IE406: Final Project

Group 4: Music Genre Classification

Methodology: Neural Network
Instructor: Prof.Manjunath Joshi

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In [13]:

```python
import pandas as pd
from sklearn.preprocessing import LabelEncoder
from sklearn.preprocessing import StandardScaler
import keras
from keras.models import Sequential
from sklearn.model_selection import train_test_split
import numpy as np
```

In [14]:

```python
DATA = pd.read_csv('Genre_data.csv')
DATA.head()
```

Out[14]:

	filename	length	chroma_stft_mean	chroma_stft_var	rms_mean	rms_var	spectral_centroid_mean	spectral_centroid_var	spectral_bandwidth_mean	spectral_bandwidth
0	blues.00000.0.wav	66149	0.335406	0.091048	0.130405	0.003521	1773.065032	167541.630869	1972.744388	117335.77
1	blues.00000.1.wav	66149	0.343065	0.086147	0.112699	0.001450	1816.693777	90525.690866	2010.051501	65671.87
2	blues.00000.2.wav	66149	0.346815	0.092243	0.132003	0.004620	1788.539719	111407.437613	2084.565132	75124.92
3	blues.00000.3.wav	66149	0.363639	0.086856	0.132565	0.002448	1655.289045	111952.284517	1960.039988	82913.63
4	blues.00000.4.wav	66149	0.335579	0.088129	0.143289	0.001701	1630.656199	79667.267654	1948.503884	60204.02

5 rows × 60 columns

In [15]:

```python
DATA.shape
```

Out[15]:

```
(9990, 60)
```

In [16]:

```python
DATA.dtypes
```

Out[16]:

```
filename                    object
length                       int64
chroma_stft_mean           float64
chroma_stft_var            float64
rms_mean                   float64
rms_var                    float64
spectral_centroid_mean     float64
spectral_centroid_var      float64
spectral_bandwidth_mean    float64
spectral_bandwidth_var     float64
rolloff_mean               float64
rolloff_var                float64
zero_crossing_rate_mean    float64
zero_crossing_rate_var     float64
harmony_mean               float64
harmony_var                float64
perceptr_mean              float64
perceptr_var               float64
tempo                      float64
mfcc1_mean                 float64
mfcc1_var                  float64
mfcc2_mean                 float64
mfcc2_var                  float64
mfcc3_mean                 float64
mfcc3_var                  float64
mfcc4_mean                 float64
mfcc4_var                  float64
mfcc5_mean                 float64
mfcc5_var                  float64
mfcc6_mean                 float64
mfcc6_var                  float64
mfcc7_mean                 float64
mfcc7_var                  float64
mfcc8_mean                 float64
mfcc8_var                  float64
mfcc9_mean                 float64
mfcc9_var                  float64
mfcc10_mean                float64
mfcc10_var                 float64
mfcc11_mean                float64
mfcc11_var                 float64
mfcc12_mean                float64
mfcc12_var                 float64
mfcc13_mean                float64
mfcc13_var                 float64
mfcc14_mean                float64
mfcc14_var                 float64
mfcc15_mean                float64
mfcc15_var                 float64
mfcc16_mean                float64
mfcc16_var                 float64
mfcc17_mean                float64
mfcc17_var                 float64
mfcc18_mean                float64
mfcc18_var                 float64
mfcc19_mean                float64
mfcc19_var                 float64
mfcc20_mean                float64
mfcc20_var                 float64
label                       object
dtype: object
```

In [17]:

```python
DATA = DATA.drop(['filename','length'],axis=1)
```

In [18]:

```python
my_genre_list = DATA.iloc[:, -1]
le = LabelEncoder()
```

In [19]:

```python
y = le.fit_transform(my_genre_list)
```

In [20]:

```python
print(y)
```

```
[0 0 0 ... 9 9 9]
```

In [21]:

```python
print(DATA.iloc[:, :-1])
```

```
      chroma_stft_mean  chroma_stft_var  rms_mean   rms_var  \
0             0.335406         0.091048  0.130405  0.003521
1             0.343065         0.086147  0.112699  0.001450
2             0.346815         0.092243  0.132003  0.004620
3             0.363639         0.086856  0.132565  0.002448
4             0.335579         0.088129  0.143289  0.001701
...                ...              ...       ...       ...
9985          0.349126         0.080515  0.050019  0.000097
9986          0.372564         0.082626  0.057897  0.000088
9987          0.347481         0.089019  0.052403  0.000701
9988          0.387527         0.084815  0.066430  0.000320
9989          0.369293         0.086759  0.050524  0.000067

      spectral_centroid_mean  spectral_centroid_var  spectral_bandwidth_mean  \
0                1773.065032          167541.630869              1972.744388
1                1816.693777           90525.690866              2010.051501
2                1788.539719          111407.437613              2084.565132
3                1655.289045          111952.284517              1960.039988
4                1630.656199           79667.267654              1948.503884
...                      ...                    ...                      ...
9985             1499.083005          164266.886443              1718.707215
9986             1847.965128          281054.935973              1906.468492
9987             1346.157659          662956.246325              1561.859087
9988             2084.515327          203891.039161              2018.366254
9989             1634.330126          411429.169769              1867.422378

      spectral_bandwidth_var  rolloff_mean   rolloff_var  ...  mfcc16_mean  \
0              117335.771563   3714.560359  1.080790e+06  ...    -2.853603
1               65671.875673   3869.682242  6.722448e+05  ...     4.074709
2               75124.921716   3997.639160  7.907127e+05  ...     4.806280
3               82913.639269   3568.300218  9.216524e+05  ...    -1.359111
4               60204.020268   3469.992864  6.102111e+05  ...     2.092937
...                      ...           ...           ...  ...          ...
9985            85931.574523   3015.559458  8.479527e+05  ...     5.773784
9986            99727.037054   3746.694524  1.170890e+06  ...     2.074155
9987           138762.841945   2442.362154  2.602871e+06  ...    -1.005473
9988            22860.992562   4313.266226  4.968878e+05  ...     4.123402
9989           119722.211518   3462.042142  1.517016e+06  ...     1.342274

      mfcc16_var  mfcc17_mean  mfcc17_var  mfcc18_mean  mfcc18_var  \
0      39.687145    -3.241280   36.488243     0.722209   38.099152
1      64.748276    -6.055294   40.677654     0.159015   51.264091
2      67.336563    -1.768610   28.348579     2.378768   45.717648
3      47.739452    -3.841155   28.337118     1.218588   34.770935
4      30.336359     0.664582   45.880913     1.689446   51.363583
...          ...          ...         ...          ...         ...
9985   42.485981    -9.094270   38.326839    -4.246976   31.049839
9986   32.415203   -12.375726   66.418587    -3.081278   54.414265
9987   78.228149    -2.524483   21.778994     4.809936   25.980829
9988   28.323744    -5.363541   17.209942     6.462601   21.442928
9989   38.801735   -11.598399   58.983097    -0.178517   55.761299

      mfcc19_mean  mfcc19_var  mfcc20_mean  mfcc20_var
0       -5.050335   33.618073    -0.243027   43.771767
1       -2.837699   97.030830     5.784063   59.943081
2       -1.938424   53.050835     2.517375   33.105122
3       -3.580352   50.836224     3.630866   32.023678
4       -3.392489   26.738789     0.536961   29.146694
...           ...         ...          ...         ...
9985    -5.625813   48.804092     1.818823   38.966969
9986   -11.960546   63.452255     0.428857   18.697033
9987     1.775686   48.582378    -0.299545   41.586990
9988     2.354765   24.843613     0.675824   12.787750
9989    -6.903252   39.485901    -3.412534   31.727489

[9990 rows x 57 columns]
```

In [22]:

```python
scaler = StandardScaler()
X = scaler.fit_transform(np.array(DATA.iloc[:, :-1], dtype = float))
```

In [23]:

```python
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.30)
```

In [24]:

```python
# Neural network
model = Sequential()
model.add(keras.layers.Dense(256, activation='relu', input_shape=(X_train.shape[1],)))
model.add(keras.layers.Dense(128, activation='relu'))
model.add(keras.layers.Dense(64, activation='relu'))
model.add(keras.layers.Dense(10, activation='softmax'))
model.compile(optimizer='adam',loss='sparse_categorical_crossentropy',metrics=['accuracy'])
```

In [25]:

```python
classifier = model.fit(X_train,y_train,epochs=200,batch_size=64)
```

```
Epoch 1/200
110/110 [==============================] - 1s 2ms/step - loss: 1.6143 - accuracy: 0.4354
Epoch 2/200
110/110 [==============================] - 0s 2ms/step - loss: 0.8102 - accuracy: 0.7185
Epoch 3/200
110/110 [==============================] - 0s 2ms/step - loss: 0.6165 - accuracy: 0.7923
Epoch 4/200
110/110 [==============================] - 0s 2ms/step - loss: 0.4554 - accuracy: 0.8553
Epoch 5/200
110/110 [==============================] - 0s 2ms/step - loss: 0.3733 - accuracy: 0.8862
Epoch 6/200
110/110 [==============================] - 0s 2ms/step - loss: 0.3117 - accuracy: 0.9054
Epoch 7/200
110/110 [==============================] - 0s 2ms/step - loss: 0.2584 - accuracy: 0.9252
Epoch 8/200
110/110 [==============================] - 0s 2ms/step - loss: 0.2028 - accuracy: 0.9453
Epoch 9/200
110/110 [==============================] - 0s 2ms/step - loss: 0.1702 - accuracy: 0.9529
Epoch 10/200
110/110 [==============================] - 0s 2ms/step - loss: 0.1336 - accuracy: 0.9624
Epoch 11/200
110/110 [==============================] - 0s 2ms/step - loss: 0.1116 - accuracy: 0.9707
Epoch 12/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0759 - accuracy: 0.9827
Epoch 13/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0814 - accuracy: 0.9780
Epoch 14/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0536 - accuracy: 0.9884
Epoch 15/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0584 - accuracy: 0.9858
Epoch 16/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0558 - accuracy: 0.9848
Epoch 17/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0422 - accuracy: 0.9910
Epoch 18/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0295 - accuracy: 0.9941
Epoch 19/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0180 - accuracy: 0.9971
Epoch 20/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0117 - accuracy: 0.9991
Epoch 21/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0209 - accuracy: 0.9969
Epoch 22/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0082 - accuracy: 0.9993
Epoch 23/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0221 - accuracy: 0.9942
Epoch 24/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0392 - accuracy: 0.9896
Epoch 25/200
110/110 [==============================] - 0s 2ms/step - loss: 0.1243 - accuracy: 0.9607
Epoch 26/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0713 - accuracy: 0.9738
Epoch 27/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0250 - accuracy: 0.9925
Epoch 28/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0188 - accuracy: 0.9948
Epoch 29/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0051 - accuracy: 0.9997
Epoch 30/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0099 - accuracy: 0.9983
Epoch 31/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0058 - accuracy: 0.9986
Epoch 32/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0046 - accuracy: 0.9987
Epoch 33/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0077 - accuracy: 0.9981
Epoch 34/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0057 - accuracy: 0.9988
Epoch 35/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0045 - accuracy: 0.9993
Epoch 36/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0045 - accuracy: 0.9994
Epoch 37/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0020 - accuracy: 0.9997
Epoch 38/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0060 - accuracy: 0.9989
Epoch 39/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0061 - accuracy: 0.9981
Epoch 40/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0035 - accuracy: 0.9995
Epoch 41/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0144 - accuracy: 0.9956
Epoch 42/200
110/110 [==============================] - 0s 2ms/step - loss: 0.2661 - accuracy: 0.9305
Epoch 43/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0900 - accuracy: 0.9716
Epoch 44/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0217 - accuracy: 0.9930
Epoch 45/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0072 - accuracy: 0.9985
Epoch 46/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0030 - accuracy: 0.9998
Epoch 47/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0240 - accuracy: 0.9949
Epoch 48/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0029 - accuracy: 0.9998
Epoch 49/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0052 - accuracy: 0.9987
Epoch 50/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9998
Epoch 51/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0028 - accuracy: 0.9992
Epoch 52/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0027 - accuracy: 0.9992
Epoch 53/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0021 - accuracy: 0.9995
Epoch 54/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0053 - accuracy: 0.9990
Epoch 55/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0043 - accuracy: 0.9993
Epoch 56/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0053 - accuracy: 0.9993
Epoch 57/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0030 - accuracy: 0.9992
Epoch 58/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9996
Epoch 59/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0012 - accuracy: 0.9998
Epoch 60/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0050 - accuracy: 0.9986
Epoch 61/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0038 - accuracy: 0.9993
Epoch 62/200
110/110 [==============================] - 0s 2ms/step - loss: 0.1195 - accuracy: 0.9645: 0s - loss: 0.1061 - accuracy: 0.96
Epoch 63/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0712 - accuracy: 0.9762
Epoch 64/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0311 - accuracy: 0.9924
Epoch 65/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0092 - accuracy: 0.9988
Epoch 66/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0044 - accuracy: 0.9996
Epoch 67/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0039 - accuracy: 0.9992
Epoch 68/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9999
Epoch 69/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0016 - accuracy: 0.9996
Epoch 70/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0029 - accuracy: 0.9994
Epoch 71/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0025 - accuracy: 0.9995
Epoch 72/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 0.9997
Epoch 73/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0018 - accuracy: 0.9995
Epoch 74/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0029 - accuracy: 0.9989
Epoch 75/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0019 - accuracy: 0.9996
Epoch 76/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0030 - accuracy: 0.9994
Epoch 77/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0022 - accuracy: 0.9996
Epoch 78/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0042 - accuracy: 0.9991
Epoch 79/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0035 - accuracy: 0.9985
Epoch 80/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0459 - accuracy: 0.9883
Epoch 81/200
110/110 [==============================] - 0s 3ms/step - loss: 0.1243 - accuracy: 0.9580
Epoch 82/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0230 - accuracy: 0.9928
Epoch 83/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0097 - accuracy: 0.9970
Epoch 84/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0043 - accuracy: 0.9988
Epoch 85/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0028 - accuracy: 0.9992
Epoch 86/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9996
Epoch 87/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0020 - accuracy: 0.9996
Epoch 88/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9996
Epoch 89/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0023 - accuracy: 0.9991
Epoch 90/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0025 - accuracy: 0.9994
Epoch 91/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9996
Epoch 92/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0020 - accuracy: 0.9995
Epoch 93/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0042 - accuracy: 0.9987
Epoch 94/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0144 - accuracy: 0.9966
Epoch 95/200
110/110 [==============================] - 0s 2ms/step - loss: 0.1377 - accuracy: 0.9570
Epoch 96/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0286 - accuracy: 0.9915
Epoch 97/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0115 - accuracy: 0.9959
Epoch 98/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0025 - accuracy: 0.9996
Epoch 99/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0030 - accuracy: 0.9991
Epoch 100/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0019 - accuracy: 0.9992
Epoch 101/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9996
Epoch 102/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9995
Epoch 103/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 0.9997
Epoch 104/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0013 - accuracy: 0.9994
Epoch 105/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0032 - accuracy: 0.9989
Epoch 106/200
110/110 [==============================] - 0s 2ms/step - loss: 9.7239e-04 - accuracy: 0.9995
Epoch 107/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9991
Epoch 108/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9990
Epoch 109/200
110/110 [==============================] - 0s 2ms/step - loss: 7.6697e-04 - accuracy: 0.9997
Epoch 110/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 0.9997
Epoch 111/200
110/110 [==============================] - 0s 2ms/step - loss: 7.3837e-04 - accuracy: 0.9998
Epoch 112/200
110/110 [==============================] - 0s 2ms/step - loss: 5.9068e-04 - accuracy: 0.9998
Epoch 113/200
110/110 [==============================] - 0s 2ms/step - loss: 9.8727e-04 - accuracy: 0.9996
Epoch 114/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9994
Epoch 115/200
110/110 [==============================] - 0s 2ms/step - loss: 8.8578e-04 - accuracy: 0.9998
Epoch 116/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0016 - accuracy: 0.9994
Epoch 117/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9997
Epoch 118/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9995
Epoch 119/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9998
Epoch 120/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9994
Epoch 121/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0012 - accuracy: 0.9993
Epoch 122/200
110/110 [==============================] - 0s 2ms/step - loss: 8.9677e-04 - accuracy: 0.9997
Epoch 123/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0018 - accuracy: 0.9987
Epoch 124/200
110/110 [==============================] - 0s 2ms/step - loss: 9.1929e-04 - accuracy: 0.9997
Epoch 125/200
110/110 [==============================] - 0s 2ms/step - loss: 9.4052e-04 - accuracy: 0.9997
Epoch 126/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0839 - accuracy: 0.9788
Epoch 127/200
110/110 [==============================] - 0s 2ms/step - loss: 0.1203 - accuracy: 0.9617
Epoch 128/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0240 - accuracy: 0.9923
Epoch 129/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0094 - accuracy: 0.9971
Epoch 130/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0045 - accuracy: 0.9988
Epoch 131/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0016 - accuracy: 0.9996
Epoch 132/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0023 - accuracy: 0.9989
Epoch 133/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9994
Epoch 134/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 0.9993
Epoch 135/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0012 - accuracy: 0.9994
Epoch 136/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 0.9997
Epoch 137/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0017 - accuracy: 0.9988
Epoch 138/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0016 - accuracy: 0.9994
Epoch 139/200
110/110 [==============================] - 0s 2ms/step - loss: 6.5278e-04 - accuracy: 0.9998
Epoch 140/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 0.9994
Epoch 141/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0024 - accuracy: 0.9981
Epoch 142/200
110/110 [==============================] - 0s 2ms/step - loss: 5.6364e-04 - accuracy: 0.9999
Epoch 143/200
110/110 [==============================] - 0s 2ms/step - loss: 4.0752e-04 - accuracy: 0.9999
Epoch 144/200
110/110 [==============================] - 0s 2ms/step - loss: 9.7102e-04 - accuracy: 0.9992
Epoch 145/200
110/110 [==============================] - 0s 3ms/step - loss: 8.6562e-04 - accuracy: 0.9997
Epoch 146/200
110/110 [==============================] - 0s 2ms/step - loss: 7.5589e-04 - accuracy: 0.9994
Epoch 147/200
110/110 [==============================] - 0s 2ms/step - loss: 4.5887e-04 - accuracy: 0.9999
Epoch 148/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0034 - accuracy: 0.9989
Epoch 149/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0672 - accuracy: 0.9805
Epoch 150/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0749 - accuracy: 0.9761
Epoch 151/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0201 - accuracy: 0.9948
Epoch 152/200
110/110 [==============================] - 0s 3ms/step - loss: 0.0056 - accuracy: 0.9979
Epoch 153/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9996
Epoch 154/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0020 - accuracy: 0.9988 ETA: 0s - loss: 0.0020 - accuracy: 0.
Epoch 155/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 0.9994
Epoch 156/200
110/110 [==============================] - 0s 2ms/step - loss: 6.8977e-04 - accuracy: 0.9997
Epoch 157/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 0.9995
Epoch 158/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9993
Epoch 159/200
110/110 [==============================] - 0s 2ms/step - loss: 6.4820e-04 - accuracy: 0.9999
Epoch 160/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 0.9992
Epoch 161/200
110/110 [==============================] - 0s 2ms/step - loss: 5.1823e-04 - accuracy: 0.9999
Epoch 162/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0013 - accuracy: 0.9995
Epoch 163/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0016 - accuracy: 0.9988
Epoch 164/200
110/110 [==============================] - 0s 2ms/step - loss: 8.8629e-04 - accuracy: 0.9997
Epoch 165/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 0.9992
Epoch 166/200
110/110 [==============================] - 0s 2ms/step - loss: 8.3241e-04 - accuracy: 0.9994
Epoch 167/200
110/110 [==============================] - 0s 2ms/step - loss: 7.9564e-04 - accuracy: 0.9994
Epoch 168/200
110/110 [==============================] - 0s 2ms/step - loss: 6.6370e-04 - accuracy: 0.9998
Epoch 169/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0024 - accuracy: 0.9987
Epoch 170/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0012 - accuracy: 0.9991
Epoch 171/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 0.9994
Epoch 172/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9995
Epoch 173/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9994
Epoch 174/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9995
Epoch 175/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0012 - accuracy: 0.9995
Epoch 176/200
110/110 [==============================] - 0s 2ms/step - loss: 6.5449e-04 - accuracy: 0.9997
Epoch 177/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0012 - accuracy: 0.9991
Epoch 178/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0013 - accuracy: 0.9995
Epoch 179/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9984
Epoch 180/200
110/110 [==============================] - 0s 2ms/step - loss: 4.3756e-04 - accuracy: 0.9996
Epoch 181/200
110/110 [==============================] - 0s 2ms/step - loss: 6.9744e-04 - accuracy: 1.0000
Epoch 182/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0862 - accuracy: 0.9772
Epoch 183/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0789 - accuracy: 0.9738
Epoch 184/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0121 - accuracy: 0.9967
Epoch 185/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0086 - accuracy: 0.9973
Epoch 186/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0015 - accuracy: 0.9995
Epoch 187/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 0.9997
Epoch 188/200
110/110 [==============================] - 0s 2ms/step - loss: 7.0222e-04 - accuracy: 0.9998
Epoch 189/200
110/110 [==============================] - 0s 2ms/step - loss: 8.1552e-04 - accuracy: 0.9998
Epoch 190/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0013 - accuracy: 0.9992
Epoch 191/200
110/110 [==============================] - 0s 2ms/step - loss: 0.0010 - accuracy: 0.9993
Epoch 192/200
110/110 [==============================] - 0s 2ms/step - loss: 6.4529e-04 - accuracy: 0.9999
Epoch 193/200
110/110 [==============================] - 0s 2ms/step - loss: 9.2291e-04 - accuracy: 0.9997: 0s - loss: 8.0366e-04 - accuracy:
Epoch 194/200
110/110 [==============================] - 0s 2ms/step - loss: 6.4998e-04 - accuracy: 0.9995
Epoch 195/200
110/110 [==============================] - 0s 2ms/step - loss: 8.0527e-04 - accuracy: 0.9996
Epoch 196/200
110/110 [==============================] - 0s 2ms/step - loss: 7.5003e-04 - accuracy: 0.9998
Epoch 197/200
110/110 [==============================] - 0s 2ms/step - loss: 7.4513e-04 - accuracy: 0.9997
Epoch 198/200
110/110 [==============================] - 0s 2ms/step - loss: 9.1771e-04 - accuracy: 0.9994
Epoch 199/200
110/110 [==============================] - 0s 2ms/step - loss: 5.7802e-04 - accuracy: 0.9997
Epoch 200/200
110/110 [==============================] - 0s 2ms/step - loss: 9.4144e-04 - accuracy: 0.9994
```

In [26]:

```python
test_loss, test_acc  = model.evaluate(X_test, y_test, batch_size=64)
```

```
47/47 [==============================] - 0s 2ms/step - loss: 0.6035 - accuracy: 0.9036
```

Observation: Accuracy on the training dataset is 0.9994 and on the test dataset is 0.9036!