Aritificial Neural Network-02

In [2]:
```
#Import Necessary Libraries
import pandas as pd
import numpy as np
import tensorflow
from sklearn.metrics import accuracy_score , confusion_matrix
from sklearn.model_selection import train_test_split , cross_val_score

#Create your first NLP in keras
from keras.models import Sequential
from keras.layers import Dense
from matplotlib import pyplot as plt
```

In [3]:
```
data = pd.read_csv('gas_turbines.csv')
data
```

Out[3]:

	AT	AP	AH	AFDP	GTEP	TIT	TAT	TEY	CDP	CO	NOX
0	6.8594	1007.9	96.799	3.5000	19.663	1059.2	550.00	114.70	10.605	3.1547	82.722
1	6.7850	1008.4	97.118	3.4998	19.728	1059.3	550.00	114.72	10.598	3.2363	82.776
2	6.8977	1008.8	95.939	3.4824	19.779	1059.4	549.87	114.71	10.601	3.2012	82.468
3	7.0569	1009.2	95.249	3.4805	19.792	1059.6	549.99	114.72	10.606	3.1923	82.670
4	7.3978	1009.7	95.150	3.4976	19.765	1059.7	549.98	114.72	10.612	3.2484	82.311
...	...	...	...	...	...	...	...	...	...	...	...
15034	9.0301	1005.6	98.460	3.5421	19.164	1049.7	546.21	111.61	10.400	4.5186	79.559
15035	7.8879	1005.9	99.093	3.5059	19.414	1046.3	543.22	111.78	10.433	4.8470	79.917
15036	7.2647	1006.3	99.496	3.4770	19.530	1037.7	537.32	110.19	10.483	7.9632	90.912
15037	7.0060	1006.8	99.008	3.4486	19.377	1043.2	541.24	110.74	10.533	6.2494	93.227
15038	6.9279	1007.2	97.533	3.4275	19.306	1049.9	545.85	111.58	10.583	4.9816	92.498

15039 rows × 11 columns

In [4]:
```
data.isna().sum()
```

Out[4]:
```
AT      0
AP      0
AH      0
AFDP    0
GTEP    0
TIT     0
TAT     0
TEY     0
CDP     0
CO      0
NOX     0
dtype: int64
```

In [5]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 15039 entries, 0 to 15038
Data columns (total 11 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   AT      15039 non-null  float64
 1   AP      15039 non-null  float64
 2   AH      15039 non-null  float64
 3   AFDP    15039 non-null  float64
 4   GTEP    15039 non-null  float64
 5   TIT     15039 non-null  float64
 6   TAT     15039 non-null  float64
 7   TEY     15039 non-null  float64
 8   CDP     15039 non-null  float64
 9   CO      15039 non-null  float64
 10  NOX     15039 non-null  float64
dtypes: float64(11)
memory usage: 1.3 MB
```

In [6]:
```
data.describe().T
```

Out[6]:

	count	mean	std	min	25%	50%	75%	max
AT	15039.0	17.764381	7.574323	0.522300	11.408000	18.1860	23.8625	34.9290
AP	15039.0	1013.199240	6.410760	985.850000	1008.900000	1012.8000	1016.9000	1034.2000
AH	15039.0	79.124174	13.793439	30.344000	69.750000	82.2660	90.0435	100.2000
AFDP	15039.0	4.200294	0.760197	2.087400	3.723900	4.1862	4.5509	7.6106
GTEP	15039.0	25.419061	4.173916	17.878000	23.294000	25.0820	27.1840	37.4020
TIT	15039.0	1083.798770	16.527806	1000.800000	1079.600000	1088.7000	1096.0000	1100.8000
TAT	15039.0	545.396183	7.866803	512.450000	542.170000	549.8900	550.0600	550.6100
TEY	15039.0	134.188464	15.829717	100.170000	127.985000	133.7800	140.8950	174.6100
CDP	15039.0	12.102353	1.103196	9.904400	11.622000	12.0250	12.5780	15.0810
CO	15039.0	1.972499	2.222206	0.000388	0.858055	1.3902	2.1604	44.1030
NOX	15039.0	68.190934	10.470586	27.765000	61.303500	66.6010	73.9355	119.8900

In [7]:
```
data.corr()
```

Out[7]:

	AT	AP	AH	AFDP	GTEP	TIT	TAT	TEY	(
AT	1.000000	-0.412953	-0.549432	-0.099333	-0.049103	0.093067	0.338569	-0.207495	-0.100
AP	-0.412953	1.000000	0.042573	0.040318	0.078575	0.029650	-0.223479	0.146939	0.131
AH	-0.549432	0.042573	1.000000	-0.119249	-0.202784	-0.247781	0.010859	-0.110272	-0.182
AFDP	-0.099333	0.040318	-0.119249	1.000000	0.744251	0.627254	-0.571541	0.717995	0.727
GTEP	-0.049103	0.078575	-0.202784	0.744251	1.000000	0.874526	-0.756884	0.977042	0.993
TIT	0.093067	0.029650	-0.247781	0.627254	0.874526	1.000000	-0.357320	0.891587	0.887
TAT	0.338569	-0.223479	0.010859	-0.571541	-0.756884	-0.357320	1.000000	-0.720356	-0.744
TEY	-0.207495	0.146939	-0.110272	0.717995	0.977042	0.891587	-0.720356	1.000000	0.988
CDP	-0.100705	0.131198	-0.182010	0.727152	0.993784	0.887238	-0.744740	0.988473	1.000
CO	-0.088588	0.041614	0.165505	-0.334207	-0.508259	-0.688272	0.063404	-0.541751	-0.520
NOX	-0.600006	0.256744	0.143061	-0.037299	-0.208496	-0.231636	0.009888	-0.102631	-0.169

In [8]:
```
# Changing position of target column 'TEY'
Target = data['TEY']
#Drop the existing column
data.drop(labels=['TEY'], axis=1,inplace = True)
data.insert(0, 'Y', Target)

data = data.rename({'Y':'TEY'}, axis = 1)

data.head(10)
```

Out[8]:

	TEY	AT	AP	AH	AFDP	GTEP	TIT	TAT	CDP	CO	NOX
0	114.70	6.8594	1007.9	96.799	3.5000	19.663	1059.2	550.00	10.605	3.1547	82.722
1	114.72	6.7850	1008.4	97.118	3.4998	19.728	1059.3	550.00	10.598	3.2363	82.776
2	114.71	6.8977	1008.8	95.939	3.4824	19.779	1059.4	549.87	10.601	3.2012	82.468
3	114.72	7.0569	1009.2	95.249	3.4805	19.792	1059.6	549.99	10.606	3.1923	82.670
4	114.72	7.3978	1009.7	95.150	3.4976	19.765	1059.7	549.98	10.612	3.2484	82.311
5	114.72	7.6998	1010.7	92.708	3.5236	19.683	1059.8	549.97	10.626	3.4467	82.409
6	114.71	7.7901	1011.6	91.983	3.5298	19.659	1060.0	549.87	10.644	3.4874	82.440
7	114.71	7.7139	1012.7	91.348	3.5088	19.673	1059.8	549.92	10.656	3.6043	83.010
8	114.72	7.7975	1013.8	90.196	3.5141	19.634	1060.1	550.09	10.644	3.3943	82.284
9	131.70	8.0820	1015.0	88.597	4.0612	23.406	1083.0	550.21	11.679	1.9081	82.782

In [9]:
```
data.corr()
```

Out[9]:

	TEY	AT	AP	AH	AFDP	GTEP	TIT	TAT	C
TEY	1.000000	-0.207495	0.146939	-0.110272	0.717995	0.977042	0.891587	-0.720356	0.988
AT	-0.207495	1.000000	-0.412953	-0.549432	-0.099333	-0.049103	0.093067	0.338569	-0.100
AP	0.146939	-0.412953	1.000000	0.042573	0.040318	0.078575	0.029650	-0.223479	0.131
AH	-0.110272	-0.549432	0.042573	1.000000	-0.119249	-0.202784	-0.247781	0.010859	-0.182
AFDP	0.717995	-0.099333	0.040318	-0.119249	1.000000	0.744251	0.627254	-0.571541	0.727
GTEP	0.977042	-0.049103	0.078575	-0.202784	0.744251	1.000000	0.874526	-0.756884	0.993
TIT	0.891587	0.093067	0.029650	-0.247781	0.627254	0.874526	1.000000	-0.357320	0.887
TAT	-0.720356	0.338569	-0.223479	0.010859	-0.571541	-0.756884	-0.357320	1.000000	-0.744
CDP	0.988473	-0.100705	0.131198	-0.182010	0.727152	0.993784	0.887238	-0.744740	1.000
CO	-0.541751	-0.088588	0.041614	0.165505	-0.334207	-0.508259	-0.688272	0.063404	-0.520
NOX	-0.102631	-0.600006	0.256744	0.143061	-0.037299	-0.208496	-0.231636	0.009888	-0.169

feature selection by using mutual information Feature Selection

In [10]:
```
from sklearn.model_selection import train_test_split
from sklearn.feature_selection import SelectKBest
from sklearn.feature_selection import mutual_info_regression
```

In [11]:
```
x = data.iloc[:,1:]
y = data.iloc[:, 0 ]
```

In [12]:
```
x
```

Out[12]:

	AT	AP	AH	AFDP	GTEP	TIT	TAT	CDP	CO	NOX
0	6.8594	1007.9	96.799	3.5000	19.663	1059.2	550.00	10.605	3.1547	82.722
1	6.7850	1008.4	97.118	3.4998	19.728	1059.3	550.00	10.598	3.2363	82.776
2	6.8977	1008.8	95.939	3.4824	19.779	1059.4	549.87	10.601	3.2012	82.468
3	7.0569	1009.2	95.249	3.4805	19.792	1059.6	549.99	10.606	3.1923	82.670
4	7.3978	1009.7	95.150	3.4976	19.765	1059.7	549.98	10.612	3.2484	82.311
...	...	...	...	...	...	...	...	...	...	...
15034	9.0301	1005.6	98.460	3.5421	19.164	1049.7	546.21	10.400	4.5186	79.559
15035	7.8879	1005.9	99.093	3.5059	19.414	1046.3	543.22	10.433	4.8470	79.917
15036	7.2647	1006.3	99.496	3.4770	19.530	1037.7	537.32	10.483	7.9632	90.912
15037	7.0060	1006.8	99.008	3.4486	19.377	1043.2	541.24	10.533	6.2494	93.227
15038	6.9279	1007.2	97.533	3.4275	19.306	1049.9	545.85	10.583	4.9816	92.498

15039 rows × 10 columns

In [13]:
```
y
```

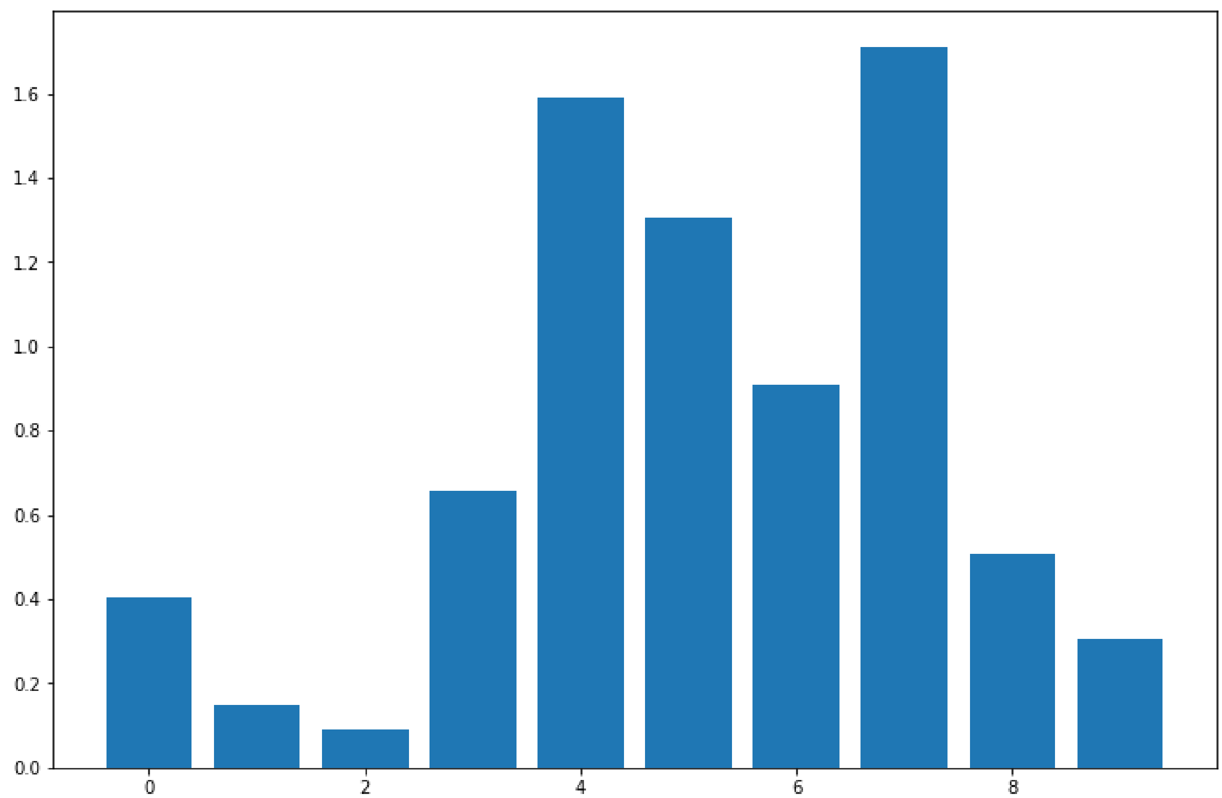
Out[13]:
```
0        114.70
1        114.72
2        114.71
3        114.72
4        114.72
          ...  
15034    111.61
15035    111.78
15036    110.19
15037    110.74
15038    111.58
Name: TEY, Length: 15039, dtype: float64
```

In [17]:
```
#Feature selection
def select_features(x_train,y_train,x_test):
    #configure to select all features
    fs = SelectKBest(score_func = mutual_info_regression,k = 'all')
    #Learn relationship from training data
    fs.fit(x_train,y_train)
    #transform train input data
    x_train_fs = fs.transform(x_train)
    #transfer test input data
    x_test_fs = fs.transform(x_test)
    return x_train_fs,x_test_fs, fs
```

In [18]:
```
# split into train and test sets
x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.33, random_
# feature selection
x_train_fs, x_test_fs, fs = select_features(x_train, y_train, x_test)
```

In [20]:
```
#What are the scores for the feature
for i in range(len(fs.scores_)):
    print('Feature %d: %f' % (i, fs.scores_[i]))
#plot the scores
fig, ax = plt.subplots(figsize= (12,8))
plt.bar([i for i in range(len(fs.scores_))],fs.scores_)
plt.show()
```

```
Feature 0: 0.402863
Feature 1: 0.147218
Feature 2: 0.091173
Feature 3: 0.656688
Feature 4: 1.590872
Feature 5: 1.306241
Feature 6: 0.909771
Feature 7: 1.711018
Feature 8: 0.507201
Feature 9: 0.303863
```



As per above features selection method , we will select only features with good score to build our model

In [21]:
```
x = data.drop(['TEY','AT','AP','AH', 'CO','NOX'], axis= 1 )
y = data.iloc[:,0]
```

In [22]:
```
x
```

Out[22]:

	AFDP	GTEP	TIT	TAT	CDP
0	3.5000	19.663	1059.2	550.00	10.605
1	3.4998	19.728	1059.3	550.00	10.598
2	3.4824	19.779	1059.4	549.87	10.601
3	3.4805	19.792	1059.6	549.99	10.606
4	3.4976	19.765	1059.7	549.98	10.612
...	...	...	...	...	...
15034	3.5421	19.164	1049.7	546.21	10.400
15035	3.5059	19.414	1046.3	543.22	10.433
15036	3.4770	19.530	1037.7	537.32	10.483
15037	3.4486	19.377	1043.2	541.24	10.533
15038	3.4275	19.306	1049.9	545.85	10.583

15039 rows × 5 columns

In [23]:
```
y
```

Out[23]:
```
0        114.70
1        114.72
2        114.71
3        114.72
4        114.72
          ...
15034    111.61
15035    111.78
15036    110.19
15037    110.74
15038    111.58
Name: TEY, Length: 15039, dtype: float64
```

In [24]:
```
from sklearn.model_selection import train_test_split
x_train,x_test,y_train,y_test = train_test_split(x,y, test_size=0.20)
```

Arificial neural network model - backpropagation

In [25]:
```
from keras.models import Sequential
from keras.layers import Dense
```

In [26]:
```
#Create model
model = Sequential()
model.add(Dense(10, input_dim=5,activation='relu'))
model.add(Dense(6, activation= 'relu'))
model.add(Dense(1, activation='sigmoid'))
```

In [27]:
```
#Compile model
model.compile(loss='mean_squared_error', optimizer = 'adam', metrics=['mse'])
```

In [28]:
```
#fit the model
history = model.fit(x, y, validation_split=0.33,epochs=100, batch_size=40)
```

```
Epoch 1/100
252/252 [==============================] - 5s 7ms/step - loss: 18290.0293 - m
se: 18290.0293 - val_loss: 17380.0664 - val_mse: 17380.0664
Epoch 2/100
252/252 [==============================] - 1s 6ms/step - loss: 18290.0254 - m
se: 18290.0254 - val_loss: 17380.0664 - val_mse: 17380.0664
Epoch 3/100
252/252 [==============================] - 1s 5ms/step - loss: 18290.0293 - m
se: 18290.0293 - val_loss: 17380.0664 - val_mse: 17380.0664
Epoch 4/100
252/252 [==============================] - 1s 6ms/step - loss: 18290.0254 - m
se: 18290.0254 - val_loss: 17380.0664 - val_mse: 17380.0664
Epoch 5/100
252/252 [==============================] - 1s 5ms/step - loss: 18290.0195 - m
se: 18290.0195 - val_loss: 17380.0664 - val_mse: 17380.0664
Epoch 6/100
252/252 [==============================] - 1s 5ms/step - loss: 18290.0352 - m
se: 18290.0352 - val_loss: 17380.0664 - val_mse: 17380.0664
Epoch 7/100
```

In [29]:
```
# evaluate the model
scores = model.evaluate(x, y)
print("%s: %.2f%%" % (model.metrics_names[1], scores[1]*100))
```

```
470/470 [==============================] - 1s 3ms/step - loss: 17989.7305 - ms
e: 17989.7305
mse: 1798973.05%
```

Hyper parameter tuning

In [31]:
```
X = data.drop(['TEY','AT', 'AP','AH','CO','NOX'], axis= 1)
Y =data.iloc[:,0]
```

In [32]:
```
X
```

Out[32]:

	AFDP	GTEP	TIT	TAT	CDP
0	3.5000	19.663	1059.2	550.00	10.605
1	3.4998	19.728	1059.3	550.00	10.598
2	3.4824	19.779	1059.4	549.87	10.601
3	3.4805	19.792	1059.6	549.99	10.606
4	3.4976	19.765	1059.7	549.98	10.612
...	...	...	...	...	...
15034	3.5421	19.164	1049.7	546.21	10.400
15035	3.5059	19.414	1046.3	543.22	10.433
15036	3.4770	19.530	1037.7	537.32	10.483
15037	3.4486	19.377	1043.2	541.24	10.533
15038	3.4275	19.306	1049.9	545.85	10.583

15039 rows × 5 columns

In [33]:
```
Y
```

Out[33]:
```
0        114.70
1        114.72
2        114.71
3        114.72
4        114.72
          ...
15034    111.61
15035    111.78
15036    110.19
15037    110.74
15038    111.58
Name: TEY, Length: 15039, dtype: float64
```

In [34]:
```
# Standardization
from sklearn.preprocessing import StandardScaler
a = StandardScaler()
a.fit(X)
X_standardized = a.transform(X)
```

In [35]:
```
pd.DataFrame(X_standardized).describe().T
```

Out[35]:

	count	mean	std	min	25%	50%	75%	max
0	15039.0	3.810001e-16	1.000033	-2.779497	-0.626693	-0.018541	0.461220	4.486233
1	15039.0	1.107344e-16	1.000033	-1.806771	-0.509146	-0.080757	0.422864	2.871006
2	15039.0	-2.324212e-15	1.000033	-5.021933	-0.254051	0.296554	0.738249	1.028678
3	15039.0	1.744899e-15	1.000033	-4.188141	-0.410115	0.571257	0.592868	0.662784
4	15039.0	3.640356e-16	1.000033	-1.992416	-0.435434	-0.070119	0.431168	2.700105

Tuning of all hyperparameters

In [42]:
```
from sklearn.model_selection import GridSearchCV
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from keras.layers import Dropout
from tensorflow.keras.optimizers import Adam

import warnings
warnings.filterwarnings('ignore')
```

In [38]:
```
# Splitting data into test and train data

from sklearn.model_selection import train_test_split

X_train,X_test,Y_train,Y_test = train_test_split(X,Y,test_size=0.3, random_state=
```

In [40]:
```
def create_model(learning_rate,dropout_rate,activation_function,init,neuron1,neur
    model = Sequential()
    model.add(Dense(neuron1,input_dim = 5,kernel_initializer = init,activation = 
    model.add(Dropout(dropout_rate))
    model.add(Dense(neuron2,input_dim = neuron1,kernel_initializer = init,activat
    model.add(Dropout(dropout_rate))
    model.add(Dense(1,activation = 'sigmoid'))

    adam = Adam(lr =learning_rate)
    model.compile(loss = 'mean_squared_error',optimizer = adam,metrics = ['mse'])
    return model
```

In [43]:
```
#Create the model
model= KerasClassifier(build_fn= create_model, verbose =0)
```

In [45]:
```
#Define the grid search parameters

batch_size =  [10,20,40]
epochs = [10,50,100]
learning_rate = [0.001,0.01,0.1]
dropout_rate = [0.0,0.1,0.2]
activation_function = ['softmax','relu', 'tanh','linear']
init = ['uniform','normal','zero']
neuron1 = [4,8,16]
neuron2 = [2,4,8]
```

In [46]:
```
# Make a dictionary of the grid search parameters

param_grids = dict(batch_size = batch_size,epochs = epochs,learning_rate = learni
                   activation_function = activation_function,init = init,neuron1
```

In [47]:
```
# Build and fit the GridSearchCV

grid = GridSearchCV(estimator = model,param_grid = param_grids,verbose = 10, scor
grid_result = grid.fit(X, Y)

# Summarize the results
print('Best : {}, using {}'.format(grid_result.best_score_,grid_result.best_param
```

```
Fitting 5 folds for each of 8748 candidates, totalling 43740 fits
[CV 1/5; 1/8748] START activation_function=softmax, batch_size=10, dropout_ra
te=0.0, epochs=10, init=uniform, learning_rate=0.001, neuron1=4, neuron2=2
[CV 1/5; 1/8748] END activation_function=softmax, batch_size=10, dropout_rate
=0.0, epochs=10, init=uniform, learning_rate=0.001, neuron1=4, neuron2=2; tot
al time=  37.7s
[CV 2/5; 1/8748] START activation_function=softmax, batch_size=10, dropout_ra
te=0.0, epochs=10, init=uniform, learning_rate=0.001, neuron1=4, neuron2=2
[CV 2/5; 1/8748] END activation_function=softmax, batch_size=10, dropout_rate
=0.0, epochs=10, init=uniform, learning_rate=0.001, neuron1=4, neuron2=2; tot
al time=  36.5s
[CV 3/5; 1/8748] START activation_function=softmax, batch_size=10, dropout_ra
te=0.0, epochs=10, init=uniform, learning_rate=0.001, neuron1=4, neuron2=2
[CV 3/5; 1/8748] END activation_function=softmax, batch_size=10, dropout_rate
=0.0, epochs=10, init=uniform, learning_rate=0.001, neuron1=4, neuron2=2; tot
al time=  35.9s
[CV 4/5; 1/8748] START activation_function=softmax, batch_size=10, dropout_ra
te=0.0, epochs=10, init=uniform, learning_rate=0.001, neuron1=4, neuron2=2
[CV 4/5; 1/8748] END activation_function=softmax, batch_size=10, dropout_rate
```