Homework 4 Part 2

This is an individual assignment.

Write your own code and justify all your answers. You may repurpose any functions built during lecture. You may use `scikit-learn` functions.

- I strongly encourage you to use the "Tensorflow-2.6.0" kernel in HiPerGator to solve this assignment.

In [10]:
```
# Import libraries and magics

import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
plt.style.use('bmh')

from sklearn.model_selection import train_test_split
```

Exercise 1 (15 points)

In this problem, you will be working with the MNIST Data Set to extract features, perform classification using the SVM algorithm and evaluate your results using metrics such as accuracy, ROC curve and confusion matrices.

The MNIST data set contains 28×28 images of handwritten digits (class labels 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9). This data set has 60,000 images for training and 10,000 images for testing. Each image is a 8-bit grayscale image and so the intensity values per pixel range from 0-255.

The following code cell loads the MNIST data set and displays some examples. (The data is already available in your repository as "mnist_train.csv" and "mnist_test.csv".)

In [2]:
```
# Loading MNIST data set
image_size = 28 # width and length
no_of_different_labels = 10 #  i.e. 0, 1, 2, 3, ..., 9
image_pixels = image_size * image_size

# Loading Training Samples
train_data = np.loadtxt("mnist_train.csv", delimiter=",")
X_train = train_data[:,1:]
t_train = train_data[:,0]
```

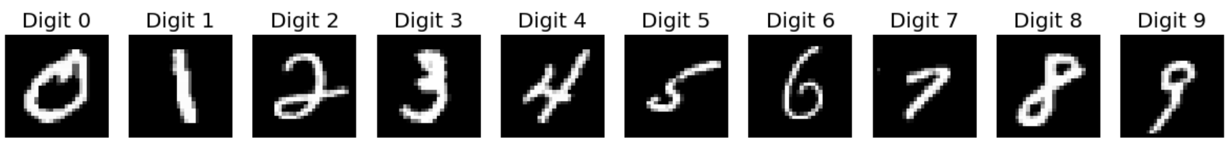
```python
# Loading Test Samples
test_data = np.loadtxt("mnist_test.csv", delimiter=",")
X_test = test_data[:,1:]
t_test = test_data[:,0]

X_train.shape, t_train.shape, X_test.shape, t_test.shape
```

Out[2]:

```
((60000, 784), (60000,), (10000, 784), (10000,))
```

In [3]:

```python
plt.figure(figsize=(15,5))
for i in range(10):
    plt.subplot(1,10,i+1)
    plt.imshow(X_train[np.where(t_train==i)[0][1],:].reshape((28,28)), cmap='gray')
    plt.title('Digit '+str(i)); plt.axis('off');
```



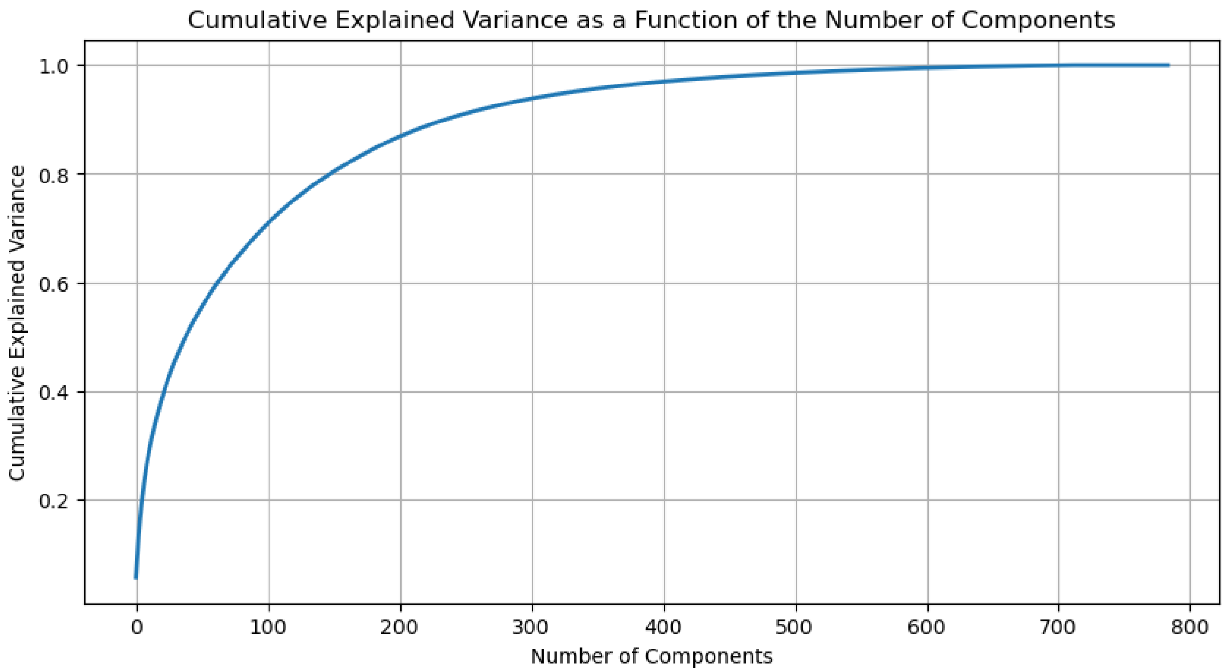
Using this dataset, answer the following questions:

1. **Create a PCA object using `scikit-learn` functions and plot the cumulative explained variance ratio. How many principal components (PCs) would you have to extract in order to preserve 90% of the explained variance in the data?**
    - **Be sure to apply any necessary preprocessing.**

In [6]:

```python
import numpy as np
import matplotlib.pyplot as plt
from sklearn.decomposition import PCA
from sklearn.impute import SimpleImputer

train_data = np.loadtxt("mnist_train.csv", delimiter=",")
test_data = np.loadtxt("mnist_test.csv", delimiter=",")

X_train = train_data[:, 1:]
t_train = train_data[:, 0]
X_test = test_data[:, 1:]
t_test = test_data[:, 0]

mean = np.mean(X_train, axis=0)
std = np.std(X_train, axis=0)

std[std == 0] = 1

X_train_std = (X_train - mean) / std

if np.isnan(X_train_std).any():
    imputer = SimpleImputer(missing_values=np.nan, strategy='mean')
    X_train_std = imputer.fit_transform(X_train_std)

pca = PCA()
pca.fit(X_train_std)

cumulative_explained_variance = np.cumsum(pca.explained_variance_ratio_)
```

```python
plt.figure(figsize=(10, 5))
plt.plot(cumulative_explained_variance, linewidth=2)
plt.xlabel('Number of Components')
plt.ylabel('Cumulative Explained Variance')
plt.title('Cumulative Explained Variance as a Function of the Number of Components')
plt.grid(True)
plt.show()

n_components_90 = np.where(cumulative_explained_variance >= 0.90)[0][0] + 1
print(f'Number of components to preserve 90% of variance: {n_components_90}')
```



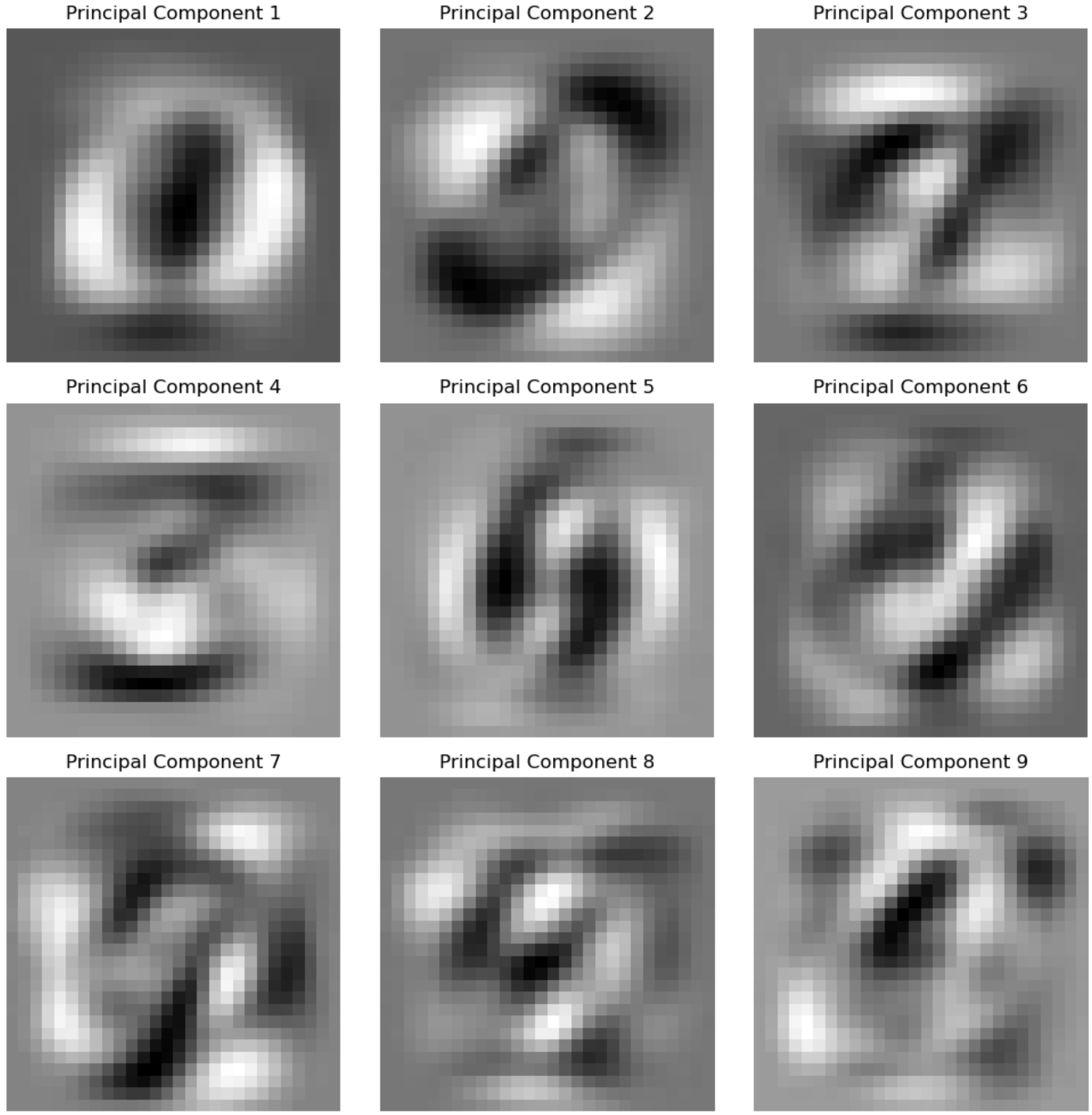

```
Number of components to preserve 90% of variance: 236
```

In [ ]:

In [ ]:

1. **Plot the first 9 principal components you found in (3) with the training data. Based on this data, what is each principal component representing?**

In [7]:
```python
fig, axes = plt.subplots(3, 3, figsize=(10, 10))
for i, ax in enumerate(axes.flat):
    ax.imshow(pca.components_[i].reshape(28, 28), cmap='gray')
    ax.set_title(f'Principal Component {i+1}')
    ax.axis('off')

plt.tight_layout()
plt.show()
```



In [ ]:

In [ ]:

1. **Reconstruct test images using the number of PCs you found in (1). Display examples.**

In [ ]:

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In [ ]:

1. **Train the following `scikit-learn` pipelines:**

A. **Pipeline 1 - scales data, reduces dimensions with PCA and train an SVM with RBF kernel.**

B. **Pipeline 2 - scales data, and train an SVM with RBF kernel.**

In [ ]:

In [ ]:

In [ ]:

1. **Evaluate performance in training and test sets.**

In [ ]:

In [ ]:

In [ ]:

Exercise 2 (15 points)

In this problem, you will be working with the California Housing dataset. The California Housing dataset consists of 20,640 samples, each described with 8 features. Let's import it:

In [10]:
```
from sklearn.datasets import fetch_california_housing
housing = fetch_california_housing()
print(housing.DESCR)
```

```
.. _california_housing_dataset:

California Housing dataset
--------------------------

**Data Set Characteristics:**

    :Number of Instances: 20640

    :Number of Attributes: 8 numeric, predictive attributes and the target

    :Attribute Information:
        - MedInc        median income in block group
        - HouseAge      median house age in block group
        - AveRooms      average number of rooms per household
        - AveBedrms     average number of bedrooms per household
        - Population    block group population
        - AveOccup      average number of household members
        - Latitude      block group latitude
        - Longitude     block group longitude

    :Missing Attribute Values: None

This dataset was obtained from the StatLib repository.
https://www.dcc.fc.up.pt/~ltorgo/Regression/cal_housing.html

The target variable is the median house value for California districts,
expressed in hundreds of thousands of dollars ($100,000).

This dataset was derived from the 1990 U.S. census, using one row per census
block group. A block group is the smallest geographical unit for which the U.S.
Census Bureau publishes sample data (a block group typically has a population
of 600 to 3,000 people).

A household is a group of people residing within a home. Since the average
number of rooms and bedrooms in this dataset are provided per household, these
columns may take surprisingly large values for block groups with few households
and many empty houses, such as vacation resorts.

It can be downloaded/loaded using the
:func:`sklearn.datasets.fetch_california_housing` function.

.. topic:: References

    - Pace, R. Kelley and Ronald Barry, Sparse Spatial Autoregressions,
      Statistics and Probability Letters, 33 (1997) 291-297
```

In [11]:

```
X = housing.data

t = housing.target

X.shape, t.shape
```

Out[11]:

```
((20640, 8), (20640,))
```

Answer the following questions:

1. (1 point) **Partition the data into a *full training set* and a test set. Use a 80/20 stratified split with a fixed `random_state`. Then partition the *full training set* into a train set and a validation set. For this last partition, use a 70/30 stratified split with a fixed `random_state`.**

In [18]:
```
from sklearn.model_selection import train_test_split

fixed_random_state = 42

X_train_full, X_test, t_train_full, t_test = train_test_split(
    X, t, test_size=0.2, random_state=fixed_random_state
)

X_train, X_val, t_train, t_val = train_test_split(
    X_train_full, t_train_full, test_size=0.3, random_state=fixed_random_state
)

print("X_train shape:", X_train.shape)
print("X_val shape:", X_val.shape)
print("X_test shape:", X_test.shape)
```

```
X_train shape: (11558, 8)
X_val shape: (4954, 8)
X_test shape: (4128, 8)
```

In [ ]:

In [ ]:

1. (1 point) **Apply the standardization scaling to the train, validation and test sets. Use the train set to find the mean and standard deviation.**

In [19]:
```
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()

X_train_scaled = scaler.fit_transform(X_train)

X_val_scaled = scaler.transform(X_val)
X_test_scaled = scaler.transform(X_test)

mean_training_set = scaler.mean_
std_training_set = scaler.scale_

print("Mean of the training set:", mean_training_set)
print("Standard deviation of the training set:", std_training_set)
```

```
Mean of the training set: [ 3.86848685e+00  2.85446444e+01  5.41018839e+00  1.09254884e
+00
  1.43099645e+03  3.03907671e+00  3.56427548e+01 -1.19578740e+02]
Standard deviation of the training set: [1.87789214e+00 1.25884394e+01 2.07991146e+00
3.63525667e-01
 1.15224422e+03 7.31847333e+00 2.12843684e+00 2.00620586e+00]
```

In [ ]:

In [ ]:

```

```

1. (5 points) **Use the Sequential API to build an MLP with 2 hidden layers with the Leaky ReLU activation function and associated `alpha=0.2`. The first hidden layer should have 50 neurons and the second 10 neurons. How many neurons should you include in the input and output layers? what should be the activation function in the output layer?**

In [21]:

```
!pip install tensorflow
```

```
Collecting tensorflow
  Obtaining dependency information for tensorflow from https://files.pythonhosted.org/packages/93/21/9b035a4f823d6aee2917c75415be9a95861ff3d73a0a65e48edbf210cec1/tensorflow-2.15.0-cp311-cp311-win_amd64.whl.metadata
  Downloading tensorflow-2.15.0-cp311-cp311-win_amd64.whl.metadata (3.6 kB)
Collecting tensorflow-intel==2.15.0 (from tensorflow)
  Obtaining dependency information for tensorflow-intel==2.15.0 from https://files.pythonhosted.org/packages/4c/48/1a5a15517f18eaa4ff8d598b1c000300b20c1bb0e624539d702117a0c369/tensorflow_intel-2.15.0-cp311-cp311-win_amd64.whl.metadata
  Downloading tensorflow_intel-2.15.0-cp311-cp311-win_amd64.whl.metadata (5.1 kB)
Collecting absl-py>=1.0.0 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for absl-py>=1.0.0 from https://files.pythonhosted.org/packages/01/e4/dc0a1dcc4e74e08d7abedab278c795eef54a224363bb18f5692f416d834f/absl_py-2.0.0-py3-none-any.whl.metadata
  Downloading absl_py-2.0.0-py3-none-any.whl.metadata (2.3 kB)
Collecting astunparse>=1.6.0 (from tensorflow-intel==2.15.0->tensorflow)
  Downloading astunparse-1.6.3-py2.py3-none-any.whl (12 kB)
Collecting flatbuffers>=23.5.26 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for flatbuffers>=23.5.26 from https://files.pythonhosted.org/packages/6f/12/d5c79ee252793ffe845d58a913197bfa02ae9a0b5c9bc3dc4b58d477b9e7/flatbuffers-23.5.26-py2.py3-none-any.whl.metadata
  Downloading flatbuffers-23.5.26-py2.py3-none-any.whl.metadata (850 bytes)
Collecting gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 (from tensorflow-intel==2.15.0->tensorflow)
  Downloading gast-0.5.4-py3-none-any.whl (19 kB)
Collecting google-pasta>=0.1.1 (from tensorflow-intel==2.15.0->tensorflow)
  Downloading google_pasta-0.2.0-py3-none-any.whl (57 kB)
     ---------------------------------------- 0.0/57.5 kB ? eta -:--:--
     ---------------------------------------- 57.5/57.5 kB 3.1 MB/s eta 0:00:00
Requirement already satisfied: h5py>=2.9.0 in d:\anaconda\lib\site-packages (from tensorflow-intel==2.15.0->tensorflow) (3.9.0)
Collecting libclang>=13.0.0 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for libclang>=13.0.0 from https://files.pythonhosted.org/packages/02/8c/dc970bc00867fe290e8c8a7befa1635af716a9ebdfe3fb9dce0ca4b522ce/libclang-16.0.6-py2.py3-none-win_amd64.whl.metadata
  Downloading libclang-16.0.6-py2.py3-none-win_amd64.whl.metadata (5.3 kB)
Collecting ml-dtypes~=0.2.0 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for ml-dtypes~=0.2.0 from https://files.pythonhosted.org/packages/08/89/c727fde1a3d12586e0b8c01abf53754707d76beaa9987640e70807d4545f/ml_dtypes-0.2.0-cp311-cp311-win_amd64.whl.metadata
  Downloading ml_dtypes-0.2.0-cp311-cp311-win_amd64.whl.metadata (20 kB)
Requirement already satisfied: numpy<2.0.0,>=1.23.5 in d:\anaconda\lib\site-packages (from tensorflow-intel==2.15.0->tensorflow) (1.24.3)
Collecting opt-einsum>=2.3.2 (from tensorflow-intel==2.15.0->tensorflow)
  Downloading opt_einsum-3.3.0-py3-none-any.whl (65 kB)
     ---------------------------------------- 0.0/65.5 kB ? eta -:--:--
     ---------------------------------------- 65.5/65.5 kB ? eta 0:00:00
Requirement already satisfied: packaging in d:\anaconda\lib\site-packages (from tensorflow-intel==2.15.0->tensorflow) (23.1)
Collecting protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3 from https://files.pythonhosted.org/packages/fe/6b/7f177e8d6fe4caa14f4065433af9f879d4fab84f0d17dcba7b407f6bd808/protobuf-4.25.1-cp310-abi3-win_amd64.whl.metadata
  Downloading protobuf-4.25.1-cp310-abi3-win_amd64.whl.metadata (541 bytes)
Requirement already satisfied: setuptools in d:\anaconda\lib\site-packages (from tensorflow-intel==2.15.0->tensorflow) (68.0.0)
Requirement already satisfied: six>=1.12.0 in d:\anaconda\lib\site-packages (from tensorflow-intel==2.15.0->tensorflow) (1.16.0)
```

```
Collecting termcolor>=1.1.0 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for termcolor>=1.1.0 from https://files.pythonhoste
d.org/packages/d9/5f/8c716e47b3a50cbd7c146f45881e11d9414def768b7cd9c5e6650ec2a80a/termc
olor-2.4.0-py3-none-any.whl.metadata
  Downloading termcolor-2.4.0-py3-none-any.whl.metadata (6.1 kB)
Requirement already satisfied: typing-extensions>=3.6.6 in d:\anaconda\lib\site-package
s (from tensorflow-intel==2.15.0->tensorflow) (4.7.1)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in d:\anaconda\lib\site-packages (fr
om tensorflow-intel==2.15.0->tensorflow) (1.14.1)
Collecting tensorflow-io-gcs-filesystem>=0.23.1 (from tensorflow-intel==2.15.0->tensorf
low)
  Downloading tensorflow_io_gcs_filesystem-0.31.0-cp311-cp311-win_amd64.whl (1.5 MB)
     ---------------------------------------- 0.0/1.5 MB ? eta -:--:--
     --------- ------------------------------ 0.3/1.5 MB 7.0 MB/s eta 0:00:01
     ------------------ --------------------- 0.7/1.5 MB 7.4 MB/s eta 0:00:01
     ------------------------------ --------- 1.2/1.5 MB 8.2 MB/s eta 0:00:01
     ---------------------------------------- 1.5/1.5 MB 7.9 MB/s eta 0:00:00
Collecting grpcio<2.0,>=1.24.3 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for grpcio<2.0,>=1.24.3 from https://files.pythonhos
ted.org/packages/bc/e5/f656b17fe1ccda1e2a4fe20298b8bcf7c804561c90ee763e39efc1c3772f/grp
cio-1.59.3-cp311-cp311-win_amd64.whl.metadata
  Downloading grpcio-1.59.3-cp311-cp311-win_amd64.whl.metadata (4.2 kB)
Collecting tensorboard<2.16,>=2.15 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for tensorboard<2.16,>=2.15 from https://files.pytho
nhosted.org/packages/6e/0c/1059a6682cf2cc1fcc0d5327837b5672fe4f5574255fa5430d0a8ceb75e
9/tensorboard-2.15.1-py3-none-any.whl.metadata
  Downloading tensorboard-2.15.1-py3-none-any.whl.metadata (1.7 kB)
Collecting tensorflow-estimator<2.16,>=2.15.0 (from tensorflow-intel==2.15.0->tensorflo
w)
  Obtaining dependency information for tensorflow-estimator<2.16,>=2.15.0 from https://
files.pythonhosted.org/packages/b6/c8/2f823c8958d5342eafc6dd3e922f0cc4fcf8c2e0460284cc4
62dae3b60a0/tensorflow_estimator-2.15.0-py2.py3-none-any.whl.metadata
  Downloading tensorflow_estimator-2.15.0-py2.py3-none-any.whl.metadata (1.3 kB)
Collecting keras<2.16,>=2.15.0 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for keras<2.16,>=2.15.0 from https://files.pythonhos
ted.org/packages/fc/a7/0d4490de967a67f68a538cc9cdb259bff971c4b5787f7765dc7c8f118f71/ker
as-2.15.0-py3-none-any.whl.metadata
  Downloading keras-2.15.0-py3-none-any.whl.metadata (2.4 kB)
Requirement already satisfied: wheel<1.0,>=0.23.0 in d:\anaconda\lib\site-packages (fro
m astunparse>=1.6.0->tensorflow-intel==2.15.0->tensorflow) (0.38.4)
Collecting google-auth<3,>=1.6.3 (from tensorboard<2.16,>=2.15->tensorflow-intel==2.15.
0->tensorflow)
  Obtaining dependency information for google-auth<3,>=1.6.3 from https://files.pythonh
osted.org/packages/ca/7e/2d41727aeba37b84e1ca515fbb2ca0d706c591ca946236466ffe575b2059/g
oogle_auth-2.24.0-py2.py3-none-any.whl.metadata
  Downloading google_auth-2.24.0-py2.py3-none-any.whl.metadata (4.7 kB)
Collecting google-auth-oauthlib<2,>=0.5 (from tensorboard<2.16,>=2.15->tensorflow-intel
==2.15.0->tensorflow)
  Obtaining dependency information for google-auth-oauthlib<2,>=0.5 from https://files.
pythonhosted.org/packages/ce/33/a907b4b67245647746dde8d61e1643ef5d210c88e090d491efd89ef
f9f95/google_auth_oauthlib-1.1.0-py2.py3-none-any.whl.metadata
  Downloading google_auth_oauthlib-1.1.0-py2.py3-none-any.whl.metadata (2.7 kB)
Requirement already satisfied: markdown>=2.6.8 in d:\anaconda\lib\site-packages (from t
ensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorflow) (3.4.1)
Collecting protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.
20.3 (from tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.
21.4,!=4.21.5,<5.0.0dev,>=3.20.3 from https://files.pythonhosted.org/packages/80/70/dc6
3d340d27b8ff22022d7dd14b8d6d68b479a003eacdc4507150a286d9a/protobuf-4.23.4-cp310-abi3-wi
n_amd64.whl.metadata
```

```
  Downloading protobuf-4.23.4-cp310-abi3-win_amd64.whl.metadata (540 bytes)
Requirement already satisfied: requests<3,>=2.21.0 in d:\anaconda\lib\site-packages (fr
om tensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorflow) (2.31.0)
Collecting tensorboard-data-server<0.8.0,>=0.7.0 (from tensorboard<2.16,>=2.15->tensorf
low-intel==2.15.0->tensorflow)
  Obtaining dependency information for tensorboard-data-server<0.8.0,>=0.7.0 from http
s://files.pythonhosted.org/packages/7a/13/e503968fefabd4c6b2650af21e110aa8466fe21432cd7
c43a84577a89438/tensorboard_data_server-0.7.2-py3-none-any.whl.metadata
  Downloading tensorboard_data_server-0.7.2-py3-none-any.whl.metadata (1.1 kB)
Requirement already satisfied: werkzeug>=1.0.1 in d:\anaconda\lib\site-packages (from t
ensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorflow) (2.2.3)
Collecting cachetools<6.0,>=2.0.0 (from google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15-
>tensorflow-intel==2.15.0->tensorflow)
  Obtaining dependency information for cachetools<6.0,>=2.0.0 from https://files.python
hosted.org/packages/a2/91/2d843adb9fbd911e0da45fbf6f18ca89d07a087c3daa23e955584f90ebf4/
cachetools-5.3.2-py3-none-any.whl.metadata
  Downloading cachetools-5.3.2-py3-none-any.whl.metadata (5.2 kB)
Requirement already satisfied: pyasn1-modules>=0.2.1 in d:\anaconda\lib\site-packages
(from google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorf
low) (0.2.8)
Collecting rsa<5,>=3.1.4 (from google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorfl
ow-intel==2.15.0->tensorflow)
  Downloading rsa-4.9-py3-none-any.whl (34 kB)
Collecting requests-oauthlib>=0.7.0 (from google-auth-oauthlib<2,>=0.5->tensorboard<2.1
6,>=2.15->tensorflow-intel==2.15.0->tensorflow)
  Downloading requests_oauthlib-1.3.1-py2.py3-none-any.whl (23 kB)
Requirement already satisfied: charset-normalizer<4,>=2 in d:\anaconda\lib\site-package
s (from requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorf
low) (2.0.4)
Requirement already satisfied: idna<4,>=2.5 in d:\anaconda\lib\site-packages (from requ
ests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorflow) (3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in d:\anaconda\lib\site-packages (fro
m requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorflow)
(1.26.16)
Requirement already satisfied: certifi>=2017.4.17 in d:\anaconda\lib\site-packages (fro
m requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorflow)
(2023.7.22)
Requirement already satisfied: MarkupSafe>=2.1.1 in d:\anaconda\lib\site-packages (from
werkzeug>=1.0.1->tensorboard<2.16,>=2.15->tensorflow-intel==2.15.0->tensorflow) (2.1.1)
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in d:\anaconda\lib\site-packages (f
rom pyasn1-modules>=0.2.1->google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow-i
ntel==2.15.0->tensorflow) (0.4.8)
Collecting oauthlib>=3.0.0 (from requests-oauthlib>=0.7.0->google-auth-oauthlib<2,>=0.5
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Downloading tensorboard_data_server-0.7.2-py3-none-any.whl (2.4 kB)
Downloading cachetools-5.3.2-py3-none-any.whl (9.3 kB)
Installing collected packages: libclang, flatbuffers, termcolor, tensorflow-io-gcs-file
system, tensorflow-estimator, tensorboard-data-server, rsa, protobuf, opt-einsum, oauth
lib, ml-dtypes, keras, grpcio, google-pasta, gast, cachetools, astunparse, absl-py, req
uests-oauthlib, google-auth, google-auth-oauthlib, tensorboard, tensorflow-intel, tenso
rflow
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5.26 gast-0.5.4 google-auth-2.24.0 google-auth-oauthlib-1.1.0 google-pasta-0.2.0 grpcio
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otobuf-4.23.4 requests-oauthlib-1.3.1 rsa-4.9 tensorboard-2.15.1 tensorboard-data-serve
r-0.7.2 tensorflow-2.15.0 tensorflow-estimator-2.15.0 tensorflow-intel-2.15.0 tensorflo
w-io-gcs-filesystem-0.31.0 termcolor-2.4.0
```

In [22]:

```python
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LeakyReLU

model = Sequential()

model.add(Dense(50, input_shape=(8,)))
model.add(LeakyReLU(alpha=0.2))

model.add(Dense(50))
model.add(LeakyReLU(alpha=0.2))

model.add(Dense(10))
model.add(LeakyReLU(alpha=0.2))

model.add(Dense(1, activation='linear'))

model.compile(optimizer='adam', loss='mean_squared_error')

model.summary()
```

```
WARNING:tensorflow:From D:\anaconda\Lib\site-packages\keras\src\losses.py:2976: The nam
e tf.losses.sparse_softmax_cross_entropy is deprecated. Please use tf.compat.v1.losses.
sparse_softmax_cross_entropy instead.

WARNING:tensorflow:From D:\anaconda\Lib\site-packages\keras\src\backend.py:873: The nam
e tf.get_default_graph is deprecated. Please use tf.compat.v1.get_default_graph instea
d.

WARNING:tensorflow:From D:\anaconda\Lib\site-packages\keras\src\optimizers\__init__.py:
309: The name tf.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer
instead.

Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense (Dense)               (None, 50)                450

 leaky_re_lu (LeakyReLU)     (None, 50)                0

 dense_1 (Dense)             (None, 50)                2550

 leaky_re_lu_1 (LeakyReLU)   (None, 50)                0

 dense_2 (Dense)             (None, 10)                510

 leaky_re_lu_2 (LeakyReLU)   (None, 10)                0

 dense_3 (Dense)             (None, 1)                 11

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Total params: 3521 (13.75 KB)
Trainable params: 3521 (13.75 KB)
Non-trainable params: 0 (0.00 Byte)
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```

In [ ]:

In [ ]:

1. (3 points) **Compile the model with the Mean Squared Error loss function, the Adam optimizer with learning rate of 0.001, and the `MeanSquaredError` performance metric.**

In [24]:

```
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.losses import MeanSquaredError

model.compile(optimizer=Adam(learning_rate=0.001), loss=MeanSquaredError(), metrics=['M
```

In [ ]:

In [ ]:

1. (2 points) **Train the model using the train and validation sets with online learning, 200 epochs and early stopping callback with a patience of 10 (on the loss value for the**

validation set). Plot the learning curves. Discuss your observations.

In [25]:
```
from tensorflow.keras.callbacks import EarlyStopping
import matplotlib.pyplot as plt

early_stopping = EarlyStopping(monitor='val_loss', patience=10, restore_best_weights=Tr

history = model.fit(
    X_train_scaled, t_train,
    validation_data=(X_val_scaled, t_val),
    epochs=200,
    callbacks=[early_stopping]
)

plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()
plt.show()
```

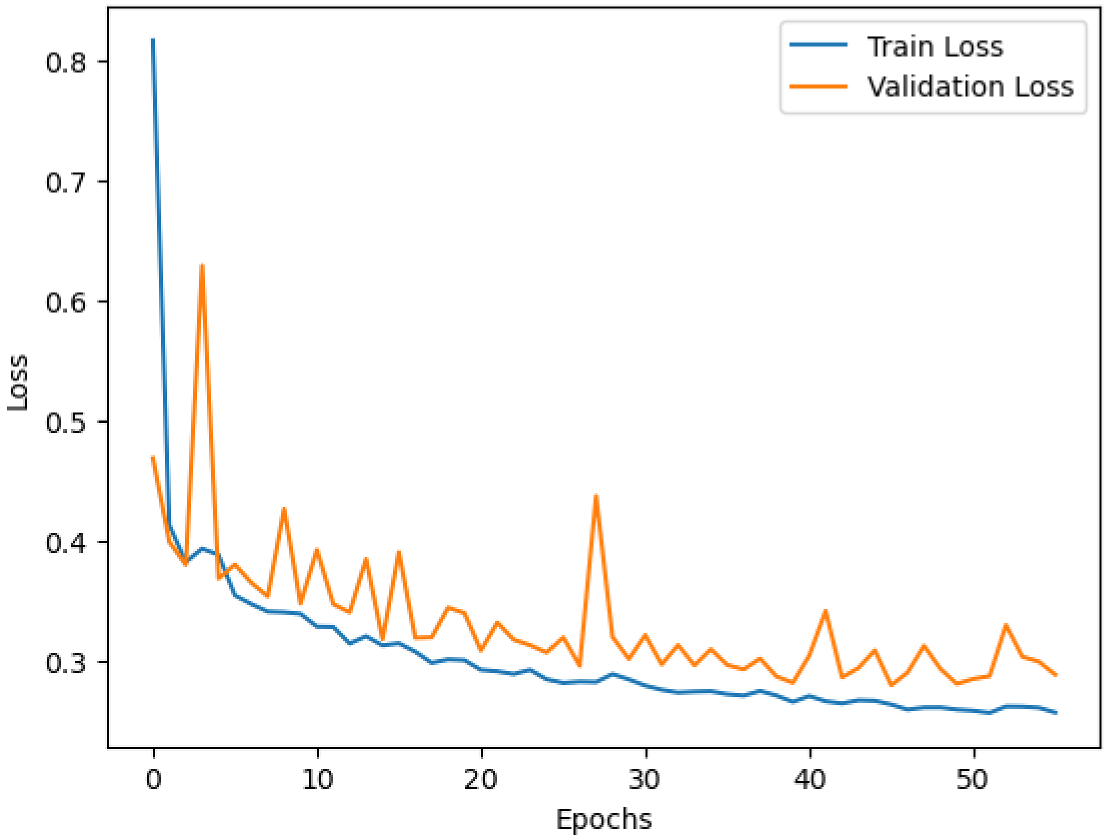
```
Epoch 1/200
WARNING:tensorflow:From D:\anaconda\Lib\site-packages\keras\src\utils\tf_utils.py:492:
The name tf.ragged.RaggedTensorValue is deprecated. Please use tf.compat.v1.ragged.Ragg
edTensorValue instead.

WARNING:tensorflow:From D:\anaconda\Lib\site-packages\keras\src\engine\base_layer_util
s.py:384: The name tf.executing_eagerly_outside_functions is deprecated. Please use tf.
compat.v1.executing_eagerly_outside_functions instead.

362/362 [==============================] - 3s 4ms/step - loss: 0.8165 - mean_squared_er
ror: 0.8165 - val_loss: 0.4688 - val_mean_squared_error: 0.4688
Epoch 2/200
362/362 [==============================] - 1s 3ms/step - loss: 0.4130 - mean_squared_er
ror: 0.4130 - val_loss: 0.3990 - val_mean_squared_error: 0.3990
Epoch 3/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3823 - mean_squared_er
ror: 0.3823 - val_loss: 0.3800 - val_mean_squared_error: 0.3800
Epoch 4/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3934 - mean_squared_er
ror: 0.3934 - val_loss: 0.6288 - val_mean_squared_error: 0.6288
Epoch 5/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3883 - mean_squared_er
ror: 0.3883 - val_loss: 0.3685 - val_mean_squared_error: 0.3685
Epoch 6/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3545 - mean_squared_er
ror: 0.3545 - val_loss: 0.3802 - val_mean_squared_error: 0.3802
Epoch 7/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3473 - mean_squared_er
ror: 0.3473 - val_loss: 0.3650 - val_mean_squared_error: 0.3650
Epoch 8/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3410 - mean_squared_er
ror: 0.3410 - val_loss: 0.3537 - val_mean_squared_error: 0.3537
Epoch 9/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3405 - mean_squared_er
ror: 0.3405 - val_loss: 0.4265 - val_mean_squared_error: 0.4265
Epoch 10/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3392 - mean_squared_er
ror: 0.3392 - val_loss: 0.3477 - val_mean_squared_error: 0.3477
Epoch 11/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3285 - mean_squared_er
ror: 0.3285 - val_loss: 0.3924 - val_mean_squared_error: 0.3924
Epoch 12/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3282 - mean_squared_er
ror: 0.3282 - val_loss: 0.3472 - val_mean_squared_error: 0.3472
Epoch 13/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3144 - mean_squared_er
ror: 0.3144 - val_loss: 0.3404 - val_mean_squared_error: 0.3404
Epoch 14/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3205 - mean_squared_er
ror: 0.3205 - val_loss: 0.3848 - val_mean_squared_error: 0.3848
Epoch 15/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3128 - mean_squared_er
ror: 0.3128 - val_loss: 0.3180 - val_mean_squared_error: 0.3180
Epoch 16/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3146 - mean_squared_er
ror: 0.3146 - val_loss: 0.3905 - val_mean_squared_error: 0.3905
Epoch 17/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3076 - mean_squared_er
ror: 0.3076 - val_loss: 0.3192 - val_mean_squared_error: 0.3192
Epoch 18/200
```

```
362/362 [==============================] - 1s 3ms/step - loss: 0.2983 - mean_squared_er
ror: 0.2983 - val_loss: 0.3196 - val_mean_squared_error: 0.3196
Epoch 19/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3011 - mean_squared_er
ror: 0.3011 - val_loss: 0.3443 - val_mean_squared_error: 0.3443
Epoch 20/200
362/362 [==============================] - 1s 3ms/step - loss: 0.3005 - mean_squared_er
ror: 0.3005 - val_loss: 0.3397 - val_mean_squared_error: 0.3397
Epoch 21/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2924 - mean_squared_er
ror: 0.2924 - val_loss: 0.3086 - val_mean_squared_error: 0.3086
Epoch 22/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2912 - mean_squared_er
ror: 0.2912 - val_loss: 0.3318 - val_mean_squared_error: 0.3318
Epoch 23/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2890 - mean_squared_er
ror: 0.2890 - val_loss: 0.3176 - val_mean_squared_error: 0.3176
Epoch 24/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2924 - mean_squared_er
ror: 0.2924 - val_loss: 0.3130 - val_mean_squared_error: 0.3130
Epoch 25/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2846 - mean_squared_er
ror: 0.2846 - val_loss: 0.3069 - val_mean_squared_error: 0.3069
Epoch 26/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2815 - mean_squared_er
ror: 0.2815 - val_loss: 0.3195 - val_mean_squared_error: 0.3195
Epoch 27/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2826 - mean_squared_er
ror: 0.2826 - val_loss: 0.2957 - val_mean_squared_error: 0.2957
Epoch 28/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2823 - mean_squared_er
ror: 0.2823 - val_loss: 0.4373 - val_mean_squared_error: 0.4373
Epoch 29/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2889 - mean_squared_er
ror: 0.2889 - val_loss: 0.3199 - val_mean_squared_error: 0.3199
Epoch 30/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2845 - mean_squared_er
ror: 0.2845 - val_loss: 0.3015 - val_mean_squared_error: 0.3015
Epoch 31/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2793 - mean_squared_er
ror: 0.2793 - val_loss: 0.3214 - val_mean_squared_error: 0.3214
Epoch 32/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2758 - mean_squared_er
ror: 0.2758 - val_loss: 0.2970 - val_mean_squared_error: 0.2970
Epoch 33/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2736 - mean_squared_er
ror: 0.2736 - val_loss: 0.3131 - val_mean_squared_error: 0.3131
Epoch 34/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2743 - mean_squared_er
ror: 0.2743 - val_loss: 0.2962 - val_mean_squared_error: 0.2962
Epoch 35/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2746 - mean_squared_er
ror: 0.2746 - val_loss: 0.3096 - val_mean_squared_error: 0.3096
Epoch 36/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2722 - mean_squared_er
ror: 0.2722 - val_loss: 0.2965 - val_mean_squared_error: 0.2965
Epoch 37/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2710 - mean_squared_er
ror: 0.2710 - val_loss: 0.2928 - val_mean_squared_error: 0.2928
Epoch 38/200
```

```
362/362 [==============================] - 1s 3ms/step - loss: 0.2749 - mean_squared_er
ror: 0.2749 - val_loss: 0.3019 - val_mean_squared_error: 0.3019
Epoch 39/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2711 - mean_squared_er
ror: 0.2711 - val_loss: 0.2870 - val_mean_squared_error: 0.2870
Epoch 40/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2658 - mean_squared_er
ror: 0.2658 - val_loss: 0.2817 - val_mean_squared_error: 0.2817
Epoch 41/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2706 - mean_squared_er
ror: 0.2706 - val_loss: 0.3043 - val_mean_squared_error: 0.3043
Epoch 42/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2663 - mean_squared_er
ror: 0.2663 - val_loss: 0.3417 - val_mean_squared_error: 0.3417
Epoch 43/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2645 - mean_squared_er
ror: 0.2645 - val_loss: 0.2862 - val_mean_squared_error: 0.2862
Epoch 44/200
362/362 [==============================] - 1s 2ms/step - loss: 0.2671 - mean_squared_er
ror: 0.2671 - val_loss: 0.2940 - val_mean_squared_error: 0.2940
Epoch 45/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2667 - mean_squared_er
ror: 0.2667 - val_loss: 0.3087 - val_mean_squared_error: 0.3087
Epoch 46/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2636 - mean_squared_er
ror: 0.2636 - val_loss: 0.2796 - val_mean_squared_error: 0.2796
Epoch 47/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2593 - mean_squared_er
ror: 0.2593 - val_loss: 0.2903 - val_mean_squared_error: 0.2903
Epoch 48/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2611 - mean_squared_er
ror: 0.2611 - val_loss: 0.3125 - val_mean_squared_error: 0.3125
Epoch 49/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2611 - mean_squared_er
ror: 0.2611 - val_loss: 0.2933 - val_mean_squared_error: 0.2933
Epoch 50/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2593 - mean_squared_er
ror: 0.2593 - val_loss: 0.2808 - val_mean_squared_error: 0.2808
Epoch 51/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2584 - mean_squared_er
ror: 0.2584 - val_loss: 0.2849 - val_mean_squared_error: 0.2849
Epoch 52/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2566 - mean_squared_er
ror: 0.2566 - val_loss: 0.2873 - val_mean_squared_error: 0.2873
Epoch 53/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2620 - mean_squared_er
ror: 0.2620 - val_loss: 0.3298 - val_mean_squared_error: 0.3298
Epoch 54/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2618 - mean_squared_er
ror: 0.2618 - val_loss: 0.3033 - val_mean_squared_error: 0.3033
Epoch 55/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2609 - mean_squared_er
ror: 0.2609 - val_loss: 0.2993 - val_mean_squared_error: 0.2993
Epoch 56/200
362/362 [==============================] - 1s 3ms/step - loss: 0.2569 - mean_squared_er
ror: 0.2569 - val_loss: 0.2885 - val_mean_squared_error: 0.2885
```



In [ ]:

In [ ]:

1. (2 points) **Evaluate the mean squared error performance in the train and test sets.**

In [26]:
```
train_loss = model.evaluate(X_train_scaled, t_train)
print(f"Mean Squared Error on Train Set: {train_loss}")

test_loss = model.evaluate(X_test_scaled, t_test)
print(f"Mean Squared Error on Test Set: {test_loss}")
```

```
362/362 [==============================] - 1s 2ms/step - loss: 0.2476 - mean_squared_er
ror: 0.2476
Mean Squared Error on Train Set: [0.24760311841964722, 0.24760311841964722]
129/129 [==============================] - 0s 1ms/step - loss: 0.2786 - mean_squared_er
ror: 0.2786
Mean Squared Error on Test Set: [0.27862438559532166, 0.27862438559532166]
```

In [ ]:

In [ ]:

1. (2 points) **Predict the housing prices for the train and test sets. Use these predictions to calculate the r^2 score.**

In [27]:
```
from sklearn.metrics import r2_score
```

```
train_predictions = model.predict(X_train_scaled)

test_predictions = model.predict(X_test_scaled)

r2_train = r2_score(t_train, train_predictions)
print(f"R^2 Score on Train Set: {r2_train}")

r2_test = r2_score(t_test, test_predictions)
print(f"R^2 Score on Test Set: {r2_test}")
```

```
362/362 [==============================] - 1s 1ms/step
129/129 [==============================] - 0s 1ms/step
R^2 Score on Train Set: 0.8133691141170697
R^2 Score on Test Set: 0.7873759293982352
```

In [ ]:

In [ ]:

Exercise 3 (15 points)

In this problem you will again be working with the Breast Cancer Dataset available in `scikit-learn`.

This dataset contains 569 samples each described by 30 attributes. Each 30-dimensional sample is labeled as benign (label 1) or malignant (label 0). Let's import the data.

In [29]:

```
from sklearn.datasets import load_breast_cancer
cancer = load_breast_cancer()

X = cancer.data
t = cancer.target

X.shape, t.shape
```

Out[29]:

```
((569, 30), (569,))
```

In [30]:

```
X_training, X_test, t_training, t_test = train_test_split(X, t,
                                                          test_size=0.2,
                                                          shuffle=True, stratify=t,
                                                          random_state=0)

X_train, X_val, t_train, t_val = train_test_split(X_training, t_training,
                                                  test_size=0.3,
                                                  shuffle=True, stratify=t_training,
                                                  random_state=0)
```

1. (7 points) **Train an MLP with the Sequential API with 2 hidden layers: 1st hidden layer with 100 units and the relu activation function, 2nd hidden layer with 50 units with the relu activation function. Compile the model with the Adam optimization with**

$\eta = 0.01$**, track the metric accuracy, and add an early stopping callback on** `val_loss` **with 10 epochs patience.**

Encode the input and output layers to solve this binary classification task. Choose appropriate activation function for the output layer and objective function.

Report the classification report in training and test sets. Discuss results.

In [31]:
```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, ReLU
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import EarlyStopping
from sklearn.metrics import classification_report

model = Sequential()
model.add(Dense(100, input_shape=(30,), activation='relu'))
model.add(Dense(50, activation='relu'))
model.add(Dense(1, activation='sigmoid'))

model.compile(optimizer=Adam(learning_rate=0.01), loss='binary_crossentropy', metrics=[

early_stopping = EarlyStopping(monitor='val_loss', patience=10, restore_best_weights=Tr

history = model.fit(
    X_train, t_train,
    validation_data=(X_val, t_val),
    epochs=100,
    callbacks=[early_stopping],
    verbose=0
)

train_predictions = (model.predict(X_train) > 0.5).astype(int)
print("Classification Report on Training Set:")
print(classification_report(t_train, train_predictions))

test_predictions = (model.predict(X_test) > 0.5).astype(int)
print("\nClassification Report on Test Set:")
print(classification_report(t_test, test_predictions))
```

```
10/10 [==============================] - 0s 2ms/step
Classification Report on Training Set:
              precision    recall  f1-score   support

           0       0.95      0.82      0.88       119
           1       0.90      0.97      0.94       199

    accuracy                           0.92       318
   macro avg       0.93      0.90      0.91       318
weighted avg       0.92      0.92      0.92       318

4/4 [==============================] - 0s 3ms/step

Classification Report on Test Set:
              precision    recall  f1-score   support

           0       0.92      0.86      0.89        42
           1       0.92      0.96      0.94        72

    accuracy                           0.92       114
   macro avg       0.92      0.91      0.91       114
weighted avg       0.92      0.92      0.92       114
```

In [ ]:

In [ ]:

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(8 points) **Train a CNN with the Sequential API with the following architecture:**

- **convolutional layer with with 8 3×1 filters, zeros-padding and the relu activation function**
- **max-pooling layer with a pool size of 2 and a stride of 2**
- **convolutional layer with 16 7×1 filters, zeros-padding and the relu activation function**
- **max-pooling layer with a pool size of 2 and a stride of 2**
- **dense hidden layer with 30 units, relu activation function**
- **output layer**

Encode the input and output layers to solve this binary classification task. Choose appropriate activation function for the output layer and objective function.

Compile the model with the Adam optimization with $\eta = 0.01$, track the metric accuracy, and add an early stopping callback on `val_loss` with 10 epochs patience.

Report the classification report in training and test sets. Discuss results.

In [32]:
```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv1D, MaxPooling1D, Flatten, Dense
```

```
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import EarlyStopping
from sklearn.metrics import classification_report

cnn_model = Sequential()
cnn_model.add(Conv1D(8, kernel_size=3, padding='same', activation='relu', input_shape=(
cnn_model.add(MaxPooling1D(pool_size=2, strides=2))
cnn_model.add(Conv1D(16, kernel_size=7, padding='same', activation='relu'))
cnn_model.add(MaxPooling1D(pool_size=2, strides=2))
cnn_model.add(Flatten())
cnn_model.add(Dense(30, activation='relu'))
cnn_model.add(Dense(1, activation='sigmoid'))

X_train_cnn = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_val_cnn = X_val.reshape(X_val.shape[0], X_val.shape[1], 1)
X_test_cnn = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

cnn_model.compile(optimizer=Adam(learning_rate=0.01), loss='binary_crossentropy', metri

early_stopping_cnn = EarlyStopping(monitor='val_loss', patience=10, restore_best_weight

history_cnn = cnn_model.fit(
    X_train_cnn, t_train,
    validation_data=(X_val_cnn, t_val),
    epochs=100,
    callbacks=[early_stopping_cnn],
    verbose=0
)

train_predictions_cnn = (cnn_model.predict(X_train_cnn) > 0.5).astype(int)
print("Classification Report on Training Set:")
print(classification_report(t_train, train_predictions_cnn))

test_predictions_cnn = (cnn_model.predict(X_test_cnn) > 0.5).astype(int)
print("\nClassification Report on Test Set:")
print(classification_report(t_test, test_predictions_cnn))
```

```
WARNING:tensorflow:From D:\anaconda\Lib\site-packages\keras\src\backend.py:6642: The na
me tf.nn.max_pool is deprecated. Please use tf.nn.max_pool2d instead.

10/10 [==============================] - 0s 2ms/step
Classification Report on Training Set:
              precision    recall  f1-score   support

           0       0.98      0.82      0.89       119
           1       0.90      0.99      0.94       199

    accuracy                           0.92       318
   macro avg       0.94      0.90      0.92       318
weighted avg       0.93      0.92      0.92       318

4/4 [==============================] - 0s 3ms/step

Classification Report on Test Set:
              precision    recall  f1-score   support

           0       0.92      0.81      0.86        42
           1       0.90      0.96      0.93        72

    accuracy                           0.90       114
   macro avg       0.91      0.88      0.89       114
weighted avg       0.90      0.90      0.90       114
```

In [ ]:

In [ ]:

In [ ]:

In [ ]:

On-Time (5 points)

Submit your assignment before the deadline.

Submit Your Solution

Confirm that you've successfully completed the assignment.

Along with the Notebook, include a PDF of the notebook with your solutions.

`add` and `commit` the final version of your work, and `push` your code to your GitHub repository.

Submit the URL of your GitHub Repository as your assignment submission on Canvas.
