Introduction to deep learning with PyTorch

INTRODUCTION TO DEEP LEARNING WITH PYTORCH



Maham Faisal Khan
Senior Data Science Content Developer



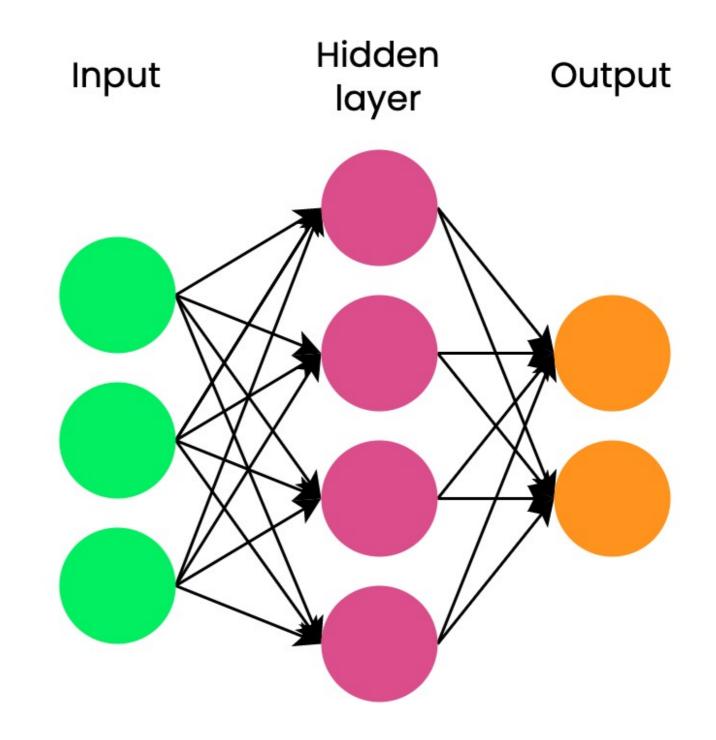
What is deep learning?

- Deep learning is everywhere:
 - Language translation
 - Self-driving cars
 - Medical diagnostics
 - Chatbots
- Being used on multiple data types: images, text and audio
- While traditional machine learning relies on hand-crafted feature engineering, the layered structure in deep learning enables feature learning from raw data



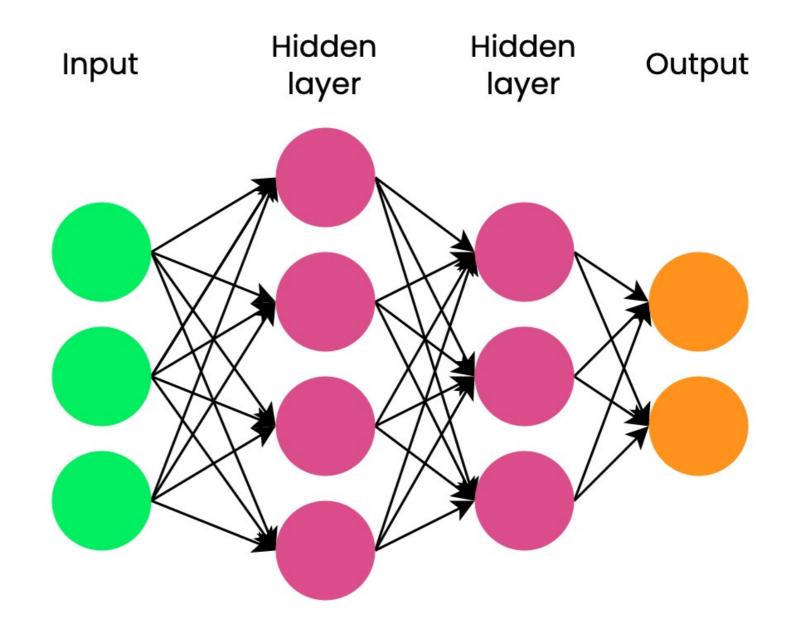
What is deep learning?

Deep learning is a subset of machine learning



What is deep learning?

- Deep learning is a subset of machine learning
- Inspired by connections in the human brain
- Models require large amount of data



PyTorch: a deep learning framework

- PyTorch is
 - one of the most popular deep learning frameworks
 - the framework used in many published deep learning papers
 - intuitive and user-friendly
 - has much in common with NumPy

Importing PyTorch and related packages

PyTorch import in Python

import torch

- PyTorch supports
 - image data with torchvision
 - audio data with torchaudio
 - text data with torchtext

Tensors: the building blocks of networks in PyTorch

Load from list

```
import torch

array = [[1, 2, 3], [4, 5, 6]]
tensor = torch.tensor(array)
```

Load from NumPy array

```
np_array = np.array(array)
np_tensor = torch.from_numpy(np_array)
```

Like NumPy arrays, tensors are multidimensional representations of their elements

Tensor attributes

Tensor shape

```
array = [[1, 2, 3], [4, 5, 6]]
tensor = torch.tensor(array)
tensor.shape
```

```
torch.Size([2, 3])
```

• Tensor data type

```
tensor.dtype
```

```
torch.int64
```

Tensor device

tensor.device

```
device(type='cpu')
```

Deep learning often requires a GPU, which, compared to a CPU can offer:

- parallel computing capabilities
- faster training times
- better performance

Getting started with tensor operations

Compatible shapes

Addition / subtraction

```
a + b
```

```
tensor([[3, 3], [5, 5]])
```

Incompatible shapes

Addition / subtraction

```
a + c
```

```
RuntimeError: The size of tensor a

(2) must match the size of tensor b (3)

at non-singleton dimension 1
```

Getting started with tensor operations

• Element-wise multiplication

```
tensor([[2, 2], [6, 6]])
```

- ... and much more
 - Transposition
 - Matrix multiplication
 - Concatenation
- Most NumPy array operations can be performed on PyTorch tensors

Let's practice!

INTRODUCTION TO DEEP LEARNING WITH PYTORCH



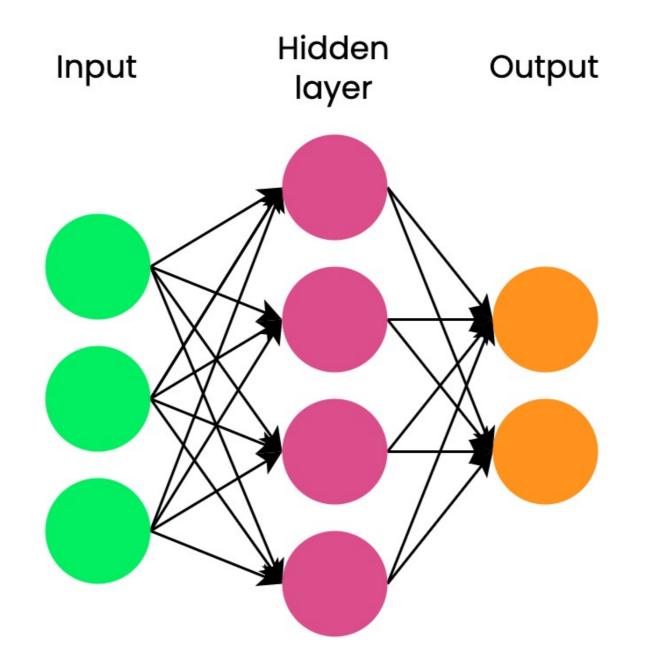
Creating our first neural network

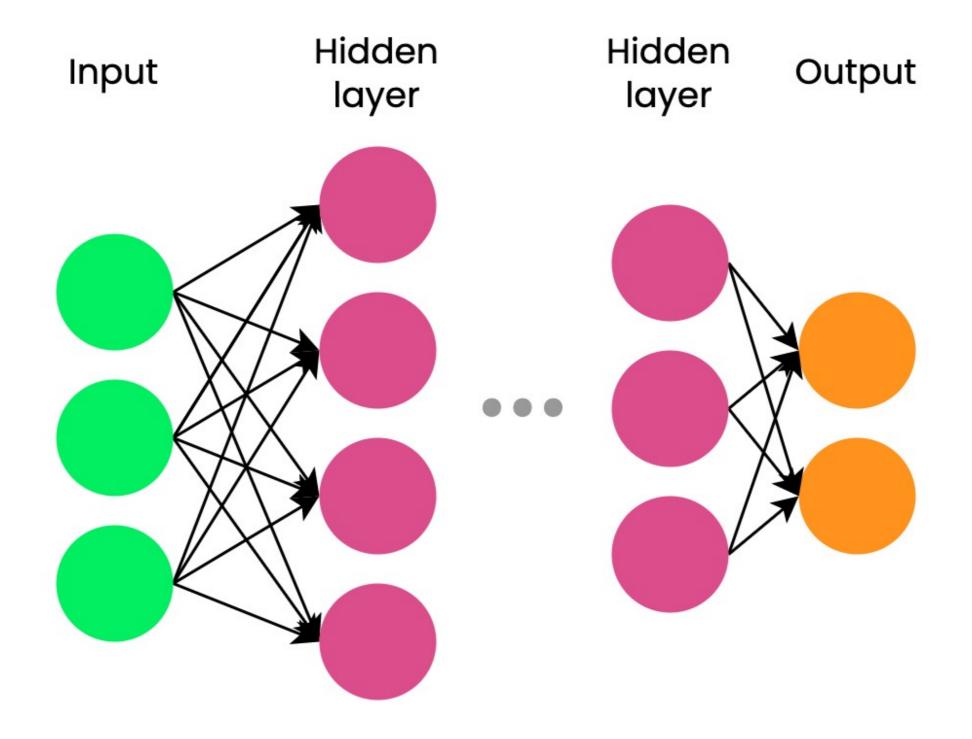
INTRODUCTION TO DEEP LEARNING WITH PYTORCH



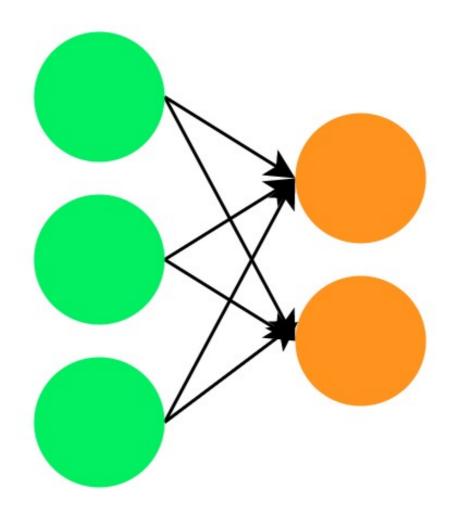
Maham Faisal Khan
Senior Data Science Content Developer







Input Output



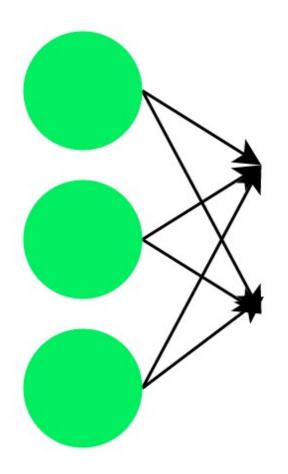
Input



```
import torch.nn as nn
```

```
## Create input_tensor with three features
input_tensor = torch.tensor(
    [[0.3471, 0.4547, -0.2356]]
    )
```

Input



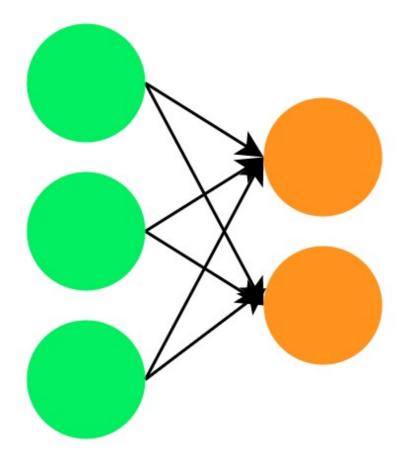
```
import torch.nn as nn

## Create input_tensor with three features
input_tensor = torch.tensor(
    [[0.3471, 0.4547, -0.2356]])
```

A linear layer takes an input, applies a linear function, and returns output

```
# Define our first linear layer
linear_layer = nn.Linear(in_features=3, out_features=2)
```

Input Output



```
import torch.nn as nn

## Create input_tensor with three features
input_tensor = torch.tensor(
```

```
# Define our first linear layer
linear_layer = nn.Linear(in_features=3, out_features=2)
```

[[0.3471, 0.4547, -0.2356]])

```
# Pass input through linear layer
output = linear_layer(input_tensor)
print(output)
```

```
tensor([[-0.2415, -0.1604]],
grad_fn=<AddmmBackward0>)
```

Getting to know the linear layer operation

Each linear layer has a .weight

and .bias property

linear_layer.weight

linear_layer.bias

```
Parameter containing:
tensor([0.0310, 0.1537],
    requires_grad=True)
```

Getting to know the linear layer operation

```
output = linear_layer(input_tensor)
```

For input X, weights WO and bias bO, the linear layer performs

$$y_0 = W_0 \cdot X + b_0$$

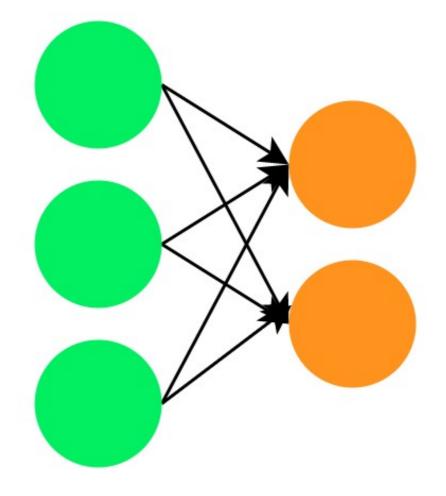
In PyTorch: output = W0 @ input + b0

- Weights and biases are initialized randomly
- They are not useful until they are tuned

Our two-layer network summary

- Input dimensions: 1 imes 3
- Linear layer arguments:
 - o in_features = 3
 - out_features = 2
- ullet Output dimensions: 1 imes 2
- Networks with only linear layers are called fully connected
- Each neuron in one layer is connected to each neuron in the next layer

Input Output



Stacking layers with nn.Sequential()

```
# Create network with three linear layers
model = nn.Sequential(
    nn.Linear(10, 18),
    nn.Linear(18, 20),
    nn.Linear(20, 5)
)
```

Stacking layers with nn.Sequential()

```
print(input_tensor)

tensor([[-0.0014,  0.4038,  1.0305,  0.7521,  0.7489, -0.3968,  0.0113, -1.3844,  0.8705, -0.9743]])

# Pass input_tensor to model to obtain output
output_tensor = model(input_tensor)
print(output_tensor)
```

```
tensor([[-0.0254, -0.0673, 0.0763, 0.0008, 0.2561]], grad_fn=<AddmmBackward0>)
```

- ullet We obtain output of 1 imes 5 dimensions
- Output is still not yet meaningful

Let's practice!

INTRODUCTION TO DEEP LEARNING WITH PYTORCH



Discovering activation functions

INTRODUCTION TO DEEP LEARNING WITH PYTORCH

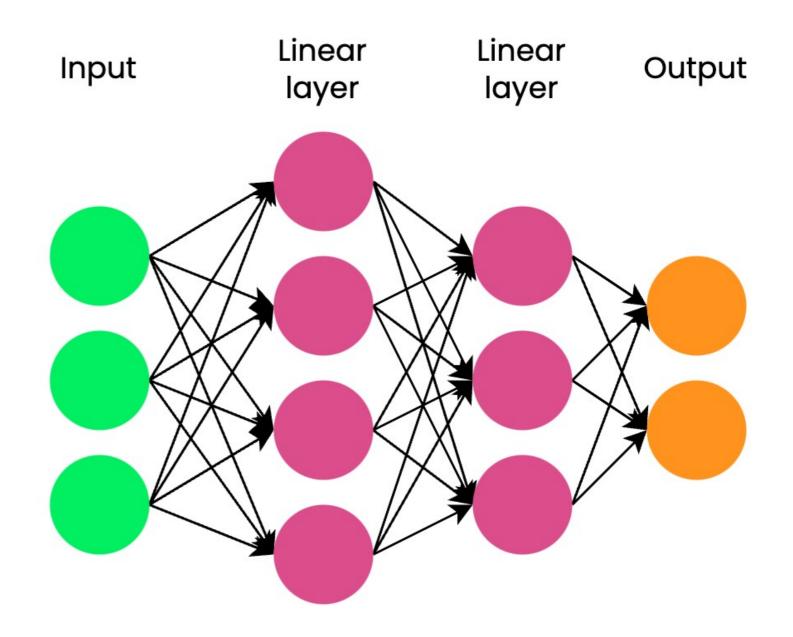


Maham Faisal Khan
Senior Data Science Content Developer



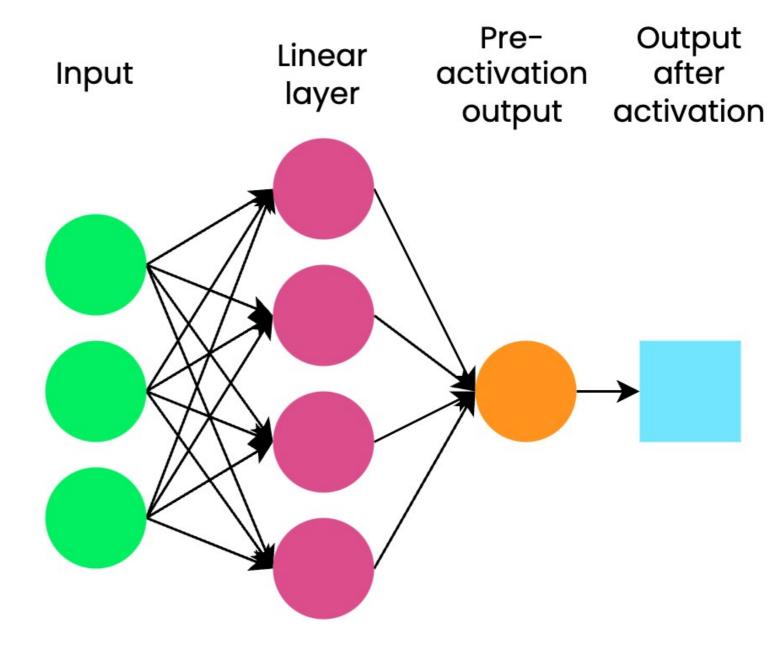
Stacked linear operations

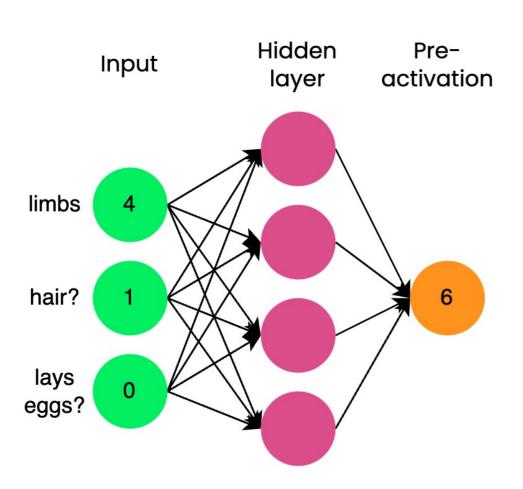
- We have only seen linear layer networks
- Each linear layer multiplies its respective input with layer weights and adds biases
- Even with multiple stacked linear layers,
 output still has linear relationship with input



Why do we need activation functions?

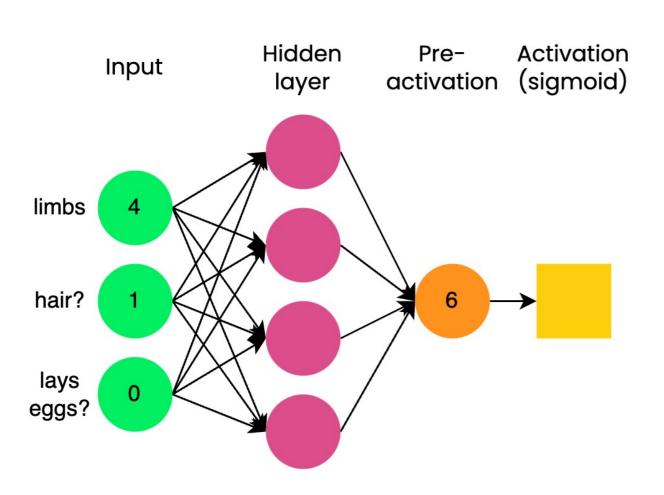
- Activation functions add non-linearity to the network
- A model can learn more complex relationships with non-linearity





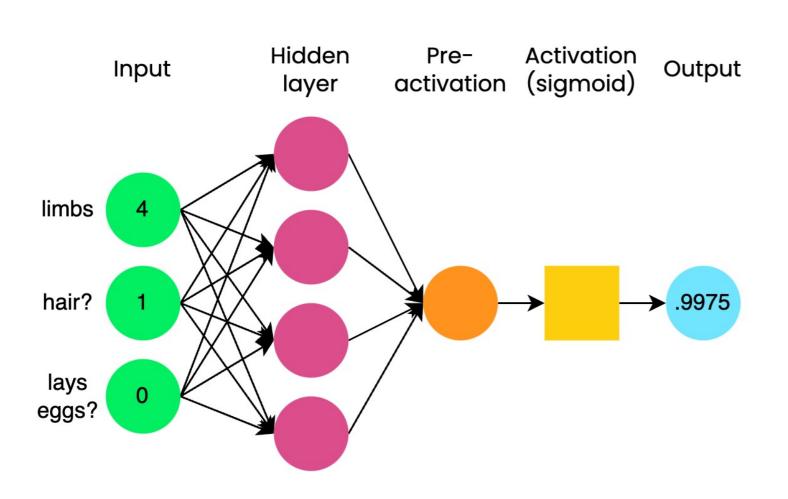
Binary classification task:

To predict whether animal is 1 (mammal) or
 0 (not mammal),



Binary classification task:

- To predict whether animal is 1 (mammal) or
 0 (not mammal),
- we take the pre-activation (6),
- pass it to the sigmoid,



Binary classification task:

- To predict whether animal is 1 (mammal) or
 0 (not mammal),
- we take the pre-activation (6),
- pass it to the sigmoid,
- and obtain a value between 0 and 1.

Using the common threshold of 0.5:

- If output is > 0.5, class label = 1 (mammal)
- If output is <= 0.5, class label = 0 (not mammal)

```
import torch
import torch.nn as nn

input_tensor = torch.tensor([[6.0]])
sigmoid = nn.Sigmoid()
output = sigmoid(input_tensor)
```

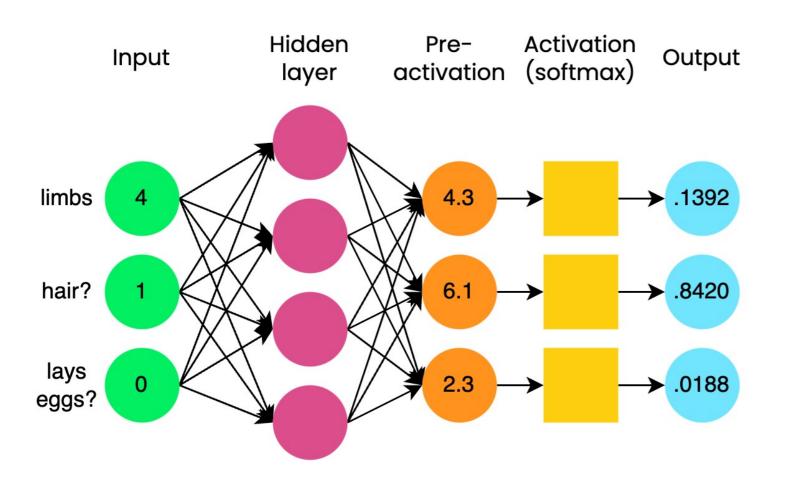
```
tensor([[0.9975]])
```

Activation function as the last layer

```
model = nn.Sequential(
    nn.Linear(6, 4), # First linear layer
    nn.Linear(4, 1), # Second linear layer
    nn.Sigmoid() # Sigmoid activation function
)
```

Note. Sigmoid as last step in network of linear layers is **equivalent** to traditional logistic regression.

Getting acquainted with softmax



- used for multi-class classification problems
- takes N-element vector as input and outputs vector of same size
- say N=3 classes:
 - bird (0), mammal (1), reptile (2)
 - output has three elements, so softmax has three elements
- outputs a probability distribution:
 - each element is a probability (it's bounded between 0 and 1)
 - the sum of the output vector is equal to 1

Getting acquainted with softmax

```
import torch
import torch.nn as nn
# Create an input tensor
input_tensor = torch.tensor(
    [[4.3, 6.1, 2.3]])
# Apply softmax along the last dimension
probabilities = nn.Softmax(dim=-1)
output_tensor = probabilities(input_tensor)
print(output_tensor)
```

```
tensor([[0.1392, 0.8420, 0.0188]])
```

- dim = -1 indicates softmax is applied to the input tensor's last dimension
- nn.Sigmoid() can be used as last step in nn.Sequential()

Let's practice!

INTRODUCTION TO DEEP LEARNING WITH PYTORCH

