even-is-activation-function

Activation Functions: ReLU and Leaky ReLU

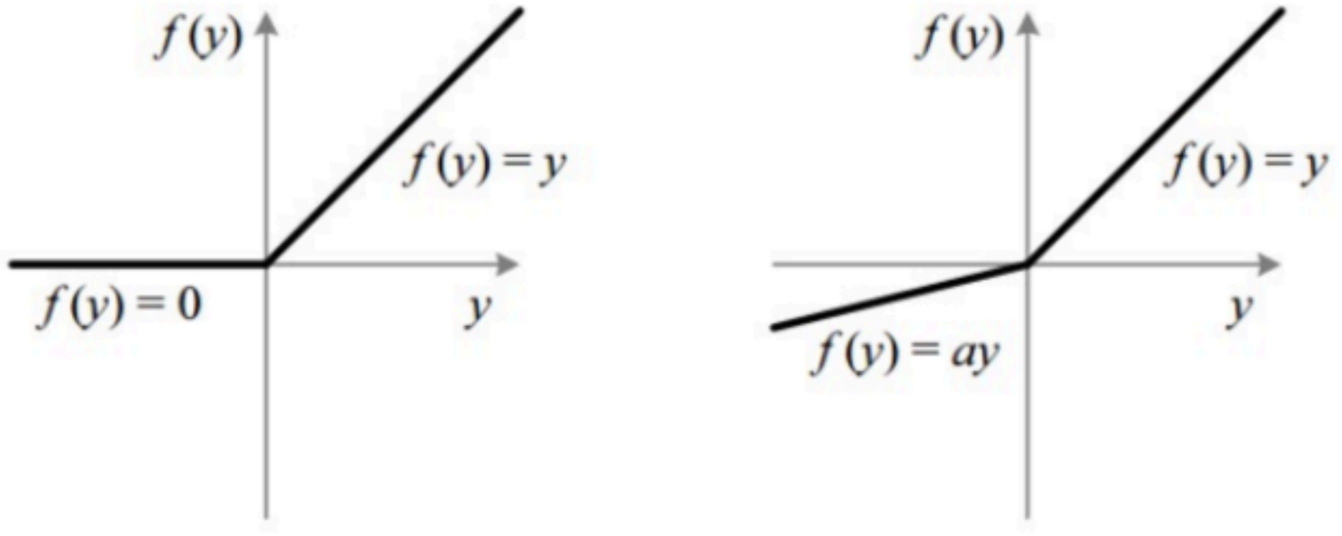


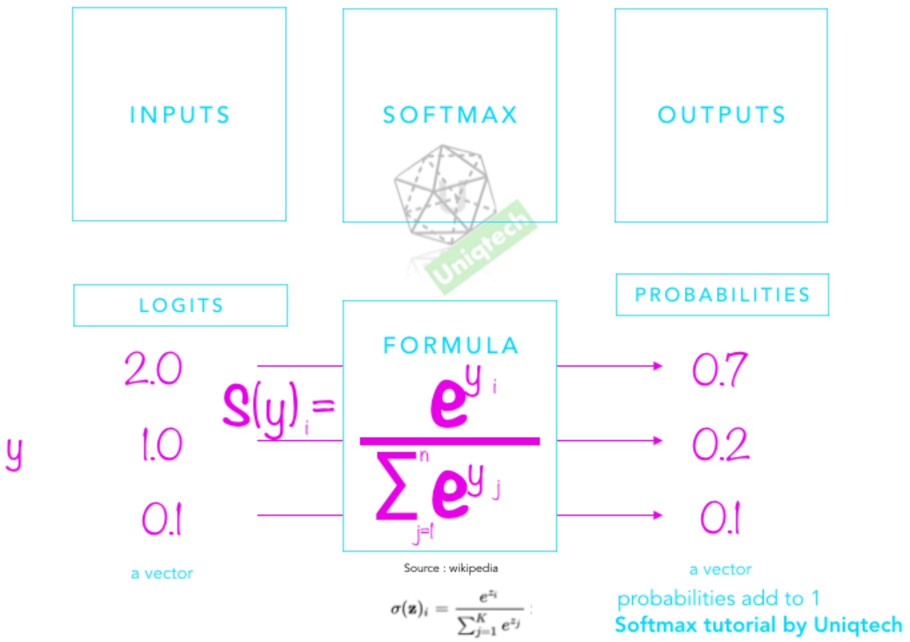
Fig : ReLU v/s Leaky ReLU

https://www.neuronactivator.com/blog/what-even-is-activation-function

Activation Function: Softmax

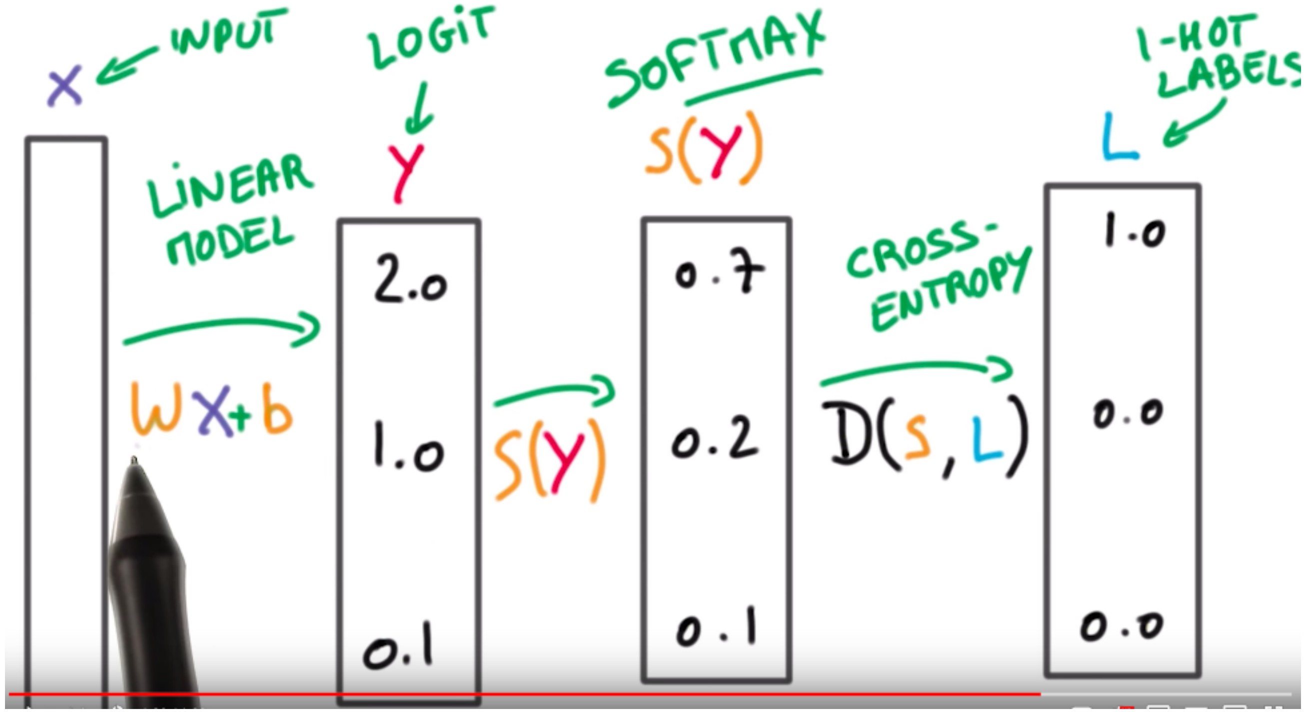
- The softmax function is often used in the final layer of a neural network-based classifier.
- All probabilities sum to one
- Often used with a log loss (or cross-entropy) cost function
- To solve a non-linear variant of multinomial logistic regression.

Activation Function: Softmax



https://medium.com/data-science-bootcamp/understand-the-softmax-function-in-minutes-f3a59641e86d

Loss Function: Cross Entropy

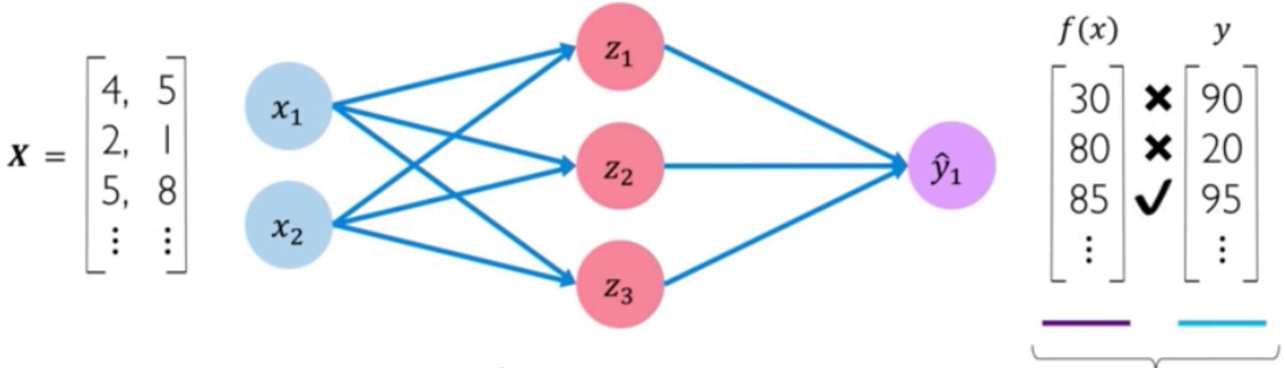


https://medium.com/data-science-bootcamp/understand-cross-entropy-loss-in-minutes-9fb263caee9a

Loss Function: Mean Squared Error

Mean Squared Error Loss

Mean squared error loss *can be used with regression models that output continuous real numbers*



Final Grades
(percentage)

$$J(\boldsymbol{W}) = \frac{1}{n}\sum_{i=1}^{n}\Big(\underbrace{y^{(i)}}_{\text{Actual}} - \underbrace{f\big(x^{(i)};\boldsymbol{W}\big)}_{\text{Predicted}}\Big)^2$$

```
loss = tf.reduce_mean( tf.square(tf.subtract(y, predicted)) )
```

http://introtodeeplearning.com/

Training is minimizing the cost

- Training a neural network is basically the problem of minimizing the cost function.
- Gradient descent is the most popular approach.
- For a given cost function, minimize cost(W, b)

Backpropagation

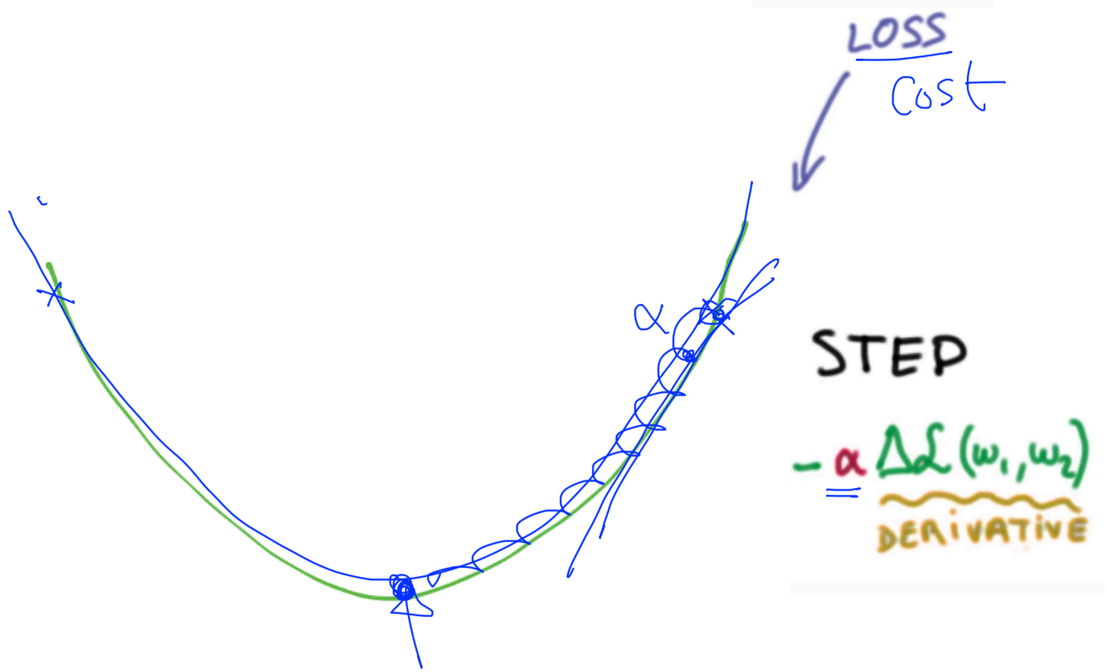
1. Use Calculus: the study of change
2. Batches, mini-batches, and stochastic batches

Steps:
1. Take the derivative: the slope of a tangent line at a specific point in time
2. Partial derivative
3. The chain rule: composite functions

- Backpropagation of errors: Updating weights using gradient descent

Backpropagation using gradient descent

Gradient descent



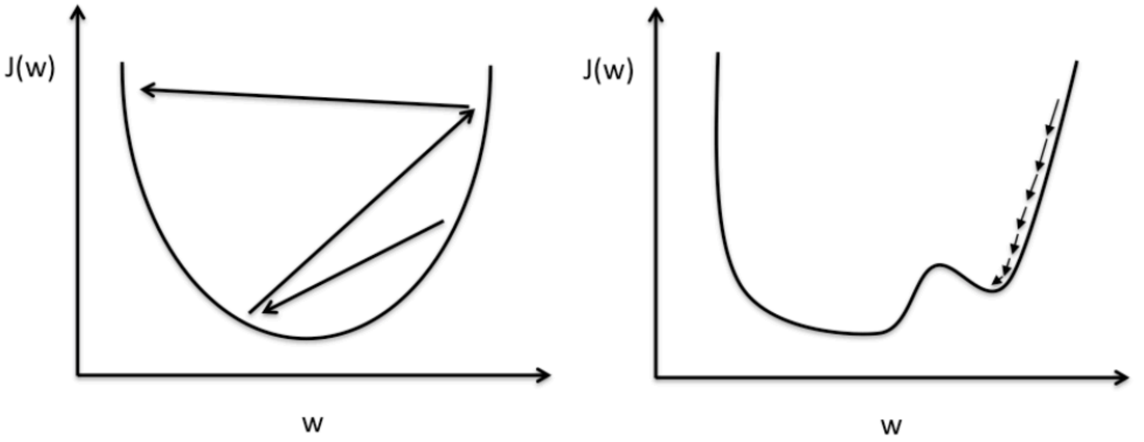
https://www.udacity.com/course/viewer#!/c-ud730/l-6370362152/m-6379811827

Problems with training

- Initial weights: random means you can’t predict
- Vanishing/exploding gradients
- Local minima
- Overfitting & underfitting
- Hyperparameters: learning rate, number of layers, etc. require human intelligence!

Learning rate

Learning rate: NaN!

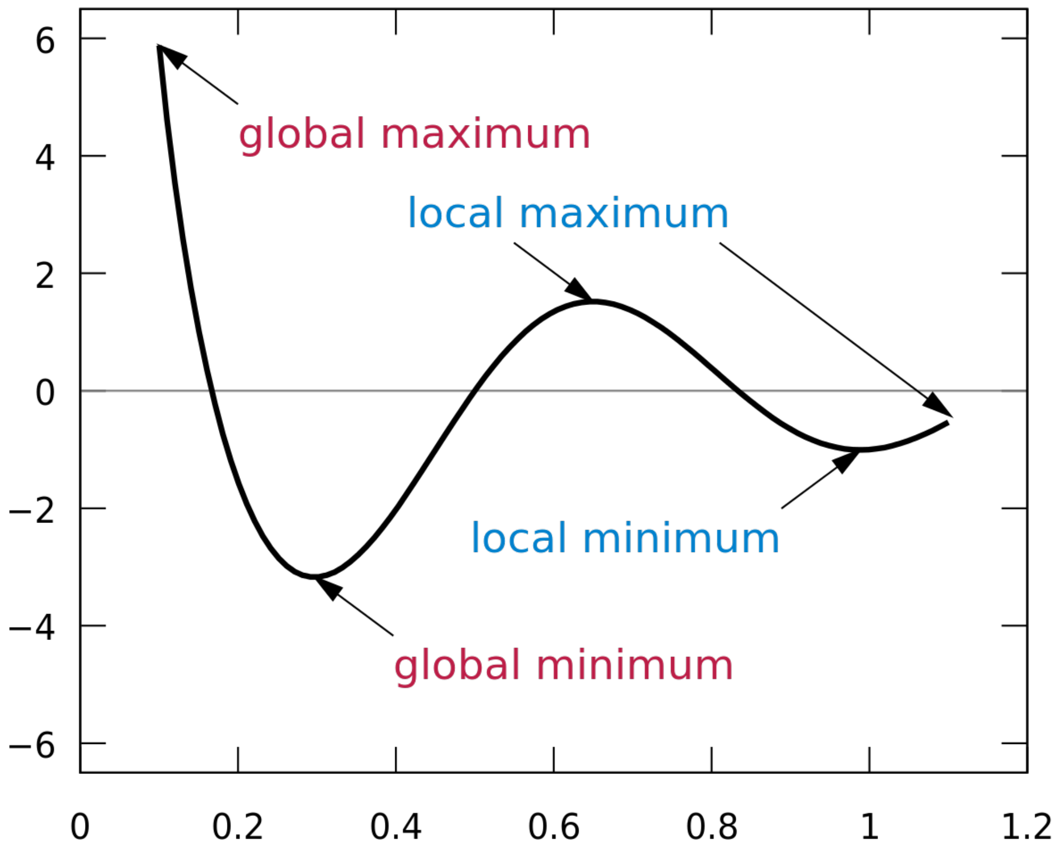


Large learning rate: Overshooting.

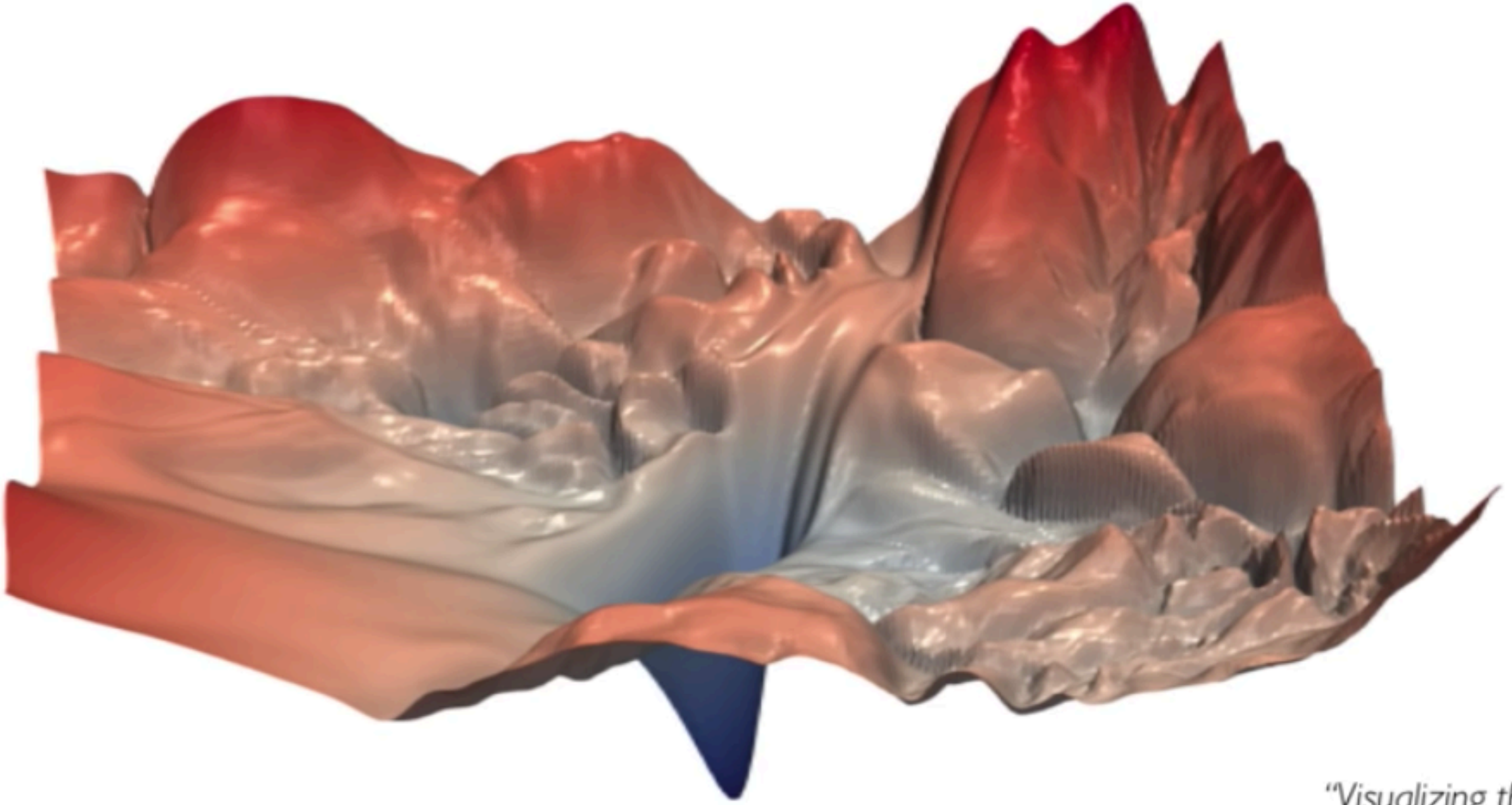
Small learning rate: Many iterations until convergence and trapping in local minima.

http://sebastianraschka.com/Articles/2015_singlelayer_neurons.html

Local minima



Training Neural Networks is Difficult



"Visualizing the loss landscape of neural nets". Dec 2017.

Lab time

- To clone: from your terminal
  - >git clone https://github.com/changsin/DeepLearning-101.git
- Or use google colab to point to the git hub repository
- [Git](Git) is an open source version control system
  - Github is a host service using git.