DEEP LEARNING

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Outline

Outline

Problems

What is Deep Learning?

Deep Learning is a subfield of machine learning (ML) in artificial intelligence (AI) that deals with algorithms inspired from the biological structure and functioning of a brain to aid machines with intelligence.

- Deep learning is just a modern name for artificial neural networks with many layers.
- It is basically due to the structure of the artificial neural networks (ANNs) which consists of some n number of layers responsible for learning the intricate patterns in the data.

Machine Learning Vs Deep Learning

Why Deep Learning?

- The success of machine learning lies in the right set of features by feature engineering/handcrafting.
- ANNs in deep learning employ several layers, it learns the intrinsic features representation of data by itself features.

Machine Learning

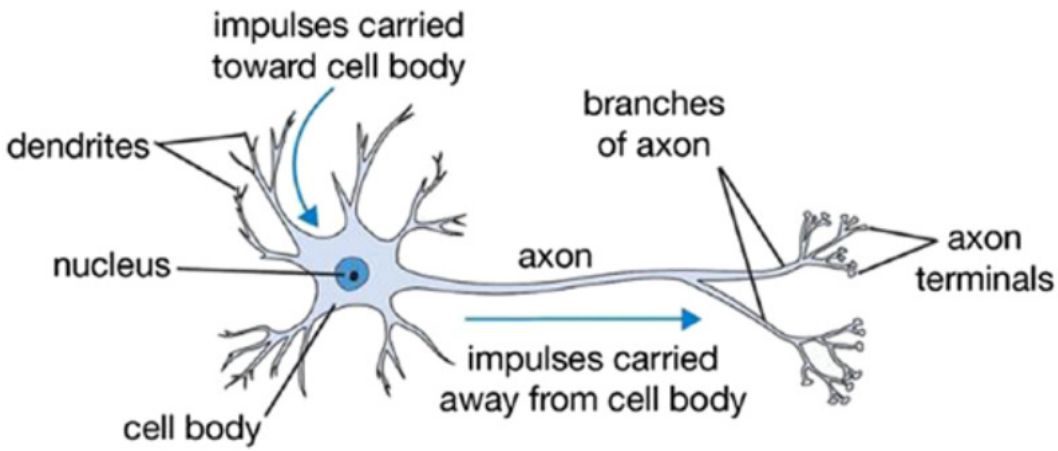
- Uses feature engineering to extract patterns from data.
- Difficult and complex because different datasets need different feature engineering approachs.

Deep Learning

- Automatically learns features representation from data.
- Allows learning complex features e.g speech and complex graphs.

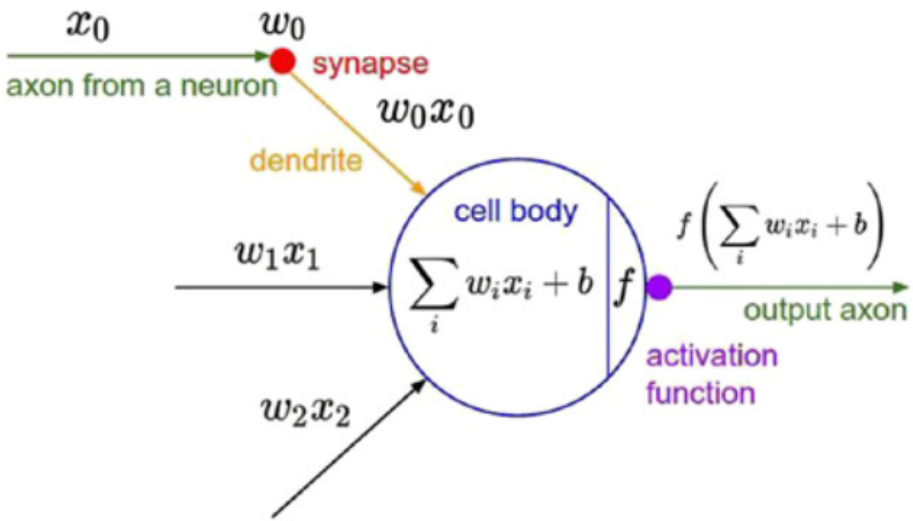
What is Biological Neuron?

A neuron can be defined as the basic computational unit of the human brain. Neurons are the fundamental units of our brain and nervous system.



What is an Artificial Neuron?

An artificial neuron is a mathematical model which mimics biological neurons in human brain, artificial neural network is an interconnected group of neurons/nodes.



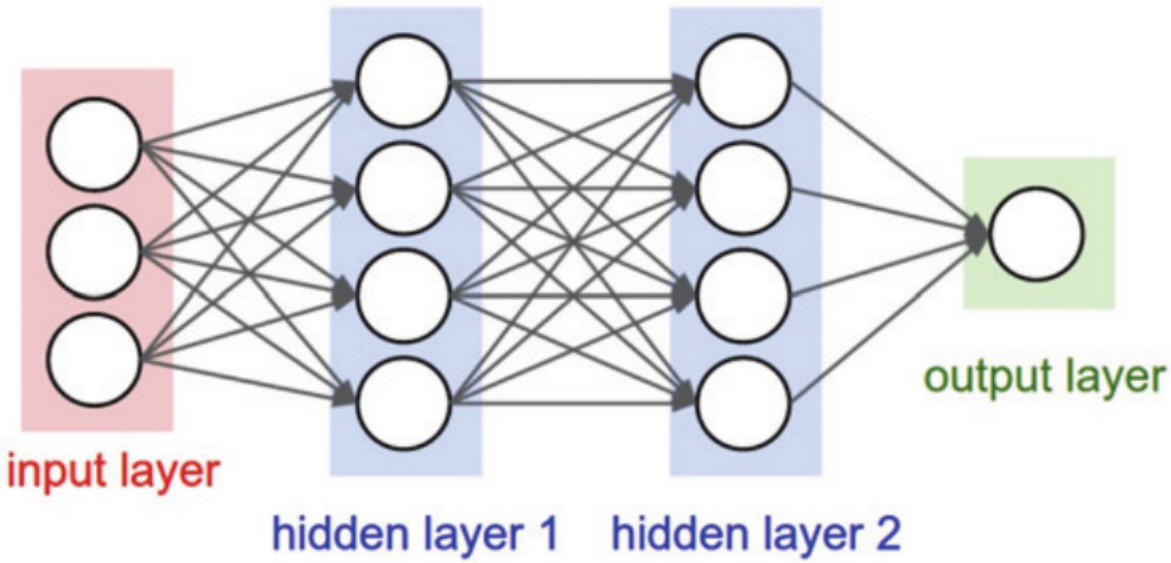
Why Deep Learning and Why Now?

1. Data(Big Data) and algorithms.
   - Large datasets.
   - New and improved algorithms.
2. Hardware availability
   - Modern GPU and TPU architectures.
     - Google Cloud and Google Colab
     - AWS and Amazon SageMaker
     - AutoML
   - Easier collection and storage.
3. Open source deep learning frameworks and models
   - TensorFlow.
   - PyTorch.
   - Keras.
4. Increased demand of AI solutions, funding and AI initiatives/startups.

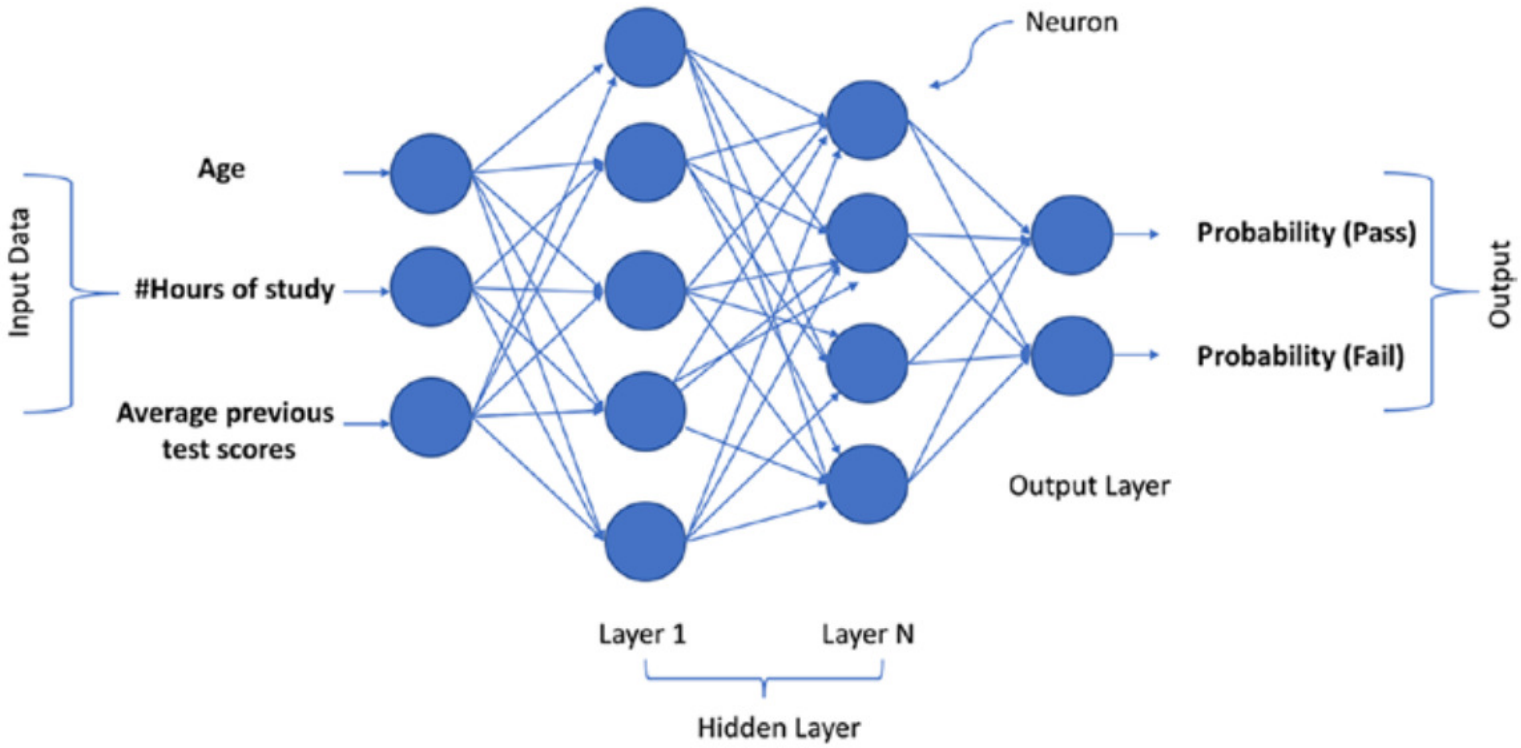
Outline

A Typical ANN Consists of Three Layers:

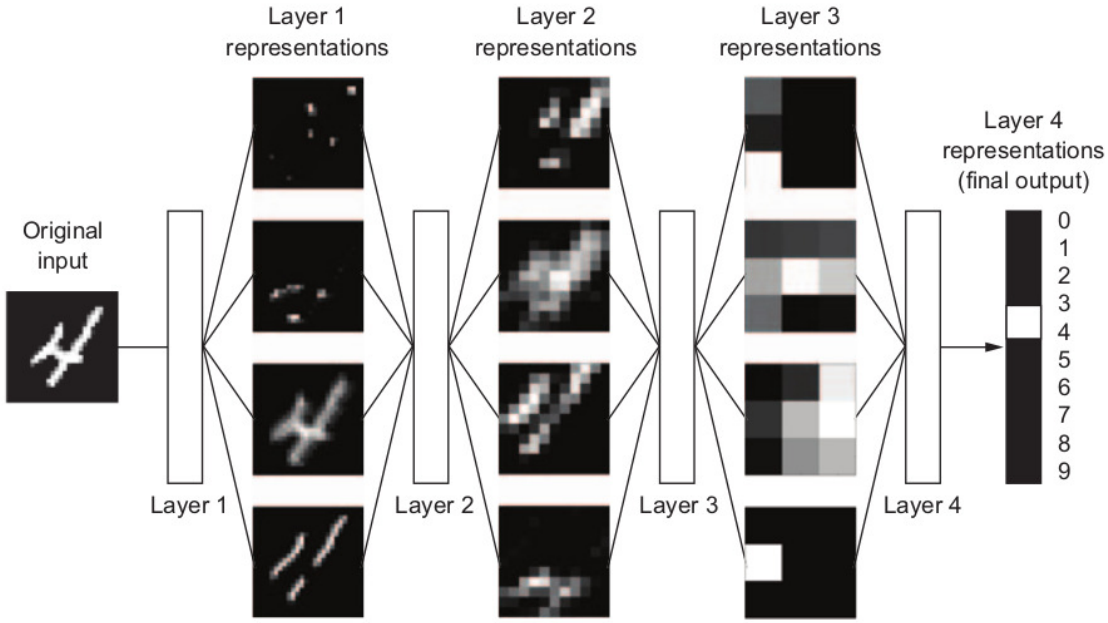
1. Input layer
2. Hidden layer
3. Output layer



Case Study 1


Neuron
Age
#Hours of study
Average previous test scores
Input Data
Probability (Pass)
Probability (Fail)
Output
Output Layer
Layer 1
Layer N
Hidden Layer

Case Study 2


Layer 1
representations
Layer 2
representations
Layer 3
representations
Layer 4
representations
(final output)
Original
input
Layer 1
Layer 2
Layer 3
Layer 4
0
1
2
3
4
5
6
7
8
9

Input Layer

- The input layer is where we feed input to the network.
- The number of neurons in the input layer is the number of inputs we feed to the network.
- Each input will have some influence on predicting the output.
- No computation is performed in the input layer; it is just used for passing information from the outside world to the network.

Hidden Layer

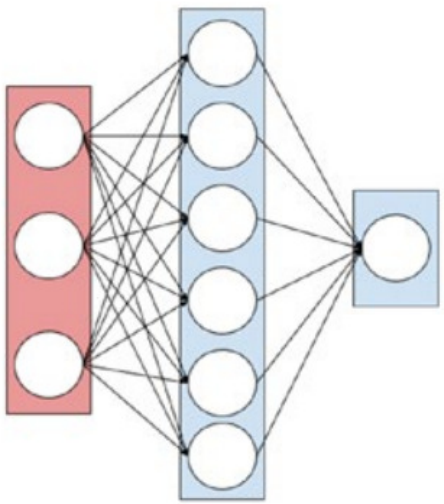
- Any layer between the input layer and the output layer is called a hidden layer.
- The hidden layer is responsible for deriving complex relationships between input and output.
- It is majorly responsible for learning the data representation and for extracting the features.

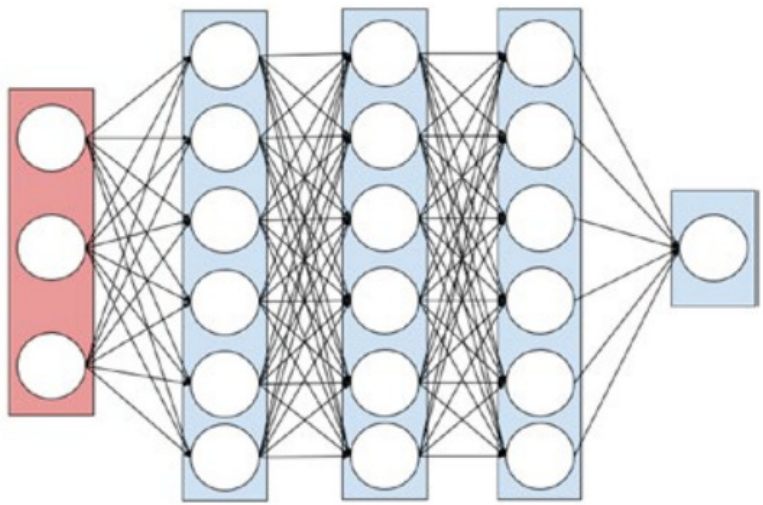
Output Layer

- After processing the input, the hidden layer sends its results to the output layer.
- The number of neurons in the output layer is based on the type of problem we want our network to solve.
- If it is a binary classification, then the number of neurons in the output layer is one that tells us which class the input belongs to.

Artificial Neural Networks and It's Layers

Different Between Shallow and Deep Neural Network





What and Why Activation Functions?

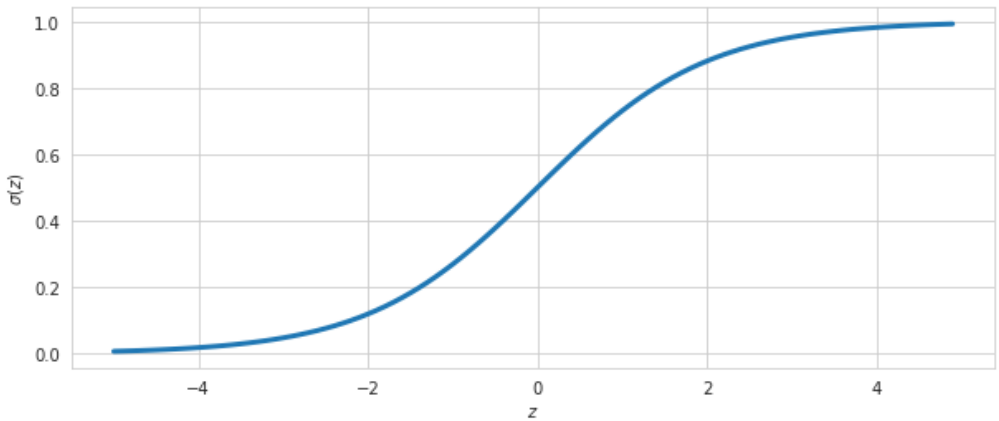
- An activation function, also known as a transfer function is used to introduce non-linearity in neural networks.
- If we do not apply the activation function, then a neuron simply resembles the linear regression.
- The aim of the activation function is to introduce a non-linear transformation to learn the complex underlying patterns in the data.

Sigmoid/Logistic

The sigmoid function is mathematically defined as

$$\sigma(z) = \frac{1}{1 + e^{-z}}$$

and represented in the following figure has small output changes in range (0,1) when the input varies in the range $(-\infty, \infty)$.

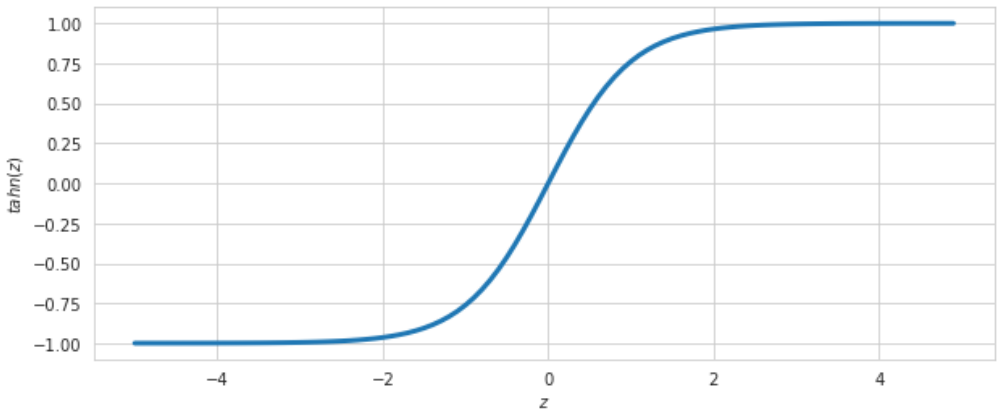


Tanh

The tahn function is mathematically defined as

$$\tanh(z) = \frac{e^z - e^{-z}}{e^z + e^{-z}}$$

and represented in the figure below and has small output changes in range $(-1, 1)$.

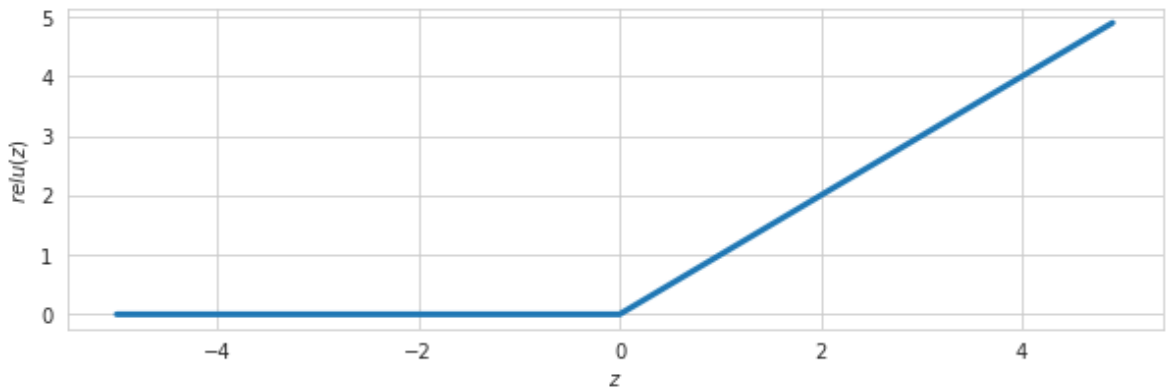


Rectified Linear Unit(ReLU)

The ReLU function is mathematically defined as:

$$f(z) = \begin{cases} z, & \text{if } z \geq 0 \\ 0, & \text{if } z < 0 \end{cases}$$

The function is zero for negative values and it grows linearly for positive values.

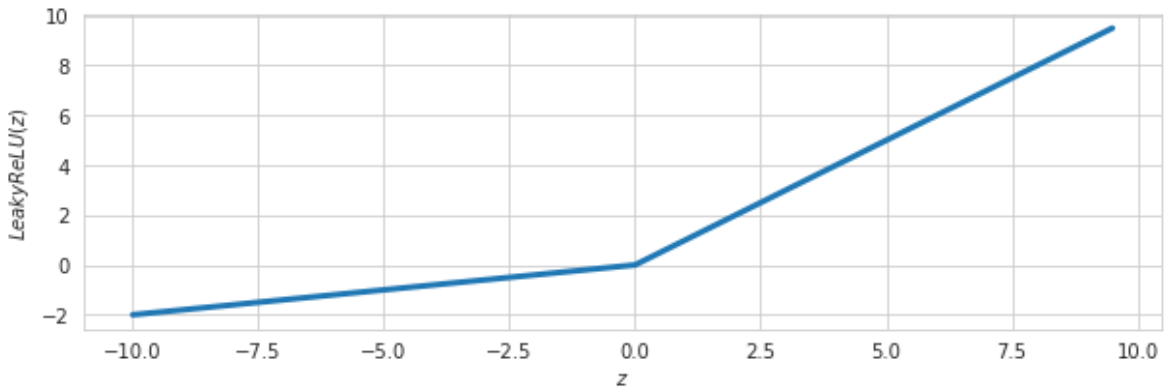


Leaky ReLU

The Leaky ReLU function is mathematically defined as:

$$f(z) = \begin{cases} z, & \text{if } z \geq 0 \\ \alpha x, & \text{if } z < 0 \end{cases}$$

Instead of converting every negative input to zero, it has a small slope for a negative.

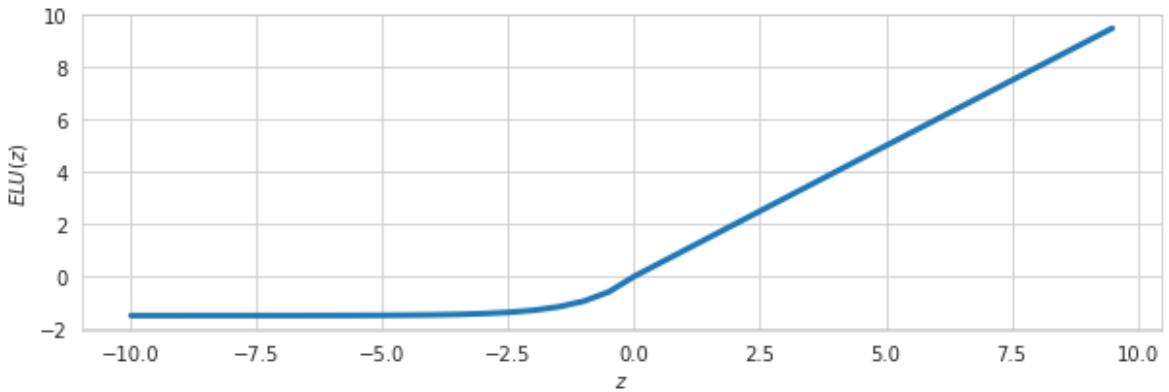


Exponential Linear Unit(ELU)

The ELU function is mathematically defined as:

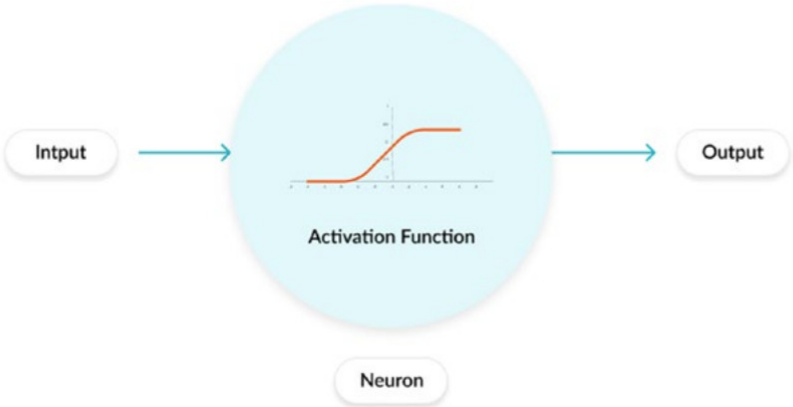
$$f(z) = \begin{cases} z, & \text{if } z \geq 0 \\ \alpha(e^z - 1), & \text{if } z < 0 \end{cases}$$

has a small slope for negative values. But instead of having a straight line, it has a log curve.



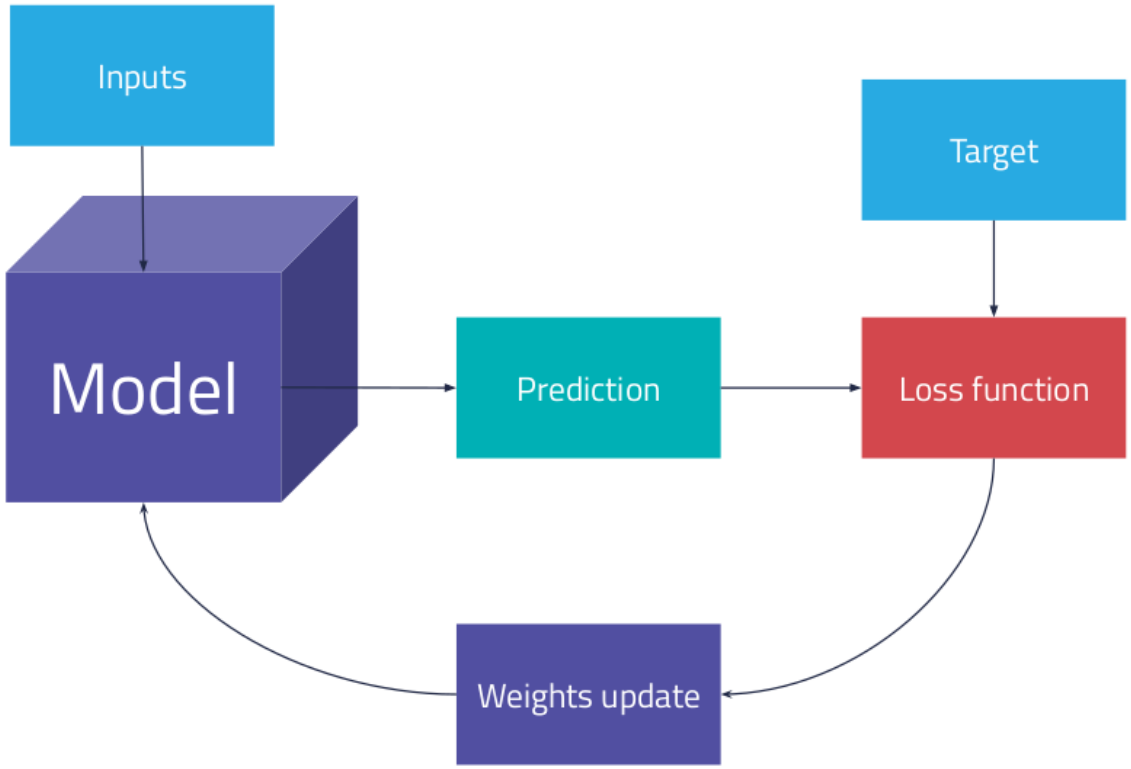
An Activation Function

- The function is attached to each neuron in the network and determines whether it should be fired or not.
- The activation function is located in between the input feeding the current neuron and its output going to the next layer.
- Other activation functions: RReLU, Softmax, CELU,PReLU, GELU, Softsign, Softplus, LogSoftmax.



How Does Artificial Neural Networks Learn?

ANN Learning/Model Training



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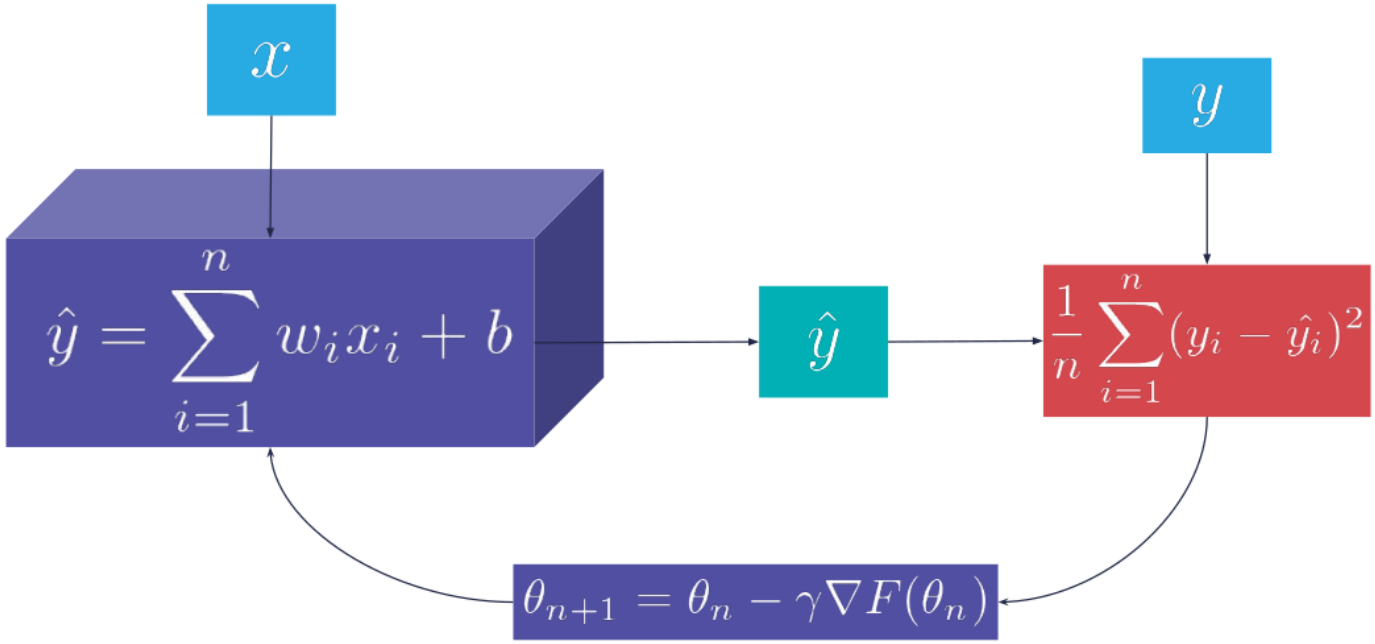
ANN Learning/Model Training(In Math)



Common Loss Functions

L1 Loss

$$\frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$$

Mean squared error (L2 Loss)

$$\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$

Negative log likelihood

$$-\sum_{i=1}^{n}\log \hat{y}_i$$

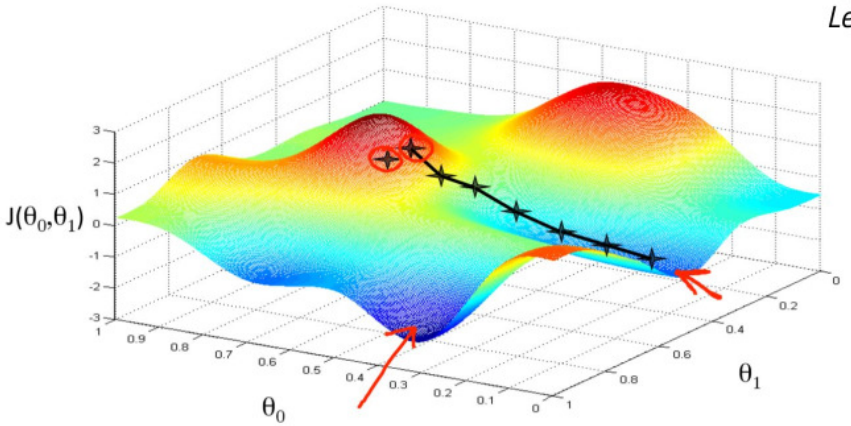
Cross entorpy

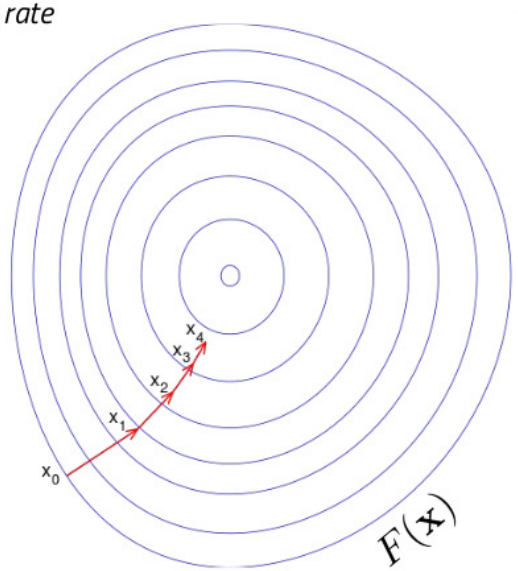
$$\frac{1}{n}\sum_{i=1}^{n} y_i \cdot \log \hat{y}_i$$

Gradient Descent

$$\theta_{n+1} = \theta_n - \gamma \Delta F(\theta_n)$$

Learning rate





Common Optimizers

Adam

$$\theta_{n+1} = \theta_n - \frac{\gamma_t}{\sqrt{\mathcal{A}_n}}(\mathcal{S}_n)$$

where:
$\mathcal{A}_n = \rho\mathcal{A}_n - (1-\rho)(\delta\mathcal{F}(\theta_n))^2$,
$\mathcal{S}_n = \rho_f\mathcal{S}_n - (1-\rho_f)\delta\mathcal{F}(\theta_n)$

AdaDelta

$$\theta_{n+1} = \theta_n - \sqrt{\frac{\delta_n}{\mathcal{A}_n}}(\delta\mathcal{F}(\theta_n))$$

where: $\delta_i = \rho\delta_i - (1-\rho)(\Delta\theta_n)^2$

RMSProp

$$\theta_{n+1} = \theta_n - \frac{\gamma}{\sqrt{\mathcal{A}_n}}(\delta\mathcal{F}(\theta_n))$$

where:
$\mathcal{A}_n = \rho\mathcal{A}_n - (1-\rho)(\delta\mathcal{F}(\theta_n))^2$

AdaGrad

$$\theta_{n+1} = \theta_n - \frac{\theta}{\sqrt{\mathcal{A}_n}}(\delta\mathcal{F}(\theta_n))$$

where: $\mathcal{A}_n = \mathcal{A}_n - (\delta\mathcal{F}(\theta_n))^2$

How Does Artificial Neural Networks Learn?

Frequently Used Terminologies

1. Forward pass/propagation: Forward pass implies forward propagating from the input layer to the output layer.
2. Backward pass/propagation: Backward pass implies backpropagating from the output layer to the input layer.
3. Epoch: The epoch specifies the number of times the neural network sees our whole training data. So, we can say one epoch is equal to one forward pass and one backward pass for all training samples.
4. Batch size: The batch size specifies the number of training samples we use in one forward pass and one backward pass.
5. Number of iterations: The number of iterations implies the number of passes where:
   one pass = *one forward pass* + *one backward pass*.

Outline

Python Libraries for Deep Learning

PyTorch

- PyTorch, and most of the other deep learning frameworks, can be used for two different things:
  - Replacing NumPy-like operations with GPU-accelerated operations.
  - Building deep neural networks.
- PyTorch extensively uses Python concepts, such as classes, structures, and conditional loops.
- This allows building of Deep Learning algorithms in a pure object-oriented fashion.
- As PyTorch was primarily built for research, it is not recommended for production usage in certain scenarios where latency requirements are very high.

TensorFlow

- TensorFlow is an open source software library from Google, which is extensively used for numerical computation.
- It is one of the most popularly used libraries for building deep learning models.
- It was originally developed by the researchers and engineers of the Google Brain team.
- TensorFlow supports execution on everything, including CPUs, GPUs, and TPUs, which are tensor processing units, and on mobile and embedded platforms.
- Due to its flexible architecture and ease of deployment, it has become a popular choice of library among many researchers and scientists for building deep learning models.

Keras

- Keras is a high-level neural network API written in Python,it provides ease and simple way of composing building blocks to create and train deep learning models in a very abstract manner.

- The simplicity of Keras is that it helps users quickly develop deep learning models and provides a ton of flexibility while still being a high-level API.

- By far the most widely adopted usage of Keras is with TensorFlow as a back end (i.e., Keras as a high-level deep learning API and TensorFlow as its low-level API back end).

Common Deep Learning Subfields

- Computer Vision: is the field of computer science that focuses on creating digital systems that can process, analyze, and make sense of visual data (images or videos) in the same way that humans do.
- The concept of computer vision is based on teaching computers to process an image at a pixel level and understand it.
- Technically, machines attempt to retrieve visual information, handle it, and interpret results through special software algorithms e.g Convolutional Neural Networks.

Common Deep Learning Subfields

- Natural Language Processing: is the ability of computational technologies and/or computational linguistics to process human natural language.

- The concept of NLP can be related to the existing NLP products from the world's top tech companies, such as Google Assistant from Google, Siri speech assistance from Apple, and so on.

- Components of NLP:
  - Natural Language Understanding (NLU).
  - Natural Language Generation (NLG).

Outline

Areas of Application

Automatic Colorization

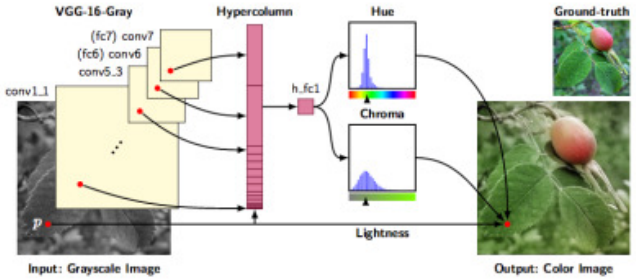


Image Captioning

Object Classification and Detection

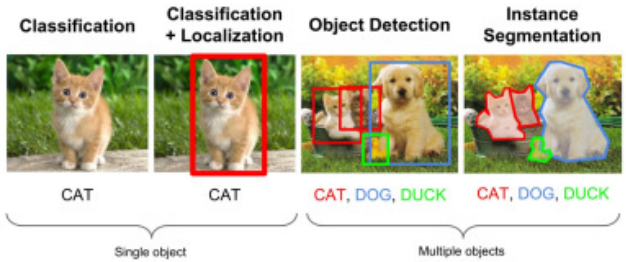


Image Style Transfer

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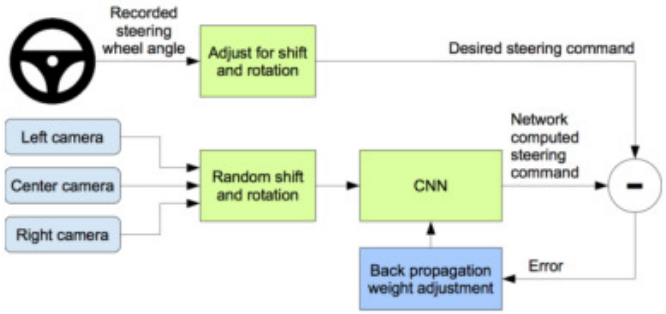
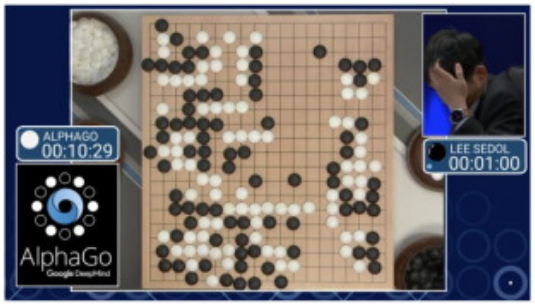
Areas of Application

Self driving car

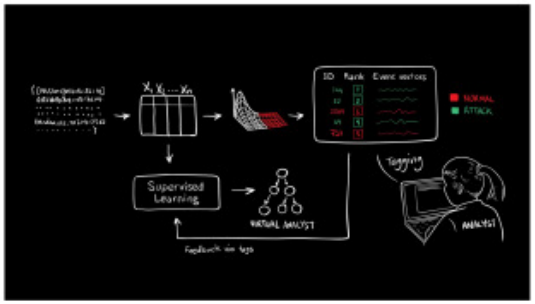


Drones

Game



Cyber attack prediction



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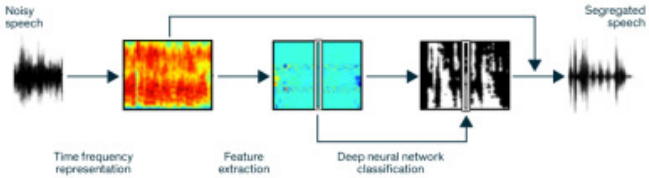
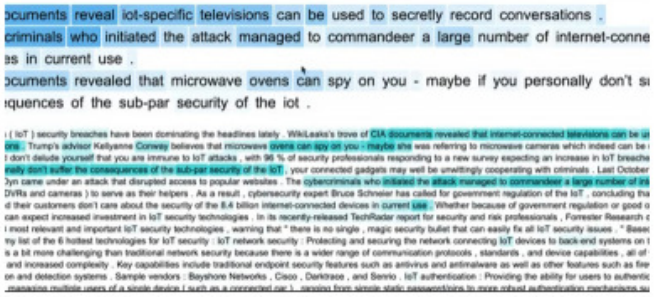
Areas of Application

Machine translation

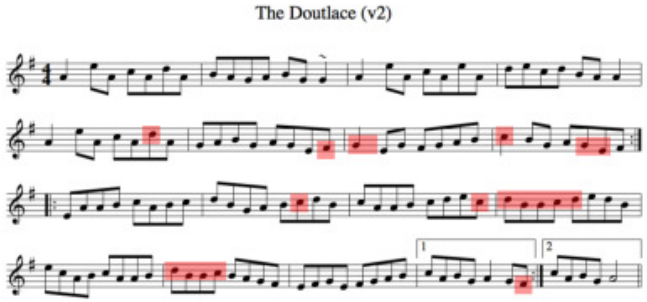
Speach Processing



Automatic Text Generation



Music composition



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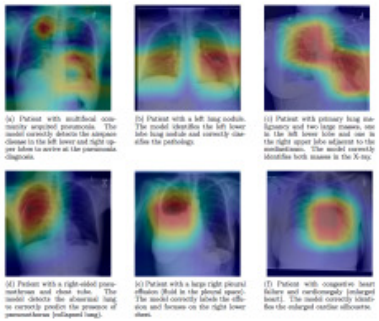
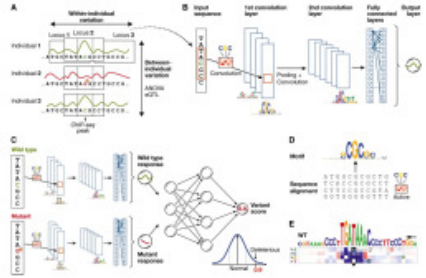
Areas of Application

Pneumonia Detection on Chest X-Rays



Computational biology



Pedict heart disease risk from eye scans

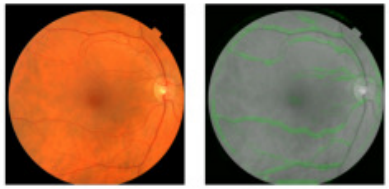
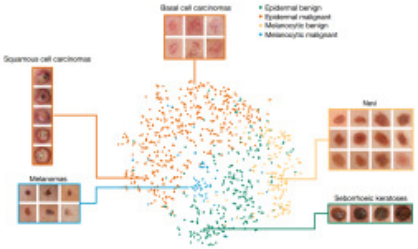


Image of retina

Blood pressure predictions focus on blood vessels

Diagnosis of Skin Cancer



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Areas of Application - Tanzania

TanzanAI Report 2019

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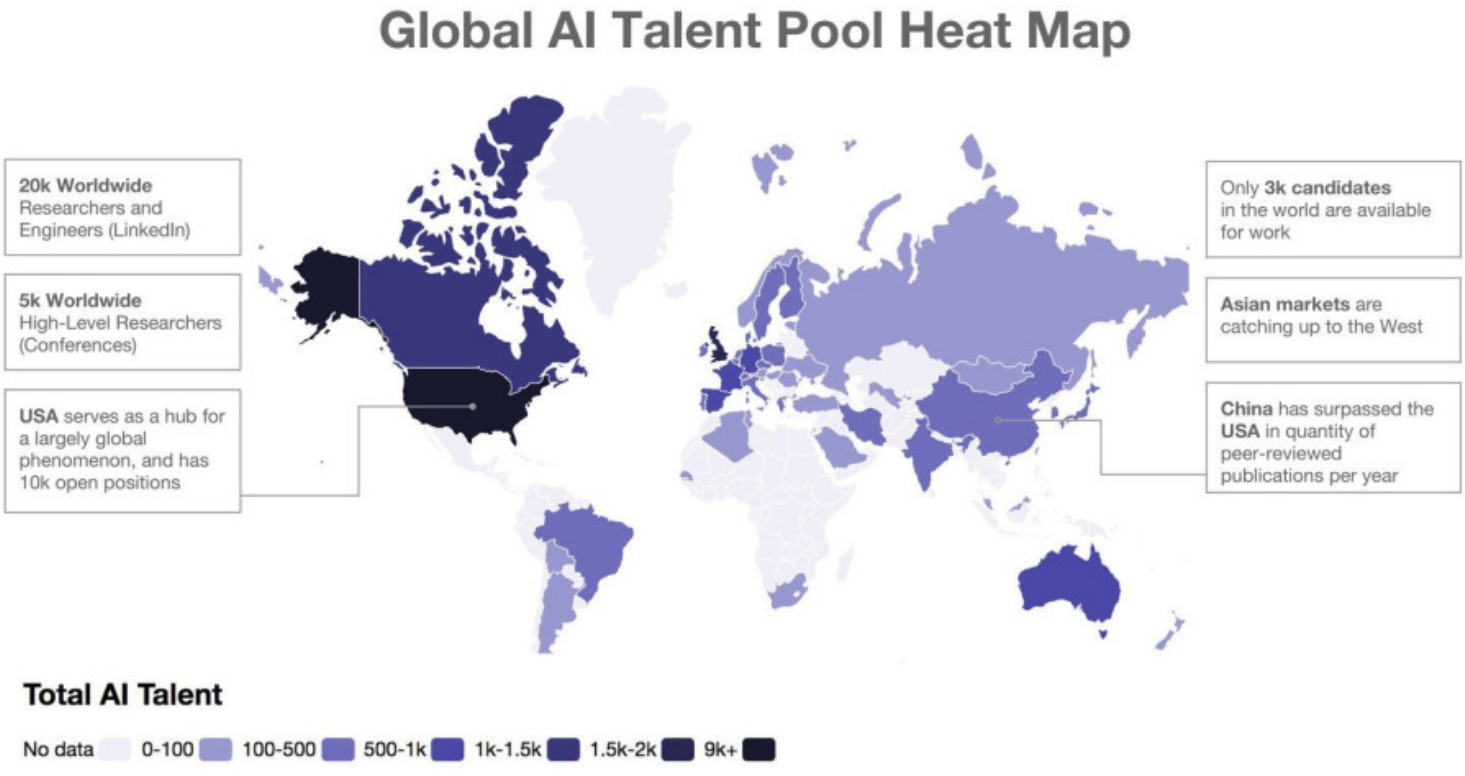

State of AI Reports: 2018 2019 2020

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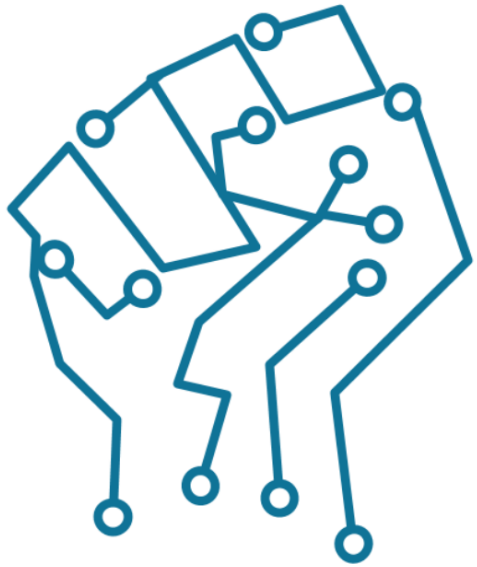
Deep Learning Communities - Africa

DEEP LEARNING
INDABA

INDABAX - TANZANIA



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Outline

- Part 1 - PyTorch Basics.
- Part 2 - Neural Networks in PyTorch.
- Part 3 - Inference and Validation in PyTorch.
- Part 4 - End - End Classification in PyTorch.
- Part 5 - End - End Classification in Keras.

References

1. Remo,K.(2019).Hands on Java Deep Learning for Computer Vision.Packt Publishing.
2. Sabramanian,V.(2018).Deep Learning with PyTorch.Packt Publishing.
3. Moolayil,J.(2019).Learn Keras for Deep Neural Networks.Apress.
4. Gulli,A.,Kapoor,A., & Pal,S.(2019).Deep Learning with TensorFlow 2 and Keras.Packt Publishing.
5. Aggarwal,C,C.(2018).Neural Network and Deep Learning.Springer.

Resources

1. MIT 6.S191: Introduction to Deep Learning.
2. Deep Learning: Do-It-Yourself.
3. Deep Learning Specialization.
4. Practical Deep Learning for Coders.
5. Intro to Neural Networks and Machine Learning.


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