

## CI Course - EX9

---

---

### Theory Overview

#### What is pytorch?

PyTorch is a popular open-source machine learning library used for building and training deep learning models. It is based on the Torch library and provides a flexible and efficient framework for creating neural networks. Torch is based on tensors as its data structure.

#### What is tensors??

In simple terms, tensors are mathematical objects that are similar to arrays or matrices. They are fundamental data structures used in PyTorch for representing and manipulating data.

Why we don't use numpy arrays and that's it???

Pytorch tensors are similar to numpy arrays, but **can also be operated on GPU**. Numpy arrays are mainly used in typical machine learning algorithms (such as algorithms and classical ML from last exercises) whereas **pytorch tensors are mainly used in deep learning** which requires heavy matrix computation.

---

### Exercise 1 - Digits classification (EX7) using pytorch

In this exercise we will solve the digits classification from exercise 7 using pytorch tools and framework.

#### Brief reminder:

Input: 1797 samples of 8X8 pixels digits (0-9) images. Each pixel, store an integer between 0-15 determining the greyscale level of the pixel.

Output: The label of the image -> the digit presented in the image.

- For more information on the task please see exercise 7.
- 

### Solution

Solution flow:

1. Load and pre-process
2. Build the model

3. Set optimizer, loss-function and hyperparameters
  4. Training loop and learning curves
  5. Evaluate
- 

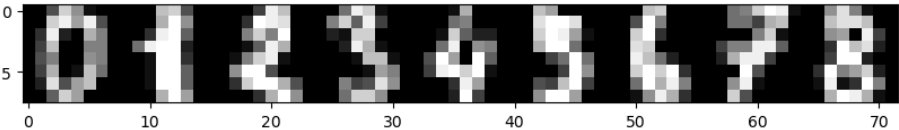
### Load and pre-process

```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.datasets import load_digits
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler

## welcome torch!
import torch
import torch.nn as nn
import torch.optim as optim

#####
### Load and perpare data ###
data = load_digits()

# Show example of 10 images from the dataset
plt.figure(figsize=(10,5))
plt.gray()
I = data.images[0]
for i in range(1,9):
    I = np.concatenate((I, data.images[i]), axis = 1)
plt.imshow(I)
plt.show()
```



### Pre-process steps:

- Flatten the 8X8 to a 1X64 np.array --> so it can be an input of fully-connected net.
- Normalize --> For better learning process during training.
- Split to train and test.

For more information on the pre-process stage -> please see ex7.

```
# Flatten the 8x8 image to a vector of length 64
X, y = [], np.array(data.target)
```

```

for x in data.images:
    x = x.reshape((-1,))
    X.append(x)
X = np.array(X)

scaler = StandardScaler().fit(X)
X = scaler.transform(X)

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.15, random_state=42)

Store the data in a tensors data structure using torch.tensor() and set the
data type stored in the tensor by using torch.<type_name>

X_train = torch.tensor(X_train, dtype=torch.float32)
y_train = torch.tensor(y_train, dtype=torch.int64)
X_test = torch.tensor(X_test, dtype=torch.float32)
y_test = torch.tensor(y_test, dtype=torch.int64)


print(f"X_train[0] tensor is: {X_train[0]} | y_train[0] tensor is: {y_train[0]}")
print("")
print(f"X_train tensor shape is: {X_train.shape} | y_train tensor shape is: {y_train.shape}")
X_train[0] tensor is: tensor([ 0.0000, -0.3350, -0.2535, -0.4322, -0.1979, -0.3145, -0.4097,
        -0.0591, -0.3110,  0.1140,  1.0111,  1.1964,  0.9625, -0.5150, -0.1304,
        -0.0446,  0.3911,  1.0717,  1.5527,  1.4419,  0.6769, -0.5488, -0.1142,
        -0.0334,  0.4865,  1.1161,  1.2206,  0.9874, -0.0939, -0.6289, -0.0472,
         0.0000,  0.4772,  1.3179,  1.1056,  0.9606, -0.1268, -0.8227,  0.0000,
        -0.0613,  0.8106,  1.3951,  1.3622,  1.3308, -0.2172, -0.7983, -0.0887,
        -0.0354,  1.3150,  1.3279,  1.2364,  1.2421,  0.5376, -0.7574, -0.2098,
        -0.0236, -0.2991, -0.1093, -0.0204,  0.0387,  0.8876, -0.2611, -0.1960]) | y_train[0]

X_train tensor shape is: torch.Size([1527, 64]) | y_train tensor shape is: torch.Size([1527])

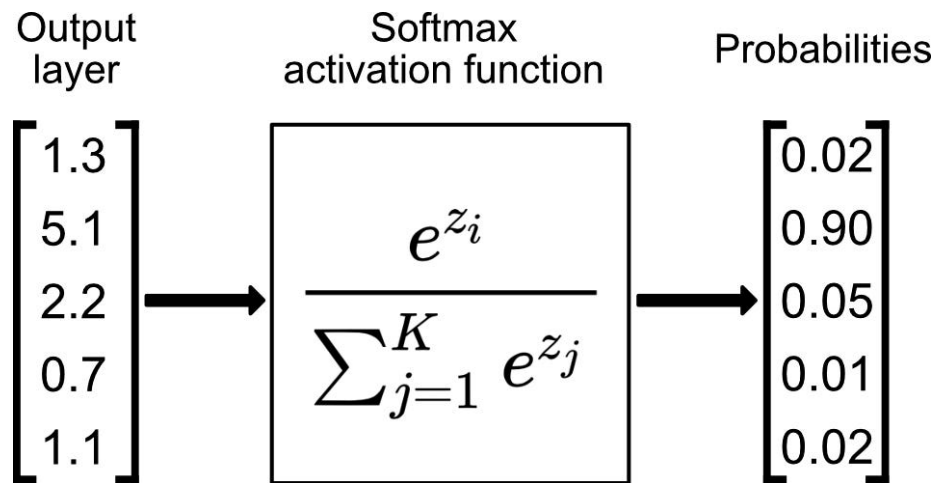
```

**Build the model** In this exercise we will use a fully-connected net with **3 layers** combining the **Relu** activation function after each linear layer, and a **softmax** activation function at the output layer.

Reminder --> Relu:

Rectified Linear Unit (ReLU)		$f(x) = \begin{cases} 0 & \text{for } x < 0 \\ x & \text{for } x \geq 0 \end{cases}$	$f'(x) = \begin{cases} 0 & \text{for } x < 0 \\ 1 & \text{for } x \geq 0 \end{cases}$
------------------------------------	---	--	---

Reminder --> SoftMax:



For neural-networks implementations we will use the `torch.nn` module that provides a set of classes and functions for creating and training neural networks.

*# The nn.Module class is a more flexible way to define a model. It allows you to define a model.*

```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(64, 32)
        self.relu = nn.ReLU()
        self.fc2 = nn.Linear(32, 16)
        self.fc3 = nn.Linear(16, 10)
        self.softmax = nn.Softmax(dim=1)

    def forward(self, x): # We don't really need so 3 layers, but for the example.
        x = self.fc1(x)
        x = self.relu(x)
        x = self.fc2(x)
        x = self.relu(x)
        x = self.fc3(x)
        x = self.softmax(x)
        return x

model = Net()
print(model)

Net(
  (fc1): Linear(in_features=64, out_features=32, bias=True)
  (relu): ReLU()
  (fc2): Linear(in_features=32, out_features=16, bias=True)
  (fc3): Linear(in_features=16, out_features=10, bias=True)
  (softmax): Softmax(dim=1)
```

)

**Set optimizer, loss-function and hyperparamters** **Loss function - Cross entropy (CRE) - reminder:**

$$\text{CRE} = - \sum_{i=1}^C y_i \log(p_i)$$

In this equation, C represents the total number of classes or categories,  $y_i$  represents the true label or target value for class i, and  $p_i$  represents the predicted probability for class i.

**Optimizer - Adam (Adaptive Moment):**

The optimizer is an algorithm used to adjust the model weights progressively to produce a better output. There are many types of optimizers to choose.

During training, Adam calculates an adaptive learning rate for each parameter by taking into account both the current gradient and the historical information. It then updates the parameters by multiplying the learning rate with the gradient. This adaptive learning rate helps in handling different scales of gradients and makes the optimization process more efficient.

*### Prepare for Training ###*

```
loss_fn = nn.CrossEntropyLoss()
```

```
# model.parameters() are the weights of the defined model that Adam will optimize.  
optimizer = optim.Adam(model.parameters(), lr=0.001)
```

```
epochs = 130  
batch_size = 100
```

**Training loop and learning curve** For training we will implement a common training loop framework in pytorch.

Important methods:

**optimizer.zero\_grad():** This line is responsible for zeroing out the gradients before running the backward pass. Gradients are computed during the backward pass and accumulated in the model's parameters. By zeroing the gradients before each iteration, we ensure that the gradients are fresh and not accumulated from previous iterations.

**loss.backward():** This line computes the gradient of the loss with respect to all the learnable parameters of the model. In other words, it calculates how each parameter should be adjusted to minimize the loss.

`optimizer.step()`: This line updates the weights or parameters of the model based on the computed gradients. The optimizer uses the gradients to determine the direction and magnitude of the parameter updates, typically using an optimization algorithm such as stochastic gradient descent (SGD) or Adam.

`model.train()`: Make sure gradient tracking is on, and do a pass over the data (don't need it if `model.evaluate()` doesn't in use).

```
### Train ###
L, L_test = [], [] # Record losses
for epoch in range(epochs):
    # Make sure gradient tracking is on, and do a pass over the data
    model.train(True)
    for i in range(0, len(X_train), batch_size):
        Xbatch = X_train[i:i+batch_size,:]
        y_pred = model(Xbatch) # Feed-forward
        ybatch = y_train[i:i+batch_size]
        loss = loss_fn(y_pred, ybatch) # Evaluate loss
        optimizer.zero_grad() # Zero the gradients before running the backward pass. This is
        loss.backward() # Compute gradient of the loss with respect to all the learnable parameters
        optimizer.step() # Update weights

    L_test.append(loss_fn(model(X_test), y_test).detach().numpy())

    # Set the model to evaluation mode, disabling dropout and using population
    # statistics for batch normalization.
    model.eval()
    # Disable gradient computation and reduce memory consumption.
    with torch.no_grad():
        L.append(loss.detach().numpy())

    print(f'{epoch} - Finished epoch: {epoch}, latest loss: {loss}, test loss: {L_test[-1]}')

plt.figure(figsize=(8,4))
plt.plot(np.arange(0, epochs), L, label='Train loss')
plt.plot(np.arange(0, epochs), L_test, '--', label='Test loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.xlim([0,epochs])
plt.legend()
plt.show()
```

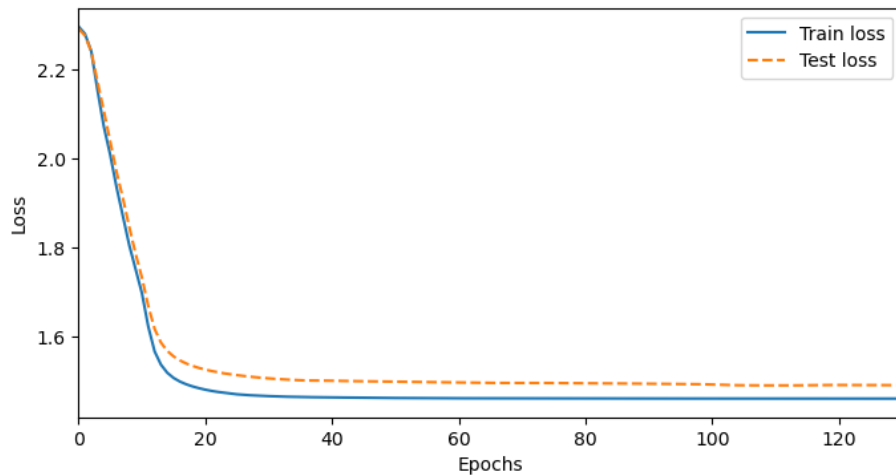
```
0 - Finished epoch: 0, latest loss: 2.2975385189056396, test loss: 2.292720079421997
1 - Finished epoch: 1, latest loss: 2.2812867164611816, test loss: 2.2771458625793457
2 - Finished epoch: 2, latest loss: 2.2420406341552734, test loss: 2.241597890853882
3 - Finished epoch: 3, latest loss: 2.153587579727173, test loss: 2.172929048538208
4 - Finished epoch: 4, latest loss: 2.071934461593628, test loss: 2.1070635318756104
```

5 - Finished epoch: 5, latest loss: 2.0088648796081543, test loss: 2.0382208824157715  
6 - Finished epoch: 6, latest loss: 1.9359023571014404, test loss: 1.970362901687622  
7 - Finished epoch: 7, latest loss: 1.8708890676498413, test loss: 1.911741852760315  
8 - Finished epoch: 8, latest loss: 1.80620276927948, test loss: 1.8471205234527588  
9 - Finished epoch: 9, latest loss: 1.7518866062164307, test loss: 1.7868030071258545  
10 - Finished epoch: 10, latest loss: 1.6981614828109741, test loss: 1.7331490516662598  
11 - Finished epoch: 11, latest loss: 1.6232924461364746, test loss: 1.6692761182785034  
12 - Finished epoch: 12, latest loss: 1.567459225654602, test loss: 1.6180368661880493  
13 - Finished epoch: 13, latest loss: 1.53756844997406, test loss: 1.58719003200531  
14 - Finished epoch: 14, latest loss: 1.519315481185913, test loss: 1.5684688091278076  
15 - Finished epoch: 15, latest loss: 1.5076326131820679, test loss: 1.556041955947876  
16 - Finished epoch: 16, latest loss: 1.4994860887527466, test loss: 1.5470606088638306  
17 - Finished epoch: 17, latest loss: 1.4933871030807495, test loss: 1.5401142835617065  
18 - Finished epoch: 18, latest loss: 1.4885642528533936, test loss: 1.5346145629882812  
19 - Finished epoch: 19, latest loss: 1.484656810760498, test loss: 1.53014075756073  
20 - Finished epoch: 20, latest loss: 1.4813047647476196, test loss: 1.5264335870742798  
21 - Finished epoch: 21, latest loss: 1.4785211086273193, test loss: 1.5232336521148682  
22 - Finished epoch: 22, latest loss: 1.4762097597122192, test loss: 1.520407795906067  
23 - Finished epoch: 23, latest loss: 1.4743332862854004, test loss: 1.517914891242981  
24 - Finished epoch: 24, latest loss: 1.4725041389465332, test loss: 1.5158029794692993  
25 - Finished epoch: 25, latest loss: 1.4709105491638184, test loss: 1.5139466524124146  
26 - Finished epoch: 26, latest loss: 1.4697684049606323, test loss: 1.5121681690216064  
27 - Finished epoch: 27, latest loss: 1.4688661098480225, test loss: 1.5105600357055664  
28 - Finished epoch: 28, latest loss: 1.4681295156478882, test loss: 1.509131669998169  
29 - Finished epoch: 29, latest loss: 1.467443585395813, test loss: 1.5078213214874268  
30 - Finished epoch: 30, latest loss: 1.4668488502502441, test loss: 1.5066158771514893  
31 - Finished epoch: 31, latest loss: 1.466312289237976, test loss: 1.5056287050247192  
32 - Finished epoch: 32, latest loss: 1.4658631086349487, test loss: 1.5047194957733154  
33 - Finished epoch: 33, latest loss: 1.4654608964920044, test loss: 1.503878116607666  
34 - Finished epoch: 34, latest loss: 1.4651238918304443, test loss: 1.5031182765960693  
35 - Finished epoch: 35, latest loss: 1.4648361206054688, test loss: 1.5024404525756836  
36 - Finished epoch: 36, latest loss: 1.4646133184432983, test loss: 1.5019402503967285  
37 - Finished epoch: 37, latest loss: 1.464435338973999, test loss: 1.501705288887024  
38 - Finished epoch: 38, latest loss: 1.4643430709838867, test loss: 1.501771092414856  
39 - Finished epoch: 39, latest loss: 1.4642128944396973, test loss: 1.5016950368881226  
40 - Finished epoch: 40, latest loss: 1.464009404182434, test loss: 1.5014216899871826  
41 - Finished epoch: 41, latest loss: 1.463820457458496, test loss: 1.5011069774627686  
42 - Finished epoch: 42, latest loss: 1.463658094406128, test loss: 1.5008424520492554  
43 - Finished epoch: 43, latest loss: 1.4634895324707031, test loss: 1.5006190538406372  
44 - Finished epoch: 44, latest loss: 1.4633336067199707, test loss: 1.500407099723816  
45 - Finished epoch: 45, latest loss: 1.4631978273391724, test loss: 1.5002142190933228  
46 - Finished epoch: 46, latest loss: 1.463073968887329, test loss: 1.5000708103179932  
47 - Finished epoch: 47, latest loss: 1.4629592895507812, test loss: 1.499926209449768  
48 - Finished epoch: 48, latest loss: 1.4628267288208008, test loss: 1.4996817111968994  
49 - Finished epoch: 49, latest loss: 1.4627100229263306, test loss: 1.4994293451309204  
50 - Finished epoch: 50, latest loss: 1.4626054763793945, test loss: 1.4992140531539917

51 - Finished epoch: 51, latest loss: 1.4625192880630493, test loss: 1.4990055561065674  
52 - Finished epoch: 52, latest loss: 1.4624382257461548, test loss: 1.4988069534301758  
53 - Finished epoch: 53, latest loss: 1.462357521057129, test loss: 1.4986234903335571  
54 - Finished epoch: 54, latest loss: 1.462287425994873, test loss: 1.4984184503555298  
55 - Finished epoch: 55, latest loss: 1.4622232913970947, test loss: 1.4982496500015259  
56 - Finished epoch: 56, latest loss: 1.4621648788452148, test loss: 1.4980552196502686  
57 - Finished epoch: 57, latest loss: 1.4621042013168335, test loss: 1.4979100227355957  
58 - Finished epoch: 58, latest loss: 1.4620516300201416, test loss: 1.4977974891662598  
59 - Finished epoch: 59, latest loss: 1.462005615234375, test loss: 1.497660756111145  
60 - Finished epoch: 60, latest loss: 1.4619652032852173, test loss: 1.4975335597991943  
61 - Finished epoch: 61, latest loss: 1.4619340896606445, test loss: 1.4973698854446411  
62 - Finished epoch: 62, latest loss: 1.4619096517562866, test loss: 1.4971922636032104  
63 - Finished epoch: 63, latest loss: 1.4618912935256958, test loss: 1.4970003366470337  
64 - Finished epoch: 64, latest loss: 1.4618841409683228, test loss: 1.4967743158340454  
65 - Finished epoch: 65, latest loss: 1.461887240409851, test loss: 1.4965672492980957  
66 - Finished epoch: 66, latest loss: 1.4618767499923706, test loss: 1.4964519739151  
67 - Finished epoch: 67, latest loss: 1.4618446826934814, test loss: 1.496474027633667  
68 - Finished epoch: 68, latest loss: 1.4618070125579834, test loss: 1.4965307712554932  
69 - Finished epoch: 69, latest loss: 1.4617714881896973, test loss: 1.4965757131576538  
70 - Finished epoch: 70, latest loss: 1.4617418050765991, test loss: 1.4965639114379883  
71 - Finished epoch: 71, latest loss: 1.4617177248001099, test loss: 1.4965242147445679  
72 - Finished epoch: 72, latest loss: 1.4616950750350952, test loss: 1.4964889287948608  
73 - Finished epoch: 73, latest loss: 1.4616727828979492, test loss: 1.49644136428833  
74 - Finished epoch: 74, latest loss: 1.46165132522583, test loss: 1.4963611364364624  
75 - Finished epoch: 75, latest loss: 1.461631178855896, test loss: 1.4962825775146484  
76 - Finished epoch: 76, latest loss: 1.4616118669509888, test loss: 1.496208667755127  
77 - Finished epoch: 77, latest loss: 1.4615973234176636, test loss: 1.496114730834961  
78 - Finished epoch: 78, latest loss: 1.4615812301635742, test loss: 1.496030330657959  
79 - Finished epoch: 79, latest loss: 1.46156686630249, test loss: 1.4959402084350586  
80 - Finished epoch: 80, latest loss: 1.4615530967712402, test loss: 1.4958330392837524  
81 - Finished epoch: 81, latest loss: 1.4615397453308105, test loss: 1.4957362413406372  
82 - Finished epoch: 82, latest loss: 1.461527705192566, test loss: 1.4956260919570923  
83 - Finished epoch: 83, latest loss: 1.4615145921707153, test loss: 1.495528221130371  
84 - Finished epoch: 84, latest loss: 1.4615031480789185, test loss: 1.4954253435134888  
85 - Finished epoch: 85, latest loss: 1.4614930152893066, test loss: 1.4953103065490723  
86 - Finished epoch: 86, latest loss: 1.461482286453247, test loss: 1.4951967000961304  
87 - Finished epoch: 87, latest loss: 1.4614726305007935, test loss: 1.4950790405273438  
88 - Finished epoch: 88, latest loss: 1.4614633321762085, test loss: 1.494965672492981  
89 - Finished epoch: 89, latest loss: 1.4614547491073608, test loss: 1.4948489665985107  
90 - Finished epoch: 90, latest loss: 1.4614461660385132, test loss: 1.4947264194488525  
91 - Finished epoch: 91, latest loss: 1.4614380598068237, test loss: 1.4945995807647705  
92 - Finished epoch: 92, latest loss: 1.461430549621582, test loss: 1.4944664239883423  
93 - Finished epoch: 93, latest loss: 1.461423635482788, test loss: 1.4943277835845947  
94 - Finished epoch: 94, latest loss: 1.4614163637161255, test loss: 1.4941905736923218  
95 - Finished epoch: 95, latest loss: 1.4614098072052002, test loss: 1.4940303564071655  
96 - Finished epoch: 96, latest loss: 1.4614051580429077, test loss: 1.4938596487045288



97 - Finished epoch: 97, latest loss: 1.461400032043457, test loss: 1.493722677230835  
98 - Finished epoch: 98, latest loss: 1.4613990783691406, test loss: 1.493605136871338  
99 - Finished epoch: 99, latest loss: 1.461402416229248, test loss: 1.4933242797851562  
100 - Finished epoch: 100, latest loss: 1.4614022970199585, test loss: 1.4929258823394775  
101 - Finished epoch: 101, latest loss: 1.4613969326019287, test loss: 1.4925460815429688  
102 - Finished epoch: 102, latest loss: 1.4613947868347168, test loss: 1.4921032190322876  
103 - Finished epoch: 103, latest loss: 1.4613993167877197, test loss: 1.4916282892227173  
104 - Finished epoch: 104, latest loss: 1.4614096879959106, test loss: 1.4912809133529663  
105 - Finished epoch: 105, latest loss: 1.4614113569259644, test loss: 1.491125226020813  
106 - Finished epoch: 106, latest loss: 1.461396336555481, test loss: 1.4910404682159424  
107 - Finished epoch: 107, latest loss: 1.4613797664642334, test loss: 1.4909754991531372  
108 - Finished epoch: 108, latest loss: 1.4613672494888306, test loss: 1.490910291671753  
109 - Finished epoch: 109, latest loss: 1.4613581895828247, test loss: 1.4908545017242432  
110 - Finished epoch: 110, latest loss: 1.4613507986068726, test loss: 1.4908167123794556  
111 - Finished epoch: 111, latest loss: 1.461344838142395, test loss: 1.4908055067062378  
112 - Finished epoch: 112, latest loss: 1.4613397121429443, test loss: 1.4908370971679688  
113 - Finished epoch: 113, latest loss: 1.4613351821899414, test loss: 1.4909300804138184  
114 - Finished epoch: 114, latest loss: 1.4613295793533325, test loss: 1.4911097288131714  
115 - Finished epoch: 115, latest loss: 1.4613195657730103, test loss: 1.4913606643676758  
116 - Finished epoch: 116, latest loss: 1.4613090753555298, test loss: 1.491593360900879  
117 - Finished epoch: 117, latest loss: 1.4613009691238403, test loss: 1.4917329549789429  
118 - Finished epoch: 118, latest loss: 1.4612953662872314, test loss: 1.4917901754379272  
119 - Finished epoch: 119, latest loss: 1.4612908363342285, test loss: 1.491803526878357  
120 - Finished epoch: 120, latest loss: 1.4612866640090942, test loss: 1.491794228553772  
121 - Finished epoch: 121, latest loss: 1.4612828493118286, test loss: 1.4917662143707275  
122 - Finished epoch: 122, latest loss: 1.461279273033142, test loss: 1.491730809211731  
123 - Finished epoch: 123, latest loss: 1.4612759351730347, test loss: 1.4916939735412598  
124 - Finished epoch: 124, latest loss: 1.4612727165222168, test loss: 1.4916521310806274  
125 - Finished epoch: 125, latest loss: 1.4612698554992676, test loss: 1.4916143417358398  
126 - Finished epoch: 126, latest loss: 1.461267113685608, test loss: 1.4915721416473389  
127 - Finished epoch: 127, latest loss: 1.4612642526626587, test loss: 1.491531491279602  
128 - Finished epoch: 128, latest loss: 1.4612617492675781, test loss: 1.491480827331543  
129 - Finished epoch: 129, latest loss: 1.461259365081787, test loss: 1.4914382696151733



**Evaluate** With pytorch during evaluation it is really important to set the model in evaluation mode by using `model.eval()`. When the model is in evaluation mode, it affects the behavior of certain layers or modules in the model, such as dropout and batch normalization, this means that the model will produce the same output for the same input data, allowing for reproducibility and consistent evaluation results.

In addition, it is very common to use `torch.no_grad()` during evaluation. When used, it prevents PyTorch from tracking the operations and creating computational graphs. This has two main benefits: it reduces memory consumption and speeds up the computations.

```
### Evaluate the model ###
model.eval()

correct = 0
with torch.no_grad():
    for x, y in zip(X_test, y_test):
        output = model(x.reshape(1,-1))
        _, predicted = output.max(1)
        correct += (predicted == y).sum().item()

# Print the accuracy
accuracy = correct / X_test.shape[0] * 100
print('Classification success rate: {}'.format(accuracy))

Classification success rate: 97.4074074074074%
```

## Exercise 2 - Fuel consumption regression (EX8) using pytorch

In this exercise we are going to solve the fuel consumption prediction from exercise 8 using pytorch tools and framework.

### Brief reminder:

Input: **399 data samples** of **4 features** of cars.

Output: **Fuel consumption** (km/l)

---

### Solution

Solution flow:

1. Load and pre-process
  2. Build the model
  3. Set optimizer, loss-function and hyperparameters
  4. Training loop and learning curves
  5. Evaluate
- 

### Load and pre-process

- Same process as we did in the exercise above.

```
import numpy as np
import torch
import torch.nn as nn
import torch.optim as optim
import pickle
from sklearn.preprocessing import StandardScaler
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split

#####
### Load and perpare data ###

# training data
with open('auto_kml.pkl', 'rb') as H:
    data = pickle.load(H)

# Input: Features of various cars
# 0. displacement
# 1. Number of cylinders
# 1. horsepower
# 2. weight
```

*# Output: Fuel consumption (km/l)*

```
X = data['features']
Y = data['kml'].reshape(-1,1)
D = np.concatenate((X,Y), axis=1)
scaler = StandardScaler()
scaler.fit(D)
D = scaler.transform(D)

X_train, X_test, y_train, y_test = train_test_split(D[:, :-1], D[:, -1], test_size=0.15, random_state=42)
X_train = torch.tensor(X_train, dtype=torch.float32)
y_train = torch.tensor(y_train, dtype=torch.float32).reshape(-1, 1)
X_test = torch.tensor(X_test, dtype=torch.float32)
y_test = torch.tensor(y_test, dtype=torch.float32).reshape(-1, 1)

print(f"X_train[0] tensor is: {X_train[0]} | y_train[0] tensor is: {y_train[0]}")
print("")
print(f"X_train tensor shape is: {X_train.shape} | y_train tensor shape is: {y_train.shape}")

X_train[0] tensor is: tensor([ 0.3232, -0.3571,  0.4671, -0.1902]) | y_train[0] tensor is: tensor([0.15])

X_train tensor shape is: torch.Size([339, 4]) | y_train tensor shape is: torch.Size([339, 1])
```

**Build the model** In this exercise we will use a fully-connected net with **3 layers** combining the **Tanh** activation function after each linear layer.

For more information about **Tanh** please see exercise 8.

We will create a Net class with a different approach for constructing layers. Instead of manually defining each layer, we will use the `nn.Sequential()` function to structure the layers in a sequential manner.

```
# The nn.Module class is a more flexible way to define a model. It allows you to define a model class
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.regressor = nn.Sequential(
            nn.Linear(X_train.shape[1], 3),
            nn.Tanh(),
            nn.Linear(3, 3),
            nn.Tanh(),
            nn.Linear(3, 1),
            nn.Tanh())

    def forward(self, x): # We don't really need so 3 layers, but for the example.
        x = self.regressor(x)
        return x
```

```

model = Net()

print(model)

Net(
  (regressor): Sequential(
    (0): Linear(in_features=4, out_features=3, bias=True)
    (1): Tanh()
    (2): Linear(in_features=3, out_features=3, bias=True)
    (3): Tanh()
    (4): Linear(in_features=3, out_features=1, bias=True)
    (5): Tanh()
  )
)

```

**Set optimizer, loss-function and hyperparamters** Loss function - Mean Squared Error (MSE) - reminder:

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

It measures the average squared difference between the predicted and actual values1.

In this equation, C represents the total number of classes or categories, y\_i represents the true label or target value for class i, and p\_i represents the predicted probability for class i.

**Optimizer - Adam --> please see exersice above.**

```
### Preparare for Training ###
```

```
loss_fn = nn.MSELoss() # Mean Square Error
```

```
# model.parameters() are the weights of the defined model that Adam will optimize.
optimizer = optim.Adam(model.parameters(), lr=0.001) # <- Include learning rate (lr)
```

```
epochs = 300
```

```
batch_size = 100
```

**Training loop and learning curve** We will use exactly the same loop as we executed in the exercise above.

```
### Train ###
```

```
L, L_test = [], [] # Record losses
```

```
for epoch in range(epochs):
```

```

model.train(True)
for i in range(0, len(X_train), batch_size):
    Xbatch = X_train[i:i+batch_size,:]
    y_pred = model(Xbatch) # Feed-forward
    ybatch = y_train[i:i+batch_size]
    loss = loss_fn(y_pred, ybatch) # Evaluate loss
    optimizer.zero_grad() # Zero the gradients before running the backward pass. This is
    loss.backward() # Compute gradient of the loss with respect to all the learnable parameters
    optimizer.step() # Update weights

L.append(loss.detach().numpy())
# Set the model to evaluation mode, disabling dropout and using population
# statistics for batch normalization.
model.eval()
# Disable gradient computation and reduce memory consumption.
with torch.no_grad():

    L_test.append(loss_fn(model(X_test), y_test).detach().numpy())

print(f'{epoch} - Finished epoch: {epoch}, latest loss: {loss}, test loss: {L_test[-1]}')

plt.figure(figsize=(8,4))
plt.plot(np.arange(0, epochs), L, label='Train loss')
plt.plot(np.arange(0, epochs), L_test, label='Test loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.xlim([0,epochs])
plt.legend()
plt.show()

0 - Finished epoch: 0, latest loss: 1.0858832597732544, test loss: 1.075387716293335
1 - Finished epoch: 1, latest loss: 1.071087121963501, test loss: 1.0608770847320557
2 - Finished epoch: 2, latest loss: 1.0565859079360962, test loss: 1.0466549396514893
3 - Finished epoch: 3, latest loss: 1.0423985719680786, test loss: 1.032738208770752
4 - Finished epoch: 4, latest loss: 1.0285311937332153, test loss: 1.0191304683685303
5 - Finished epoch: 5, latest loss: 1.0149762630462646, test loss: 1.0058225393295288
6 - Finished epoch: 6, latest loss: 1.0017142295837402, test loss: 0.9927927255630493
7 - Finished epoch: 7, latest loss: 0.98871248960495, test loss: 0.9800068736076355
8 - Finished epoch: 8, latest loss: 0.9759263396263123, test loss: 0.9674186110496521
9 - Finished epoch: 9, latest loss: 0.9632986783981323, test loss: 0.9549702405929565
10 - Finished epoch: 10, latest loss: 0.9507624506950378, test loss: 0.9425942897796631
11 - Finished epoch: 11, latest loss: 0.9382426738739014, test loss: 0.9302166700363159
12 - Finished epoch: 12, latest loss: 0.9256605505943298, test loss: 0.9177600741386414
13 - Finished epoch: 13, latest loss: 0.9129371643066406, test loss: 0.9051493406295776
14 - Finished epoch: 14, latest loss: 0.9000000357627869, test loss: 0.8923158049583435
15 - Finished epoch: 15, latest loss: 0.8867868185043335, test loss: 0.8792024254798889

```

16 - Finished epoch: 16, latest loss: 0.8732485771179199, test loss: 0.8657655715942383  
 17 - Finished epoch: 17, latest loss: 0.8593515157699585, test loss: 0.8519763350486755  
 18 - Finished epoch: 18, latest loss: 0.8450760245323181, test loss: 0.837819516658783  
 19 - Finished epoch: 19, latest loss: 0.8304153084754944, test loss: 0.8232919573783875  
 20 - Finished epoch: 20, latest loss: 0.8153732419013977, test loss: 0.8084009289741516  
 21 - Finished epoch: 21, latest loss: 0.7999634146690369, test loss: 0.7931619882583618  
 22 - Finished epoch: 22, latest loss: 0.7842071056365967, test loss: 0.7775982618331909  
 23 - Finished epoch: 23, latest loss: 0.7681314945220947, test loss: 0.7617384195327759  
 24 - Finished epoch: 24, latest loss: 0.7517697811126709, test loss: 0.7456162571907043  
 25 - Finished epoch: 25, latest loss: 0.7351590394973755, test loss: 0.7292696237564087  
 26 - Finished epoch: 26, latest loss: 0.7183401584625244, test loss: 0.7127392888069153  
 27 - Finished epoch: 27, latest loss: 0.7013565897941589, test loss: 0.6960687041282654  
 28 - Finished epoch: 28, latest loss: 0.6842541098594666, test loss: 0.6793027520179749  
 29 - Finished epoch: 29, latest loss: 0.6670791506767273, test loss: 0.662487268447876  
 30 - Finished epoch: 30, latest loss: 0.6498788595199585, test loss: 0.6456681489944458  
 31 - Finished epoch: 31, latest loss: 0.6327000856399536, test loss: 0.628890872001648  
 32 - Finished epoch: 32, latest loss: 0.6155882477760315, test loss: 0.612199604511261  
 33 - Finished epoch: 33, latest loss: 0.5985879302024841, test loss: 0.5956366658210754  
 34 - Finished epoch: 34, latest loss: 0.5817410945892334, test loss: 0.5792425274848938  
 35 - Finished epoch: 35, latest loss: 0.5650871992111206, test loss: 0.5630548000335693  
 36 - Finished epoch: 36, latest loss: 0.5486631393432617, test loss: 0.5471081137657166  
 37 - Finished epoch: 37, latest loss: 0.5325025320053101, test loss: 0.5314342975616455  
 38 - Finished epoch: 38, latest loss: 0.5166357755661011, test loss: 0.5160618424415588  
 39 - Finished epoch: 39, latest loss: 0.5010899901390076, test loss: 0.5010159015655518  
 40 - Finished epoch: 40, latest loss: 0.48588913679122925, test loss: 0.4863184690475464  
 41 - Finished epoch: 41, latest loss: 0.47105368971824646, test loss: 0.4719885587692261  
 42 - Finished epoch: 42, latest loss: 0.45660117268562317, test loss: 0.4580416977405548  
 43 - Finished epoch: 43, latest loss: 0.442546010017395, test loss: 0.44449082016944885  
 44 - Finished epoch: 44, latest loss: 0.42889952659606934, test loss: 0.4313458800315857  
 45 - Finished epoch: 45, latest loss: 0.4156707227230072, test loss: 0.41861432790756226  
 46 - Finished epoch: 46, latest loss: 0.40286555886268616, test loss: 0.40630099177360535  
 47 - Finished epoch: 47, latest loss: 0.390487939119339, test loss: 0.3944084048271179  
 48 - Finished epoch: 48, latest loss: 0.37853941321372986, test loss: 0.3829372823238373  
 49 - Finished epoch: 49, latest loss: 0.36701950430870056, test loss: 0.3718859553337097  
 50 - Finished epoch: 50, latest loss: 0.3559257388114929, test loss: 0.36125123500823975  
 51 - Finished epoch: 51, latest loss: 0.34525415301322937, test loss: 0.35102829337120056  
 52 - Finished epoch: 52, latest loss: 0.3349989950656891, test loss: 0.34121087193489075  
 53 - Finished epoch: 53, latest loss: 0.3251534402370453, test loss: 0.33179134130477905  
 54 - Finished epoch: 54, latest loss: 0.31570932269096375, test loss: 0.32276126742362976  
 55 - Finished epoch: 55, latest loss: 0.30665743350982666, test loss: 0.31411096453666687  
 56 - Finished epoch: 56, latest loss: 0.29798784852027893, test loss: 0.305830180644989  
 57 - Finished epoch: 57, latest loss: 0.2896897792816162, test loss: 0.2979080080986023  
 58 - Finished epoch: 58, latest loss: 0.28175196051597595, test loss: 0.2903329133987427  
 59 - Finished epoch: 59, latest loss: 0.274162620306015, test loss: 0.28309324383735657  
 60 - Finished epoch: 60, latest loss: 0.26690980792045593, test loss: 0.2761768102645874  
 61 - Finished epoch: 61, latest loss: 0.25998127460479736, test loss: 0.2695714831352234

62 - Finished epoch: 62, latest loss: 0.2533646523952484, test loss: 0.26326513290405273  
63 - Finished epoch: 63, latest loss: 0.24704772233963013, test loss: 0.2572454810142517  
64 - Finished epoch: 64, latest loss: 0.24101807177066803, test loss: 0.25150054693222046  
65 - Finished epoch: 65, latest loss: 0.2352636754512787, test loss: 0.2460184097290039  
66 - Finished epoch: 66, latest loss: 0.22977253794670105, test loss: 0.24078741669654846  
67 - Finished epoch: 67, latest loss: 0.22453303635120392, test loss: 0.23579616844654083  
68 - Finished epoch: 68, latest loss: 0.219533771276474, test loss: 0.23103366792201996  
69 - Finished epoch: 69, latest loss: 0.21476371586322784, test loss: 0.22648917138576508  
70 - Finished epoch: 70, latest loss: 0.21021197736263275, test loss: 0.22215226292610168  
71 - Finished epoch: 71, latest loss: 0.20586830377578735, test loss: 0.21801303327083588  
72 - Finished epoch: 72, latest loss: 0.20172272622585297, test loss: 0.21406182646751404  
73 - Finished epoch: 73, latest loss: 0.1977655440568924, test loss: 0.21028946340084076  
74 - Finished epoch: 74, latest loss: 0.19398756325244904, test loss: 0.20668700337409973  
75 - Finished epoch: 75, latest loss: 0.19037994742393494, test loss: 0.20324620604515076  
76 - Finished epoch: 76, latest loss: 0.18693426251411438, test loss: 0.19995886087417603  
77 - Finished epoch: 77, latest loss: 0.1836424320936203, test loss: 0.19681736826896667  
78 - Finished epoch: 78, latest loss: 0.18049675226211548, test loss: 0.19381436705589294  
79 - Finished epoch: 79, latest loss: 0.17748987674713135, test loss: 0.19094295799732208  
80 - Finished epoch: 80, latest loss: 0.1746148020029068, test loss: 0.18819648027420044  
81 - Finished epoch: 81, latest loss: 0.17186495661735535, test loss: 0.185568705201149  
82 - Finished epoch: 82, latest loss: 0.16923391819000244, test loss: 0.18305359780788422  
83 - Finished epoch: 83, latest loss: 0.16671578586101532, test loss: 0.18064557015895844  
84 - Finished epoch: 84, latest loss: 0.16430483758449554, test loss: 0.17833925783634186  
85 - Finished epoch: 85, latest loss: 0.16199567914009094, test loss: 0.176129549741745  
86 - Finished epoch: 86, latest loss: 0.15978319942951202, test loss: 0.17401166260242462  
87 - Finished epoch: 87, latest loss: 0.1576625406742096, test loss: 0.17198102176189423  
88 - Finished epoch: 88, latest loss: 0.15562915802001953, test loss: 0.170033261177924  
89 - Finished epoch: 89, latest loss: 0.15367859601974487, test loss: 0.16816440224647522  
90 - Finished epoch: 90, latest loss: 0.1518068164587021, test loss: 0.1663704663515091  
91 - Finished epoch: 91, latest loss: 0.1500098705291748, test loss: 0.16464786231517792  
92 - Finished epoch: 92, latest loss: 0.14828412234783173, test loss: 0.16299308836460114  
93 - Finished epoch: 93, latest loss: 0.14662602543830872, test loss: 0.1614028364419937  
94 - Finished epoch: 94, latest loss: 0.14503228664398193, test loss: 0.15987400710582733  
95 - Finished epoch: 95, latest loss: 0.14349976181983948, test loss: 0.1584036648273468  
96 - Finished epoch: 96, latest loss: 0.1420254409313202, test loss: 0.15698902308940887  
97 - Finished epoch: 97, latest loss: 0.14060662686824799, test loss: 0.15562739968299866  
98 - Finished epoch: 98, latest loss: 0.13924051821231842, test loss: 0.15431632101535797  
99 - Finished epoch: 99, latest loss: 0.1379247009754181, test loss: 0.1530533879995346  
100 - Finished epoch: 100, latest loss: 0.13665671646595, test loss: 0.15183638036251068  
101 - Finished epoch: 101, latest loss: 0.1354343742132187, test loss: 0.15066313743591309  
102 - Finished epoch: 102, latest loss: 0.13425548374652863, test loss: 0.14953163266181946  
103 - Finished epoch: 103, latest loss: 0.13311803340911865, test loss: 0.14843995869159698  
104 - Finished epoch: 104, latest loss: 0.13202010095119476, test loss: 0.1473863124847412  
105 - Finished epoch: 105, latest loss: 0.1309598684310913, test loss: 0.14636893570423126  
106 - Finished epoch: 106, latest loss: 0.12993557751178741, test loss: 0.14538615942001343  
107 - Finished epoch: 107, latest loss: 0.12894555926322937, test loss: 0.14443644881248474



108 - Finished epoch: 108, latest loss: 0.12798836827278137, test loss: 0.1435183584690094  
 109 - Finished epoch: 109, latest loss: 0.12706245481967926, test loss: 0.1426304131746292  
 110 - Finished epoch: 110, latest loss: 0.12616640329360962, test loss: 0.1417713463306427  
 111 - Finished epoch: 111, latest loss: 0.12529891729354858, test loss: 0.14093981683254242  
 112 - Finished epoch: 112, latest loss: 0.12445873022079468, test loss: 0.14013467729091644  
 113 - Finished epoch: 113, latest loss: 0.1236446350812912, test loss: 0.13935472071170807  
 114 - Finished epoch: 114, latest loss: 0.12285549193620682, test loss: 0.13859888911247253  
 115 - Finished epoch: 115, latest loss: 0.12209022790193558, test loss: 0.13786610960960388  
 116 - Finished epoch: 116, latest loss: 0.12134779244661331, test loss: 0.13715539872646332  
 117 - Finished epoch: 117, latest loss: 0.12062724679708481, test loss: 0.13646583259105682  
 118 - Finished epoch: 118, latest loss: 0.11992757767438889, test loss: 0.1357964724302292  
 119 - Finished epoch: 119, latest loss: 0.11924798786640167, test loss: 0.13514646887779236  
 120 - Finished epoch: 120, latest loss: 0.11858759075403214, test loss: 0.13451503217220306  
 121 - Finished epoch: 121, latest loss: 0.1179455891251564, test loss: 0.13390134274959564  
 122 - Finished epoch: 122, latest loss: 0.11732122302055359, test loss: 0.1333046555519104  
 123 - Finished epoch: 123, latest loss: 0.11671376973390579, test loss: 0.13272428512573242  
 124 - Finished epoch: 124, latest loss: 0.11612249910831451, test loss: 0.1321595311164856  
 125 - Finished epoch: 125, latest loss: 0.1155468001961708, test loss: 0.1316097378730774  
 126 - Finished epoch: 126, latest loss: 0.11498599499464035, test loss: 0.13107430934906006  
 127 - Finished epoch: 127, latest loss: 0.11443950980901718, test loss: 0.13055261969566345  
 128 - Finished epoch: 128, latest loss: 0.11390678584575653, test loss: 0.1300441473722458  
 129 - Finished epoch: 129, latest loss: 0.11338724195957184, test loss: 0.1295483261346817  
 130 - Finished epoch: 130, latest loss: 0.11288036406040192, test loss: 0.12906458973884583  
 131 - Finished epoch: 131, latest loss: 0.11238563805818558, test loss: 0.12859252095222473  
 132 - Finished epoch: 132, latest loss: 0.11190260201692581, test loss: 0.12813159823417664  
 133 - Finished epoch: 133, latest loss: 0.11143083870410919, test loss: 0.1276814192533493  
 134 - Finished epoch: 134, latest loss: 0.11096984893083572, test loss: 0.12724146246910095  
 135 - Finished epoch: 135, latest loss: 0.11051925271749496, test loss: 0.12681140005588531  
 136 - Finished epoch: 136, latest loss: 0.11007864028215408, test loss: 0.12639078497886658  
 137 - Finished epoch: 137, latest loss: 0.10964765399694443, test loss: 0.1259792447090149  
 138 - Finished epoch: 138, latest loss: 0.10922588407993317, test loss: 0.12557640671730042  
 139 - Finished epoch: 139, latest loss: 0.10881301760673523, test loss: 0.12518192827701569  
 140 - Finished epoch: 140, latest loss: 0.10840870440006256, test loss: 0.12479546666145325  
 141 - Finished epoch: 141, latest loss: 0.10801265388727188, test loss: 0.12441671639680862  
 142 - Finished epoch: 142, latest loss: 0.10762451589107513, test loss: 0.12404534965753555  
 143 - Finished epoch: 143, latest loss: 0.10724403709173203, test loss: 0.12368108332157135  
 144 - Finished epoch: 144, latest loss: 0.10687091946601868, test loss: 0.12332363426685333  
 145 - Finished epoch: 145, latest loss: 0.10650491714477539, test loss: 0.12297270447015762  
 146 - Finished epoch: 146, latest loss: 0.10614573955535889, test loss: 0.12262807786464691  
 147 - Finished epoch: 147, latest loss: 0.10579314827919006, test loss: 0.12228946387767792  
 148 - Finished epoch: 148, latest loss: 0.10544692724943161, test loss: 0.12195663899183273  
 149 - Finished epoch: 149, latest loss: 0.10510684549808502, test loss: 0.12162936478853226  
 150 - Finished epoch: 150, latest loss: 0.1047726646065712, test loss: 0.12130741775035858  
 151 - Finished epoch: 151, latest loss: 0.10444419831037521, test loss: 0.12099060416221619  
 152 - Finished epoch: 152, latest loss: 0.10412123054265976, test loss: 0.12067867815494537  
 153 - Finished epoch: 153, latest loss: 0.10380358248949051, test loss: 0.1203714981675148

154 - Finished epoch: 154, latest loss: 0.10349109768867493, test loss: 0.12006881833076477  
155 - Finished epoch: 155, latest loss: 0.1031835526227951, test loss: 0.11977051198482513  
156 - Finished epoch: 156, latest loss: 0.10288078337907791, test loss: 0.11947634816169739  
157 - Finished epoch: 157, latest loss: 0.1025826632976532, test loss: 0.11918619275093079  
158 - Finished epoch: 158, latest loss: 0.10228901356458664, test loss: 0.1188998892903328  
159 - Finished epoch: 159, latest loss: 0.1019996628165245, test loss: 0.11861726641654968  
160 - Finished epoch: 160, latest loss: 0.10171452164649963, test loss: 0.1183381974697113  
161 - Finished epoch: 161, latest loss: 0.1014334186911583, test loss: 0.11806253343820572  
162 - Finished epoch: 162, latest loss: 0.10115622729063034, test loss: 0.11779012531042099  
163 - Finished epoch: 163, latest loss: 0.10088282823562622, test loss: 0.11752084642648697  
164 - Finished epoch: 164, latest loss: 0.10061309486627579, test loss: 0.1172545775771141  
165 - Finished epoch: 165, latest loss: 0.10034690797328949, test loss: 0.11699118465185165  
166 - Finished epoch: 166, latest loss: 0.10008417069911957, test loss: 0.11673059314489365  
167 - Finished epoch: 167, latest loss: 0.09982475638389587, test loss: 0.11647262424230576  
168 - Finished epoch: 168, latest loss: 0.09956857562065125, test loss: 0.1162172481417656  
169 - Finished epoch: 169, latest loss: 0.09931553900241852, test loss: 0.11596430093050003  
170 - Finished epoch: 170, latest loss: 0.09906553477048874, test loss: 0.1157137081027031  
171 - Finished epoch: 171, latest loss: 0.09881848841905594, test loss: 0.11546538025140762  
172 - Finished epoch: 172, latest loss: 0.09857428073883057, test loss: 0.11521921306848526  
173 - Finished epoch: 173, latest loss: 0.09833286702632904, test loss: 0.11497511714696884  
174 - Finished epoch: 174, latest loss: 0.0980941504240036, test loss: 0.11473305523395538  
175 - Finished epoch: 175, latest loss: 0.09785806387662888, test loss: 0.11449290066957474  
176 - Finished epoch: 176, latest loss: 0.0976245179772377, test loss: 0.11425459384918213  
177 - Finished epoch: 177, latest loss: 0.0973934531211853, test loss: 0.11401806026697159  
178 - Finished epoch: 178, latest loss: 0.0971648171544075, test loss: 0.11378322541713715  
179 - Finished epoch: 179, latest loss: 0.09693852066993713, test loss: 0.11355005949735641  
180 - Finished epoch: 180, latest loss: 0.09671451151371002, test loss: 0.11331845819950104  
181 - Finished epoch: 181, latest loss: 0.0964927226305008, test loss: 0.11308836191892624  
182 - Finished epoch: 182, latest loss: 0.09627312421798706, test loss: 0.11285972595214844  
183 - Finished epoch: 183, latest loss: 0.09605561941862106, test loss: 0.11263251304626465  
184 - Finished epoch: 184, latest loss: 0.0958402156829834, test loss: 0.1124066635966301  
185 - Finished epoch: 185, latest loss: 0.0956268161535263, test loss: 0.11218211054801941  
186 - Finished epoch: 186, latest loss: 0.09541536122560501, test loss: 0.1119588240981102  
187 - Finished epoch: 187, latest loss: 0.0952058658003807, test loss: 0.11173674464225769  
188 - Finished epoch: 188, latest loss: 0.09499822556972504, test loss: 0.1115158423781395  
189 - Finished epoch: 189, latest loss: 0.0947924554347992, test loss: 0.11129608750343323  
190 - Finished epoch: 190, latest loss: 0.09458846598863602, test loss: 0.11107742786407471  
191 - Finished epoch: 191, latest loss: 0.09438624978065491, test loss: 0.11085984110832214  
192 - Finished epoch: 192, latest loss: 0.09418576210737228, test loss: 0.11064326018095016  
193 - Finished epoch: 193, latest loss: 0.09398696571588516, test loss: 0.11042769998311996  
194 - Finished epoch: 194, latest loss: 0.09378983080387115, test loss: 0.11021311581134796  
195 - Finished epoch: 195, latest loss: 0.09359432756900787, test loss: 0.10999945551156998  
196 - Finished epoch: 196, latest loss: 0.09340042620897293, test loss: 0.1097867339849472  
197 - Finished epoch: 197, latest loss: 0.09320810437202454, test loss: 0.10957489162683487  
198 - Finished epoch: 198, latest loss: 0.0930173248052597, test loss: 0.10936393588781357  
199 - Finished epoch: 199, latest loss: 0.09282806515693665, test loss: 0.10915382951498032

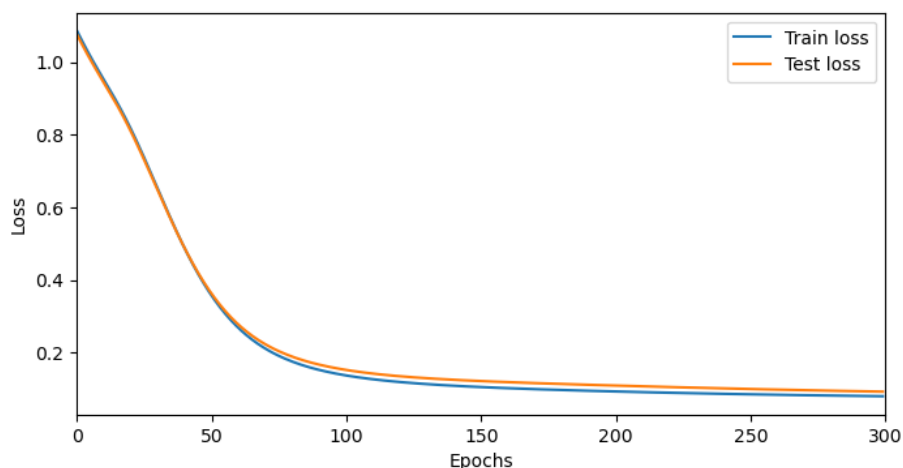
200 - Finished epoch: 200, latest loss: 0.09264030307531357, test loss: 0.10894453525543213  
 201 - Finished epoch: 201, latest loss: 0.09245400130748749, test loss: 0.1087360829114914  
 202 - Finished epoch: 202, latest loss: 0.0922691598534584, test loss: 0.10852844268083572  
 203 - Finished epoch: 203, latest loss: 0.09208575636148453, test loss: 0.10832156240940094  
 204 - Finished epoch: 204, latest loss: 0.09190373867750168, test loss: 0.10811544954776764  
 205 - Finished epoch: 205, latest loss: 0.09172312170267105, test loss: 0.10791012644767761  
 206 - Finished epoch: 206, latest loss: 0.09154388308525085, test loss: 0.10770554840564728  
 207 - Finished epoch: 207, latest loss: 0.0913660004734993, test loss: 0.10750170797109604  
 208 - Finished epoch: 208, latest loss: 0.0911894366145134, test loss: 0.1072985976934433  
 209 - Finished epoch: 209, latest loss: 0.09101419895887375, test loss: 0.10709621757268906  
 210 - Finished epoch: 210, latest loss: 0.09084028750658035, test loss: 0.10689454525709152  
 211 - Finished epoch: 211, latest loss: 0.09066764265298843, test loss: 0.10669361799955368  
 212 - Finished epoch: 212, latest loss: 0.09049628674983978, test loss: 0.10649339109659195  
 213 - Finished epoch: 213, latest loss: 0.09032619744539261, test loss: 0.10629387199878693  
 214 - Finished epoch: 214, latest loss: 0.09015737473964691, test loss: 0.10609506070613861  
 215 - Finished epoch: 215, latest loss: 0.08998976647853851, test loss: 0.1058969497680664  
 216 - Finished epoch: 216, latest loss: 0.08982342481613159, test loss: 0.10569954663515091  
 217 - Finished epoch: 217, latest loss: 0.08965826779603958, test loss: 0.10550285875797272  
 218 - Finished epoch: 218, latest loss: 0.08949434012174606, test loss: 0.10530686378479004  
 219 - Finished epoch: 219, latest loss: 0.08933161199092865, test loss: 0.10511159896850586  
 220 - Finished epoch: 220, latest loss: 0.08917006105184555, test loss: 0.1049170270562172  
 221 - Finished epoch: 221, latest loss: 0.08900968730449677, test loss: 0.10472317785024643  
 222 - Finished epoch: 222, latest loss: 0.08885050565004349, test loss: 0.10453004390001297  
 223 - Finished epoch: 223, latest loss: 0.08869247138500214, test loss: 0.10433761030435562  
 224 - Finished epoch: 224, latest loss: 0.0885356068611145, test loss: 0.10414593666791916  
 225 - Finished epoch: 225, latest loss: 0.0883798748254776, test loss: 0.10395497828722  
 226 - Finished epoch: 226, latest loss: 0.08822529017925262, test loss: 0.10376475751399994  
 227 - Finished epoch: 227, latest loss: 0.08807183802127838, test loss: 0.10357526689767838  
 228 - Finished epoch: 228, latest loss: 0.08791951835155487, test loss: 0.10338655114173889  
 229 - Finished epoch: 229, latest loss: 0.0877683013677597, test loss: 0.1031985729932785  
 230 - Finished epoch: 230, latest loss: 0.08761820942163467, test loss: 0.103011354804039  
 231 - Finished epoch: 231, latest loss: 0.08746921271085739, test loss: 0.10282491147518158  
 232 - Finished epoch: 232, latest loss: 0.08732131868600845, test loss: 0.10263923555612564  
 233 - Finished epoch: 233, latest loss: 0.08717453479766846, test loss: 0.10245434194803238  
 234 - Finished epoch: 234, latest loss: 0.08702883124351501, test loss: 0.10227024555206299  
 235 - Finished epoch: 235, latest loss: 0.08688420802354813, test loss: 0.10208693146705627  
 236 - Finished epoch: 236, latest loss: 0.0867406576871872, test loss: 0.10190444439649582  
 237 - Finished epoch: 237, latest loss: 0.08659817278385162, test loss: 0.10172274708747864  
 238 - Finished epoch: 238, latest loss: 0.08645675331354141, test loss: 0.10154188424348831  
 239 - Finished epoch: 239, latest loss: 0.08631639927625656, test loss: 0.10136184096336365  
 240 - Finished epoch: 240, latest loss: 0.08617709577083588, test loss: 0.10118265450000763  
 241 - Finished epoch: 241, latest loss: 0.08603884279727936, test loss: 0.10100428760051727  
 242 - Finished epoch: 242, latest loss: 0.08590161055326462, test loss: 0.10082678496837616  
 243 - Finished epoch: 243, latest loss: 0.08576545119285583, test loss: 0.10065014660358429  
 244 - Finished epoch: 244, latest loss: 0.08563029021024704, test loss: 0.10047437250614166  
 245 - Finished epoch: 245, latest loss: 0.08549616485834122, test loss: 0.10029946267604828

246 - Finished epoch: 246, latest loss: 0.08536306768655777, test loss: 0.10012545436620712  
247 - Finished epoch: 247, latest loss: 0.0852309837937355, test loss: 0.0999523177742958  
248 - Finished epoch: 248, latest loss: 0.08509990572929382, test loss: 0.09978009760379791  
249 - Finished epoch: 249, latest loss: 0.08496984094381332, test loss: 0.09960877895355225  
250 - Finished epoch: 250, latest loss: 0.08484076708555222, test loss: 0.09943836182355881  
251 - Finished epoch: 251, latest loss: 0.0847126841545105, test loss: 0.09926886856555939  
252 - Finished epoch: 252, latest loss: 0.08458558470010757, test loss: 0.09910029917955399  
253 - Finished epoch: 253, latest loss: 0.08445947617292404, test loss: 0.0989326536655426  
254 - Finished epoch: 254, latest loss: 0.08433433622121811, test loss: 0.09876596182584763  
255 - Finished epoch: 255, latest loss: 0.08421017229557037, test loss: 0.09860021620988846  
256 - Finished epoch: 256, latest loss: 0.08408696949481964, test loss: 0.09843539446592331  
257 - Finished epoch: 257, latest loss: 0.08396473526954651, test loss: 0.09827154129743576  
258 - Finished epoch: 258, latest loss: 0.08384345471858978, test loss: 0.09810864925384521  
259 - Finished epoch: 259, latest loss: 0.08372310549020767, test loss: 0.09794672578573227  
260 - Finished epoch: 260, latest loss: 0.08360370248556137, test loss: 0.09778575599193573  
261 - Finished epoch: 261, latest loss: 0.08348524570465088, test loss: 0.09762577712535858  
262 - Finished epoch: 262, latest loss: 0.0833677127957344, test loss: 0.09746677428483963  
263 - Finished epoch: 263, latest loss: 0.08325111865997314, test loss: 0.09730874747037888  
264 - Finished epoch: 264, latest loss: 0.08313541859388351, test loss: 0.09715171158313751  
265 - Finished epoch: 265, latest loss: 0.0830206647515297, test loss: 0.09699565917253494  
266 - Finished epoch: 266, latest loss: 0.08290679007768631, test loss: 0.09684060513973236  
267 - Finished epoch: 267, latest loss: 0.08279382437467575, test loss: 0.09668651968240738  
268 - Finished epoch: 268, latest loss: 0.08268175274133682, test loss: 0.09653345495462418  
269 - Finished epoch: 269, latest loss: 0.08257056772708893, test loss: 0.09638138860464096  
270 - Finished epoch: 270, latest loss: 0.08246028423309326, test loss: 0.09623031318187714  
271 - Finished epoch: 271, latest loss: 0.08235085755586624, test loss: 0.0960802510380745  
272 - Finished epoch: 272, latest loss: 0.08224230259656906, test loss: 0.09593117982149124  
273 - Finished epoch: 273, latest loss: 0.08213460445404053, test loss: 0.09578310698270798  
274 - Finished epoch: 274, latest loss: 0.08202779293060303, test loss: 0.09563605487346649  
275 - Finished epoch: 275, latest loss: 0.08192180097103119, test loss: 0.09549000859260559  
276 - Finished epoch: 276, latest loss: 0.08181668072938919, test loss: 0.09534496814012527  
277 - Finished epoch: 277, latest loss: 0.08171240240335464, test loss: 0.09520091861486435  
278 - Finished epoch: 278, latest loss: 0.08160893619060516, test loss: 0.0950578823685646  
279 - Finished epoch: 279, latest loss: 0.08150630444288254, test loss: 0.09491584450006485  
280 - Finished epoch: 280, latest loss: 0.08140451461076736, test loss: 0.09477481991052628  
281 - Finished epoch: 281, latest loss: 0.08130352944135666, test loss: 0.09463479369878769  
282 - Finished epoch: 282, latest loss: 0.08120334148406982, test loss: 0.0944957584142685  
283 - Finished epoch: 283, latest loss: 0.08110395818948746, test loss: 0.09435772150754929  
284 - Finished epoch: 284, latest loss: 0.08100537210702896, test loss: 0.09422068297863007  
285 - Finished epoch: 285, latest loss: 0.08090757578611374, test loss: 0.09408465027809143  
286 - Finished epoch: 286, latest loss: 0.0808105617761612, test loss: 0.09394959360361099  
287 - Finished epoch: 287, latest loss: 0.08071433752775192, test loss: 0.09381552785634995  
288 - Finished epoch: 288, latest loss: 0.08061886578798294, test loss: 0.09368244558572769  
289 - Finished epoch: 289, latest loss: 0.08052416145801544, test loss: 0.09355035424232483  
290 - Finished epoch: 290, latest loss: 0.08043023198843002, test loss: 0.09341923147439957  
291 - Finished epoch: 291, latest loss: 0.0803370401263237, test loss: 0.0932890921831131

```

292 - Finished epoch: 292, latest loss: 0.08024459332227707, test loss: 0.09315992146730423
293 - Finished epoch: 293, latest loss: 0.08015290647745132, test loss: 0.09303172677755356
294 - Finished epoch: 294, latest loss: 0.08006194233894348, test loss: 0.0929044708609581
295 - Finished epoch: 295, latest loss: 0.07997170835733414, test loss: 0.09277819842100143
296 - Finished epoch: 296, latest loss: 0.0798821970820427, test loss: 0.09265287220478058
297 - Finished epoch: 297, latest loss: 0.07979339361190796, test loss: 0.09252848476171494
298 - Finished epoch: 298, latest loss: 0.07970530539751053, test loss: 0.0924050509929657
299 - Finished epoch: 299, latest loss: 0.07961791753768921, test loss: 0.09228256344795227

```



**Evaluate** Exactly as we did last time.

```
### Evaluate the model ###
```

```
model.eval()
```

```

x_query = X_test[5,:]
with torch.no_grad():
    #for sample
    prediction = model(x_query)
    #for a batch
    y_pred = model(X_test[:30,:])

```

```

d = np.concatenate((x_query.detach().numpy(), y_test[5].detach().numpy()), axis=0)
d = d.reshape(1,-1)
d = scaler.inverse_transform(d)
print('For query sample: ', d[0][:4], ' and label: ', d[0][-1])

```

```

d = np.concatenate((x_query.detach().numpy(), prediction.detach().numpy()), axis=0)
d = d.reshape(1,-1)
d = scaler.inverse_transform(d)

```

```

print('Prediction for query is: ', d[0][-1])

print(f"Predictions of batch are: {y_pred}")
For query sample: [ 4.  98.  80. 2164.] and label: 1.700576
Prediction for query is: 1.7154651
Predictions of batch are: tensor([[ -0.8419],
                                   [ -0.8448],
                                   [ -0.8476],
                                   [ -0.7836],
                                   [  0.9571],
                                   [ -0.8338],
                                   [ -0.7934],
                                   [  0.9537],
                                   [  0.9510],
                                   [  0.1834],
                                   [  0.9608],
                                   [ -0.7917],
                                   [ -0.8442],
                                   [ -0.8605],
                                   [ -0.8487],
                                   [  0.9536],
                                   [ -0.8215],
                                   [ -0.6154],
                                   [  0.4816],
                                   [ -0.8423],
                                   [ -0.7862],
                                   [  0.1957],
                                   [  0.5603],
                                   [ -0.8420],
                                   [  0.9457],
                                   [ -0.8455],
                                   [  0.0959],
                                   [ -0.8360],
                                   [  0.4851],
                                   [  0.9582]])

```

---

## Summary

In this exercise we covered:

1. ANN - classification task using pytorch.
  2. ANN - regression task using pytorch.
-

### **Helpful and extra links**

1. Pytorch - official website
2. Pytorch tutorials
- 3.

### **Another pytorch tutorials**