UrbanSoundClassification

March 27, 2025

[1]:
```
import os
import librosa
import numpy as np
import pandas as pd
import tensorflow as tf
from tqdm import tqdm
```

[2]:
```
df = pd.read_csv("UrbanSound8K/metadata/UrbanSound8K.csv");
print(df.head());
```

```
      slice_file_name    fsID  start        end  salience  fold  classID  \
0    100032-3-0-0.wav  100032    0.0   0.317551         1     5        3
1  100263-2-0-117.wav  100263   58.5  62.500000         1     5        2
2  100263-2-0-121.wav  100263   60.5  64.500000         1     5        2
3  100263-2-0-126.wav  100263   63.0  67.000000         1     5        2
4  100263-2-0-137.wav  100263   68.5  72.500000         1     5        2

              class
0         dog_bark
1  children_playing
2  children_playing
3  children_playing
4  children_playing
```

[3]:
```
print(df.shape);
```

```
(8732, 8)
```

[4]:
```
def extractfeatures(filepath):
    y,sr = librosa.load(filepath,sr = None);
    mfcc = librosa.feature.mfcc(y = y,sr = sr,n_mfcc = 40);
    return np.mean(mfcc.T,axis = 0);
```

[5]:
```
x = [];
y = [];
for _,row in tqdm(df.iterrows(),total = len(df)):
    filepath = f"UrbanSound8K/audio/fold{row['fold']}/{row['slice_file_name']}";
    if os.path.exists(filepath):
        features = extractfeatures(filepath);
```

```
        x.append(features);
        y.append(row["classID"]);
x = np.array(x);
y = np.array(y);
print(x.shape,y.shape);
```

```
/opt/anaconda3/lib/python3.11/site-packages/librosa/feature/spectral.py:2148:
UserWarning: Empty filters detected in mel frequency basis. Some channels will
produce empty responses. Try increasing your sampling rate (and fmax) or
reducing n_mels.
  mel_basis = filters.mel(sr=sr, n_fft=n_fft, **kwargs)
100%|                                | 8732/8732
[01:20<00:00, 108.74it/s]
```

```
(8732, 40) (8732,)
```

[6]:
```
from sklearn.model_selection import train_test_split
xtrain,xtest,ytrain,ytest = train_test_split(x,y,test_size = 0.2,random_state =␣
↪0);
print(xtrain.shape,ytrain.shape,xtest.shape,ytest.shape);
```

```
(6985, 40) (6985,) (1747, 40) (1747,)
```

[7]:
```
arr = list(set(ytrain));
print(arr);
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

[8]:
```
from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler(feature_range = (0,1));
xtrain = scaler.fit_transform(xtrain);
xtest = scaler.transform(xtest);
```

[9]:
```
xtrain = xtrain.reshape(xtrain.shape[0],xtrain.shape[1],1);
xtest = xtest.reshape(xtest.shape[0],xtest.shape[1],1);
print(xtrain.shape,xtest.shape);
```

```
(6985, 40, 1) (1747, 40, 1)
```

[10]:
```
ytrain = tf.keras.utils.to_categorical(ytrain);
ytest = tf.keras.utils.to_categorical(ytest);
print(ytrain.shape,ytest.shape);
```

```
(6985, 10) (1747, 10)
```

[11]:
```
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Conv1D,MaxPooling1D,Flatten,Dense,Dropout
model = Sequential();
```

[12]:
```
model.add(Conv1D(64,kernel_size = 5,activation = "relu",input_shape = (xtrain.
↪shape[1],xtrain.shape[2])));
model.add(MaxPooling1D(2));
model.add(Conv1D(64,kernel_size = 5,activation = "relu"));
model.add(MaxPooling1D(2));
model.add(Flatten());
model.add(Dense(256,activation = "relu"));
model.add(Dropout(0.2));
model.add(Dense(128,activation = "relu"));
model.add(Dropout(0.2));
model.add(Dense(64,activation = "relu"));
model.add(Dense(10,activation = "softmax"));
```

```
/opt/anaconda3/lib/python3.11/site-
packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not
pass an `input_shape`/`input_dim` argument to a layer. When using Sequential
models, prefer using an `Input(shape)` object as the first layer in the model
instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

[13]:
```
model.compile(optimizer = "adam",loss = "categorical_crossentropy",
metrics = ["accuracy",tf.keras.metrics.Precision(),tf.keras.metrics.Recall(),tf.
↪keras.metrics.AUC()]);
```

[14]:
```
history = model.fit(xtrain,ytrain,epochs = 100,batch_size = 128,validation_data␣
↪= (xtest,ytest));
```

```
Epoch 1/100
55/55             1s 7ms/step -
accuracy: 0.1199 - auc: 0.5616 - loss: 2.2747 - precision: 0.0000e+00 - recall:
0.0000e+00 - val_accuracy: 0.1322 - val_auc: 0.6009 - val_loss: 2.2498 -
val_precision: 0.0000e+00 - val_recall: 0.0000e+00
Epoch 2/100
55/55             0s 5ms/step -
accuracy: 0.1761 - auc: 0.6308 - loss: 2.2105 - precision: 0.3763 - recall:
7.7530e-04 - val_accuracy: 0.2719 - val_auc: 0.7142 - val_loss: 2.0502 -
val_precision: 1.0000 - val_recall: 0.0080
Epoch 3/100
55/55             0s 5ms/step -
accuracy: 0.2923 - auc: 0.7527 - loss: 1.9486 - precision: 0.7724 - recall:
0.0337 - val_accuracy: 0.3921 - val_auc: 0.8195 - val_loss: 1.7162 -
val_precision: 0.7252 - val_recall: 0.1254
Epoch 4/100
55/55             0s 5ms/step -
accuracy: 0.4105 - auc: 0.8348 - loss: 1.6618 - precision: 0.7452 - recall:
0.1266 - val_accuracy: 0.4665 - val_auc: 0.8688 - val_loss: 1.4950 -
val_precision: 0.7451 - val_recall: 0.2192
Epoch 5/100
```

```
55/55            0s 5ms/step -
accuracy: 0.4841 - auc: 0.8749 - loss: 1.4709 - precision: 0.7663 - recall:
0.2232 - val_accuracy: 0.5369 - val_auc: 0.8972 - val_loss: 1.3359 -
val_precision: 0.7607 - val_recall: 0.3165
Epoch 6/100
55/55            0s 5ms/step -
accuracy: 0.5374 - auc: 0.8996 - loss: 1.3312 - precision: 0.7639 - recall:
0.2950 - val_accuracy: 0.5930 - val_auc: 0.9153 - val_loss: 1.2191 -
val_precision: 0.7868 - val_recall: 0.3612
Epoch 7/100
55/55            0s 5ms/step -
accuracy: 0.5819 - auc: 0.9206 - loss: 1.1894 - precision: 0.7852 - recall:
0.3707 - val_accuracy: 0.6193 - val_auc: 0.9304 - val_loss: 1.1095 -
val_precision: 0.8157 - val_recall: 0.4333
Epoch 8/100
55/55            0s 5ms/step -
accuracy: 0.6244 - auc: 0.9355 - loss: 1.0761 - precision: 0.7925 - recall:
0.4415 - val_accuracy: 0.6800 - val_auc: 0.9431 - val_loss: 1.0066 -
val_precision: 0.8422 - val_recall: 0.5009
Epoch 9/100
55/55            0s 6ms/step -
accuracy: 0.6643 - auc: 0.9457 - loss: 0.9848 - precision: 0.8113 - recall:
0.5051 - val_accuracy: 0.6886 - val_auc: 0.9480 - val_loss: 0.9495 -
val_precision: 0.7992 - val_recall: 0.5673
Epoch 10/100
55/55            0s 6ms/step -
accuracy: 0.6911 - auc: 0.9526 - loss: 0.9157 - precision: 0.8165 - recall:
0.5637 - val_accuracy: 0.7195 - val_auc: 0.9562 - val_loss: 0.8663 -
val_precision: 0.8112 - val_recall: 0.6245
Epoch 11/100
55/55            0s 5ms/step -
accuracy: 0.7174 - auc: 0.9607 - loss: 0.8286 - precision: 0.8252 - recall:
0.6063 - val_accuracy: 0.7212 - val_auc: 0.9563 - val_loss: 0.8604 -
val_precision: 0.8089 - val_recall: 0.6348
Epoch 12/100
55/55            0s 6ms/step -
accuracy: 0.7289 - auc: 0.9638 - loss: 0.8021 - precision: 0.8325 - recall:
0.6220 - val_accuracy: 0.7418 - val_auc: 0.9605 - val_loss: 0.8077 -
val_precision: 0.8252 - val_recall: 0.6623
Epoch 13/100
55/55            0s 5ms/step -
accuracy: 0.7529 - auc: 0.9696 - loss: 0.7257 - precision: 0.8410 - recall:
0.6586 - val_accuracy: 0.7705 - val_auc: 0.9705 - val_loss: 0.7060 -
val_precision: 0.8605 - val_recall: 0.6955
Epoch 14/100
55/55            0s 6ms/step -
accuracy: 0.7744 - auc: 0.9749 - loss: 0.6662 - precision: 0.8561 - recall:
0.6906 - val_accuracy: 0.7894 - val_auc: 0.9732 - val_loss: 0.6600 -
```

```
val_precision: 0.8557 - val_recall: 0.7230
Epoch 15/100
55/55            0s 6ms/step -
accuracy: 0.7921 - auc: 0.9791 - loss: 0.6033 - precision: 0.8684 - recall:
0.7241 - val_accuracy: 0.7831 - val_auc: 0.9721 - val_loss: 0.6812 -
val_precision: 0.8605 - val_recall: 0.7029
Epoch 16/100
55/55            0s 6ms/step -
accuracy: 0.7957 - auc: 0.9787 - loss: 0.6071 - precision: 0.8717 - recall:
0.7202 - val_accuracy: 0.8077 - val_auc: 0.9753 - val_loss: 0.6131 -
val_precision: 0.8672 - val_recall: 0.7550
Epoch 17/100
55/55            0s 6ms/step -
accuracy: 0.8190 - auc: 0.9834 - loss: 0.5330 - precision: 0.8826 - recall:
0.7632 - val_accuracy: 0.8157 - val_auc: 0.9780 - val_loss: 0.5835 -
val_precision: 0.8713 - val_recall: 0.7710
Epoch 18/100
55/55            0s 5ms/step -
accuracy: 0.8173 - auc: 0.9826 - loss: 0.5339 - precision: 0.8789 - recall:
0.7637 - val_accuracy: 0.8042 - val_auc: 0.9771 - val_loss: 0.6037 -
val_precision: 0.8639 - val_recall: 0.7521
Epoch 19/100
55/55            0s 5ms/step -
accuracy: 0.8262 - auc: 0.9835 - loss: 0.5219 - precision: 0.8856 - recall:
0.7648 - val_accuracy: 0.8260 - val_auc: 0.9803 - val_loss: 0.5519 -
val_precision: 0.8797 - val_recall: 0.7785
Epoch 20/100
55/55            0s 6ms/step -
accuracy: 0.8469 - auc: 0.9882 - loss: 0.4408 - precision: 0.8991 - recall:
0.8049 - val_accuracy: 0.8380 - val_auc: 0.9804 - val_loss: 0.5462 -
val_precision: 0.8820 - val_recall: 0.7745
Epoch 21/100
55/55            0s 6ms/step -
accuracy: 0.8441 - auc: 0.9886 - loss: 0.4449 - precision: 0.8996 - recall:
0.7960 - val_accuracy: 0.8369 - val_auc: 0.9822 - val_loss: 0.5195 -
val_precision: 0.8854 - val_recall: 0.7916
Epoch 22/100
55/55            0s 5ms/step -
accuracy: 0.8563 - auc: 0.9895 - loss: 0.4198 - precision: 0.8977 - recall:
0.8123 - val_accuracy: 0.8414 - val_auc: 0.9815 - val_loss: 0.5183 -
val_precision: 0.8820 - val_recall: 0.8002
Epoch 23/100
55/55            0s 5ms/step -
accuracy: 0.8621 - auc: 0.9904 - loss: 0.3969 - precision: 0.9117 - recall:
0.8217 - val_accuracy: 0.8351 - val_auc: 0.9824 - val_loss: 0.5095 -
val_precision: 0.8786 - val_recall: 0.7997
Epoch 24/100
55/55            0s 5ms/step -
```

```
accuracy: 0.8689 - auc: 0.9909 - loss: 0.3856 - precision: 0.9072 - recall:
0.8304 - val_accuracy: 0.8374 - val_auc: 0.9826 - val_loss: 0.5137 -
val_precision: 0.8745 - val_recall: 0.8054
Epoch 25/100
55/55            0s 5ms/step -
accuracy: 0.8723 - auc: 0.9912 - loss: 0.3783 - precision: 0.9135 - recall:
0.8352 - val_accuracy: 0.8535 - val_auc: 0.9828 - val_loss: 0.4844 -
val_precision: 0.8859 - val_recall: 0.8226
Epoch 26/100
55/55            0s 5ms/step -
accuracy: 0.8861 - auc: 0.9929 - loss: 0.3373 - precision: 0.9194 - recall:
0.8531 - val_accuracy: 0.8546 - val_auc: 0.9837 - val_loss: 0.4823 -
val_precision: 0.8851 - val_recall: 0.8248
Epoch 27/100
55/55            0s 5ms/step -
accuracy: 0.8861 - auc: 0.9928 - loss: 0.3298 - precision: 0.9092 - recall:
0.8575 - val_accuracy: 0.8546 - val_auc: 0.9837 - val_loss: 0.4683 -
val_precision: 0.8871 - val_recall: 0.8185
Epoch 28/100
55/55            0s 5ms/step -
accuracy: 0.8960 - auc: 0.9941 - loss: 0.3065 - precision: 0.9227 - recall:
0.8678 - val_accuracy: 0.8626 - val_auc: 0.9854 - val_loss: 0.4574 -
val_precision: 0.8903 - val_recall: 0.8266
Epoch 29/100
55/55            0s 5ms/step -
accuracy: 0.9064 - auc: 0.9952 - loss: 0.2790 - precision: 0.9300 - recall:
0.8822 - val_accuracy: 0.8678 - val_auc: 0.9869 - val_loss: 0.4431 -
val_precision: 0.8934 - val_recall: 0.8300
Epoch 30/100
55/55            0s 5ms/step -
accuracy: 0.8987 - auc: 0.9949 - loss: 0.2913 - precision: 0.9264 - recall:
0.8678 - val_accuracy: 0.8420 - val_auc: 0.9835 - val_loss: 0.4974 -
val_precision: 0.8728 - val_recall: 0.8248
Epoch 31/100
55/55            0s 5ms/step -
accuracy: 0.8999 - auc: 0.9941 - loss: 0.2893 - precision: 0.9222 - recall:
0.8730 - val_accuracy: 0.8672 - val_auc: 0.9866 - val_loss: 0.4392 -
val_precision: 0.8908 - val_recall: 0.8454
Epoch 32/100
55/55            0s 5ms/step -
accuracy: 0.9116 - auc: 0.9952 - loss: 0.2551 - precision: 0.9344 - recall:
0.8911 - val_accuracy: 0.8769 - val_auc: 0.9862 - val_loss: 0.4281 -
val_precision: 0.8974 - val_recall: 0.8512
Epoch 33/100
55/55            0s 5ms/step -
accuracy: 0.9107 - auc: 0.9956 - loss: 0.2604 - precision: 0.9324 - recall:
0.8912 - val_accuracy: 0.8764 - val_auc: 0.9863 - val_loss: 0.4294 -
val_precision: 0.8983 - val_recall: 0.8540
```

```
Epoch 34/100
55/55            0s 5ms/step -
accuracy: 0.9105 - auc: 0.9958 - loss: 0.2551 - precision: 0.9332 - recall:
0.8930 - val_accuracy: 0.8695 - val_auc: 0.9872 - val_loss: 0.4315 -
val_precision: 0.8906 - val_recall: 0.8483
Epoch 35/100
55/55            0s 5ms/step -
accuracy: 0.9273 - auc: 0.9970 - loss: 0.2097 - precision: 0.9438 - recall:
0.9131 - val_accuracy: 0.8746 - val_auc: 0.9871 - val_loss: 0.4157 -
val_precision: 0.9041 - val_recall: 0.8529
Epoch 36/100
55/55            0s 5ms/step -
accuracy: 0.9213 - auc: 0.9966 - loss: 0.2320 - precision: 0.9422 - recall:
0.9024 - val_accuracy: 0.8884 - val_auc: 0.9874 - val_loss: 0.4043 -
val_precision: 0.9096 - val_recall: 0.8643
Epoch 37/100
55/55            0s 5ms/step -
accuracy: 0.9331 - auc: 0.9975 - loss: 0.1984 - precision: 0.9464 - recall:
0.9164 - val_accuracy: 0.8695 - val_auc: 0.9837 - val_loss: 0.4557 -
val_precision: 0.8878 - val_recall: 0.8563
Epoch 38/100
55/55            0s 5ms/step -
accuracy: 0.9246 - auc: 0.9972 - loss: 0.2089 - precision: 0.9377 - recall:
0.9087 - val_accuracy: 0.8907 - val_auc: 0.9883 - val_loss: 0.3951 -
val_precision: 0.9097 - val_recall: 0.8764
Epoch 39/100
55/55            0s 5ms/step -
accuracy: 0.9379 - auc: 0.9980 - loss: 0.1827 - precision: 0.9518 - recall:
0.9263 - val_accuracy: 0.8861 - val_auc: 0.9873 - val_loss: 0.4084 -
val_precision: 0.9018 - val_recall: 0.8729
Epoch 40/100
55/55            0s 5ms/step -
accuracy: 0.9325 - auc: 0.9973 - loss: 0.1960 - precision: 0.9474 - recall:
0.9173 - val_accuracy: 0.8804 - val_auc: 0.9879 - val_loss: 0.4166 -
val_precision: 0.8940 - val_recall: 0.8643
Epoch 41/100
55/55            0s 5ms/step -
accuracy: 0.9361 - auc: 0.9978 - loss: 0.1867 - precision: 0.9513 - recall:
0.9235 - val_accuracy: 0.8827 - val_auc: 0.9848 - val_loss: 0.4562 -
val_precision: 0.8969 - val_recall: 0.8712
Epoch 42/100
55/55            0s 5ms/step -
accuracy: 0.9342 - auc: 0.9978 - loss: 0.1855 - precision: 0.9490 - recall:
0.9213 - val_accuracy: 0.8981 - val_auc: 0.9872 - val_loss: 0.4027 -
val_precision: 0.9087 - val_recall: 0.8827
Epoch 43/100
55/55            0s 5ms/step -
accuracy: 0.9428 - auc: 0.9982 - loss: 0.1629 - precision: 0.9551 - recall:
```

```
0.9321 - val_accuracy: 0.8941 - val_auc: 0.9872 - val_loss: 0.4021 -
val_precision: 0.9056 - val_recall: 0.8838
Epoch 44/100
55/55            0s 6ms/step -
accuracy: 0.9506 - auc: 0.9984 - loss: 0.1438 - precision: 0.9582 - recall:
0.9412 - val_accuracy: 0.8930 - val_auc: 0.9877 - val_loss: 0.3885 -
val_precision: 0.9075 - val_recall: 0.8821
Epoch 45/100
55/55            0s 6ms/step -
accuracy: 0.9528 - auc: 0.9987 - loss: 0.1414 - precision: 0.9625 - recall:
0.9435 - val_accuracy: 0.8890 - val_auc: 0.9874 - val_loss: 0.4236 -
val_precision: 0.8985 - val_recall: 0.8769
Epoch 46/100
55/55            0s 5ms/step -
accuracy: 0.9497 - auc: 0.9983 - loss: 0.1485 - precision: 0.9594 - recall:
0.9396 - val_accuracy: 0.8872 - val_auc: 0.9852 - val_loss: 0.4486 -
val_precision: 0.8988 - val_recall: 0.8798
Epoch 47/100
55/55            0s 5ms/step -
accuracy: 0.9476 - auc: 0.9987 - loss: 0.1497 - precision: 0.9571 - recall:
0.9387 - val_accuracy: 0.8849 - val_auc: 0.9864 - val_loss: 0.4287 -
val_precision: 0.8991 - val_recall: 0.8718
Epoch 48/100
55/55            0s 5ms/step -
accuracy: 0.9523 - auc: 0.9987 - loss: 0.1324 - precision: 0.9608 - recall:
0.9450 - val_accuracy: 0.8884 - val_auc: 0.9862 - val_loss: 0.4370 -
val_precision: 0.9012 - val_recall: 0.8769
Epoch 49/100
55/55            0s 5ms/step -
accuracy: 0.9483 - auc: 0.9988 - loss: 0.1367 - precision: 0.9551 - recall:
0.9402 - val_accuracy: 0.8970 - val_auc: 0.9865 - val_loss: 0.4292 -
val_precision: 0.9077 - val_recall: 0.8895
Epoch 50/100
55/55            0s 5ms/step -
accuracy: 0.9538 - auc: 0.9990 - loss: 0.1286 - precision: 0.9620 - recall:
0.9473 - val_accuracy: 0.9004 - val_auc: 0.9867 - val_loss: 0.4018 -
val_precision: 0.9084 - val_recall: 0.8912
Epoch 51/100
55/55            0s 5ms/step -
accuracy: 0.9520 - auc: 0.9986 - loss: 0.1238 - precision: 0.9614 - recall:
0.9440 - val_accuracy: 0.9044 - val_auc: 0.9873 - val_loss: 0.4050 -
val_precision: 0.9130 - val_recall: 0.8947
Epoch 52/100
55/55            0s 5ms/step -
accuracy: 0.9593 - auc: 0.9988 - loss: 0.1168 - precision: 0.9657 - recall:
0.9528 - val_accuracy: 0.9038 - val_auc: 0.9861 - val_loss: 0.4348 -
val_precision: 0.9109 - val_recall: 0.8952
Epoch 53/100
```

```
55/55            0s 5ms/step -
accuracy: 0.9617 - auc: 0.9990 - loss: 0.1088 - precision: 0.9688 - recall:
0.9560 - val_accuracy: 0.9021 - val_auc: 0.9855 - val_loss: 0.4484 -
val_precision: 0.9126 - val_recall: 0.8970
Epoch 54/100
55/55            0s 6ms/step -
accuracy: 0.9662 - auc: 0.9991 - loss: 0.1023 - precision: 0.9713 - recall:
0.9602 - val_accuracy: 0.8855 - val_auc: 0.9842 - val_loss: 0.4858 -
val_precision: 0.8949 - val_recall: 0.8775
Epoch 55/100
55/55            0s 5ms/step -
accuracy: 0.9549 - auc: 0.9988 - loss: 0.1205 - precision: 0.9627 - recall:
0.9474 - val_accuracy: 0.9038 - val_auc: 0.9854 - val_loss: 0.4503 -
val_precision: 0.9106 - val_recall: 0.8981
Epoch 56/100
55/55            0s 6ms/step -
accuracy: 0.9632 - auc: 0.9990 - loss: 0.1103 - precision: 0.9695 - recall:
0.9559 - val_accuracy: 0.8987 - val_auc: 0.9853 - val_loss: 0.4390 -
val_precision: 0.9085 - val_recall: 0.8924
Epoch 57/100
55/55            0s 6ms/step -
accuracy: 0.9636 - auc: 0.9994 - loss: 0.1004 - precision: 0.9683 - recall:
0.9568 - val_accuracy: 0.8987 - val_auc: 0.9853 - val_loss: 0.4474 -
val_precision: 0.9100 - val_recall: 0.8918
Epoch 58/100
55/55            0s 6ms/step -
accuracy: 0.9665 - auc: 0.9989 - loss: 0.1020 - precision: 0.9706 - recall:
0.9624 - val_accuracy: 0.9050 - val_auc: 0.9867 - val_loss: 0.4205 -
val_precision: 0.9157 - val_recall: 0.8958
Epoch 59/100
55/55            0s 6ms/step -
accuracy: 0.9691 - auc: 0.9991 - loss: 0.1012 - precision: 0.9739 - recall:
0.9640 - val_accuracy: 0.9038 - val_auc: 0.9859 - val_loss: 0.4384 -
val_precision: 0.9134 - val_recall: 0.8998
Epoch 60/100
55/55            0s 6ms/step -
accuracy: 0.9690 - auc: 0.9995 - loss: 0.0904 - precision: 0.9730 - recall:
0.9638 - val_accuracy: 0.8975 - val_auc: 0.9852 - val_loss: 0.4663 -
val_precision: 0.9052 - val_recall: 0.8912
Epoch 61/100
55/55            0s 6ms/step -
accuracy: 0.9670 - auc: 0.9992 - loss: 0.0914 - precision: 0.9727 - recall:
0.9647 - val_accuracy: 0.9147 - val_auc: 0.9863 - val_loss: 0.4196 -
val_precision: 0.9238 - val_recall: 0.9090
Epoch 62/100
55/55            0s 6ms/step -
accuracy: 0.9709 - auc: 0.9995 - loss: 0.0835 - precision: 0.9730 - recall:
0.9682 - val_accuracy: 0.8918 - val_auc: 0.9859 - val_loss: 0.4642 -
```

```
val_precision: 0.8998 - val_recall: 0.8844
Epoch 63/100
55/55            0s 5ms/step -
accuracy: 0.9689 - auc: 0.9995 - loss: 0.0828 - precision: 0.9729 - recall:
0.9636 - val_accuracy: 0.9136 - val_auc: 0.9854 - val_loss: 0.4261 -
val_precision: 0.9242 - val_recall: 0.9073
Epoch 64/100
55/55            0s 5ms/step -
accuracy: 0.9735 - auc: 0.9996 - loss: 0.0815 - precision: 0.9763 - recall:
0.9688 - val_accuracy: 0.9015 - val_auc: 0.9854 - val_loss: 0.4777 -
val_precision: 0.9091 - val_recall: 0.8987
Epoch 65/100
55/55            0s 6ms/step -
accuracy: 0.9747 - auc: 0.9994 - loss: 0.0773 - precision: 0.9778 - recall:
0.9701 - val_accuracy: 0.9038 - val_auc: 0.9825 - val_loss: 0.4763 -
val_precision: 0.9080 - val_recall: 0.8981
Epoch 66/100
55/55            0s 6ms/step -
accuracy: 0.9680 - auc: 0.9990 - loss: 0.1008 - precision: 0.9719 - recall:
0.9627 - val_accuracy: 0.9010 - val_auc: 0.9853 - val_loss: 0.4530 -
val_precision: 0.9058 - val_recall: 0.8970
Epoch 67/100
55/55            0s 6ms/step -
accuracy: 0.9770 - auc: 0.9995 - loss: 0.0700 - precision: 0.9802 - recall:
0.9744 - val_accuracy: 0.9084 - val_auc: 0.9847 - val_loss: 0.4487 -
val_precision: 0.9155 - val_recall: 0.9050
Epoch 68/100
55/55            0s 6ms/step -
accuracy: 0.9758 - auc: 0.9995 - loss: 0.0705 - precision: 0.9781 - recall:
0.9725 - val_accuracy: 0.8998 - val_auc: 0.9819 - val_loss: 0.5027 -
val_precision: 0.9095 - val_recall: 0.8970
Epoch 69/100
55/55            0s 7ms/step -
accuracy: 0.9736 - auc: 0.9997 - loss: 0.0697 - precision: 0.9769 - recall:
0.9714 - val_accuracy: 0.9056 - val_auc: 0.9828 - val_loss: 0.4796 -
val_precision: 0.9144 - val_recall: 0.8993
Epoch 70/100
55/55            0s 7ms/step -
accuracy: 0.9740 - auc: 0.9995 - loss: 0.0764 - precision: 0.9776 - recall:
0.9711 - val_accuracy: 0.9010 - val_auc: 0.9841 - val_loss: 0.4722 -
val_precision: 0.9100 - val_recall: 0.8970
Epoch 71/100
55/55            0s 5ms/step -
accuracy: 0.9777 - auc: 0.9998 - loss: 0.0636 - precision: 0.9807 - recall:
0.9756 - val_accuracy: 0.9084 - val_auc: 0.9841 - val_loss: 0.4582 -
val_precision: 0.9135 - val_recall: 0.9067
Epoch 72/100
55/55            0s 7ms/step -
```

```
accuracy: 0.9707 - auc: 0.9995 - loss: 0.0807 - precision: 0.9734 - recall:
0.9667 - val_accuracy: 0.9021 - val_auc: 0.9835 - val_loss: 0.4740 -
val_precision: 0.9070 - val_recall: 0.8987
Epoch 73/100
55/55            0s 7ms/step -
accuracy: 0.9793 - auc: 0.9992 - loss: 0.0712 - precision: 0.9808 - recall:
0.9758 - val_accuracy: 0.9170 - val_auc: 0.9851 - val_loss: 0.4571 -
val_precision: 0.9221 - val_recall: 0.9141
Epoch 74/100
55/55            0s 7ms/step -
accuracy: 0.9765 - auc: 0.9995 - loss: 0.0704 - precision: 0.9777 - recall:
0.9739 - val_accuracy: 0.9010 - val_auc: 0.9840 - val_loss: 0.4909 -
val_precision: 0.9098 - val_recall: 0.8952
Epoch 75/100
55/55            0s 6ms/step -
accuracy: 0.9725 - auc: 0.9992 - loss: 0.0790 - precision: 0.9754 - recall:
0.9696 - val_accuracy: 0.9107 - val_auc: 0.9849 - val_loss: 0.4436 -
val_precision: 0.9160 - val_recall: 0.9050
Epoch 76/100
55/55            0s 7ms/step -
accuracy: 0.9751 - auc: 0.9990 - loss: 0.0748 - precision: 0.9769 - recall:
0.9733 - val_accuracy: 0.9101 - val_auc: 0.9863 - val_loss: 0.4415 -
val_precision: 0.9172 - val_recall: 0.9073
Epoch 77/100
55/55            0s 7ms/step -
accuracy: 0.9839 - auc: 0.9999 - loss: 0.0481 - precision: 0.9852 - recall:
0.9794 - val_accuracy: 0.9015 - val_auc: 0.9849 - val_loss: 0.4795 -
val_precision: 0.9044 - val_recall: 0.8987
Epoch 78/100
55/55            0s 6ms/step -
accuracy: 0.9801 - auc: 0.9996 - loss: 0.0613 - precision: 0.9808 - recall:
0.9768 - val_accuracy: 0.9159 - val_auc: 0.9855 - val_loss: 0.4417 -
val_precision: 0.9198 - val_recall: 0.9124
Epoch 79/100
55/55            0s 6ms/step -
accuracy: 0.9798 - auc: 0.9996 - loss: 0.0586 - precision: 0.9819 - recall:
0.9772 - val_accuracy: 0.8993 - val_auc: 0.9828 - val_loss: 0.5123 -
val_precision: 0.9046 - val_recall: 0.8958
Epoch 80/100
55/55            0s 6ms/step -
accuracy: 0.9774 - auc: 0.9993 - loss: 0.0682 - precision: 0.9807 - recall:
0.9749 - val_accuracy: 0.9141 - val_auc: 0.9824 - val_loss: 0.4900 -
val_precision: 0.9159 - val_recall: 0.9101
Epoch 81/100
55/55            0s 6ms/step -
accuracy: 0.9817 - auc: 0.9998 - loss: 0.0536 - precision: 0.9831 - recall:
0.9799 - val_accuracy: 0.9056 - val_auc: 0.9838 - val_loss: 0.5114 -
val_precision: 0.9068 - val_recall: 0.9027
```

```
Epoch 82/100
55/55            0s 6ms/step -
accuracy: 0.9790 - auc: 0.9996 - loss: 0.0616 - precision: 0.9816 - recall:
0.9774 - val_accuracy: 0.9078 - val_auc: 0.9840 - val_loss: 0.4936 -
val_precision: 0.9102 - val_recall: 0.9056
Epoch 83/100
55/55            0s 6ms/step -
accuracy: 0.9792 - auc: 0.9994 - loss: 0.0634 - precision: 0.9806 - recall:
0.9779 - val_accuracy: 0.9107 - val_auc: 0.9842 - val_loss: 0.4821 -
val_precision: 0.9159 - val_recall: 0.9101
Epoch 84/100
55/55            0s 7ms/step -
accuracy: 0.9780 - auc: 0.9996 - loss: 0.0552 - precision: 0.9796 - recall:
0.9770 - val_accuracy: 0.8970 - val_auc: 0.9820 - val_loss: 0.5153 -
val_precision: 0.8999 - val_recall: 0.8952
Epoch 85/100
55/55            0s 7ms/step -
accuracy: 0.9777 - auc: 0.9995 - loss: 0.0620 - precision: 0.9799 - recall:
0.9764 - val_accuracy: 0.9101 - val_auc: 0.9824 - val_loss: 0.5003 -
val_precision: 0.9157 - val_recall: 0.9073
Epoch 86/100
55/55            0s 6ms/step -
accuracy: 0.9789 - auc: 0.9997 - loss: 0.0583 - precision: 0.9810 - recall:
0.9778 - val_accuracy: 0.9050 - val_auc: 0.9826 - val_loss: 0.5076 -
val_precision: 0.9128 - val_recall: 0.8987
Epoch 87/100
55/55            0s 6ms/step -
accuracy: 0.9758 - auc: 0.9996 - loss: 0.0699 - precision: 0.9776 - recall:
0.9740 - val_accuracy: 0.9015 - val_auc: 0.9837 - val_loss: 0.5177 -
val_precision: 0.9082 - val_recall: 0.9004
Epoch 88/100
55/55            0s 7ms/step -
accuracy: 0.9743 - auc: 0.9996 - loss: 0.0652 - precision: 0.9776 - recall:
0.9709 - val_accuracy: 0.9147 - val_auc: 0.9824 - val_loss: 0.5017 -
val_precision: 0.9181 - val_recall: 0.9113
Epoch 89/100
55/55            0s 6ms/step -
accuracy: 0.9853 - auc: 0.9999 - loss: 0.0406 - precision: 0.9875 - recall:
0.9827 - val_accuracy: 0.9033 - val_auc: 0.9814 - val_loss: 0.5296 -
val_precision: 0.9057 - val_recall: 0.9021
Epoch 90/100
55/55            0s 6ms/step -
accuracy: 0.9784 - auc: 0.9996 - loss: 0.0611 - precision: 0.9803 - recall:
0.9762 - val_accuracy: 0.9193 - val_auc: 0.9870 - val_loss: 0.4456 -
val_precision: 0.9217 - val_recall: 0.9170
Epoch 91/100
55/55            0s 7ms/step -
accuracy: 0.9856 - auc: 0.9996 - loss: 0.0452 - precision: 0.9864 - recall:
```

```
0.9846 - val_accuracy: 0.9170 - val_auc: 0.9851 - val_loss: 0.4537 -
val_precision: 0.9215 - val_recall: 0.9136
Epoch 92/100
55/55            0s 7ms/step -
accuracy: 0.9845 - auc: 0.9999 - loss: 0.0476 - precision: 0.9864 - recall:
0.9819 - val_accuracy: 0.9187 - val_auc: 0.9831 - val_loss: 0.5020 -
val_precision: 0.9221 - val_recall: 0.9147
Epoch 93/100
55/55            0s 6ms/step -
accuracy: 0.9849 - auc: 0.9997 - loss: 0.0427 - precision: 0.9865 - recall:
0.9837 - val_accuracy: 0.9073 - val_auc: 0.9838 - val_loss: 0.5069 -
val_precision: 0.9129 - val_recall: 0.9061
Epoch 94/100
55/55            0s 6ms/step -
accuracy: 0.9774 - auc: 0.9991 - loss: 0.0642 - precision: 0.9787 - recall:
0.9764 - val_accuracy: 0.9113 - val_auc: 0.9843 - val_loss: 0.4698 -
val_precision: 0.9168 - val_recall: 0.9084
Epoch 95/100
55/55            0s 7ms/step -
accuracy: 0.9816 - auc: 0.9998 - loss: 0.0487 - precision: 0.9839 - recall:
0.9800 - val_accuracy: 0.9061 - val_auc: 0.9831 - val_loss: 0.4908 -
val_precision: 0.9107 - val_recall: 0.9050
Epoch 96/100
55/55            0s 7ms/step -
accuracy: 0.9874 - auc: 0.9999 - loss: 0.0368 - precision: 0.9883 - recall:
0.9867 - val_accuracy: 0.9073 - val_auc: 0.9841 - val_loss: 0.4877 -
val_precision: 0.9138 - val_recall: 0.9044
Epoch 97/100
55/55            0s 7ms/step -
accuracy: 0.9813 - auc: 0.9995 - loss: 0.0568 - precision: 0.9823 - recall:
0.9786 - val_accuracy: 0.9027 - val_auc: 0.9841 - val_loss: 0.5132 -
val_precision: 0.9084 - val_recall: 0.8970
Epoch 98/100
55/55            0s 7ms/step -
accuracy: 0.9789 - auc: 0.9998 - loss: 0.0543 - precision: 0.9813 - recall:
0.9769 - val_accuracy: 0.9176 - val_auc: 0.9851 - val_loss: 0.4729 -
val_precision: 0.9200 - val_recall: 0.9147
Epoch 99/100
55/55            0s 7ms/step -
accuracy: 0.9855 - auc: 0.9999 - loss: 0.0405 - precision: 0.9861 - recall:
0.9844 - val_accuracy: 0.9136 - val_auc: 0.9844 - val_loss: 0.5256 -
val_precision: 0.9165 - val_recall: 0.9107
Epoch 100/100
55/55            0s 7ms/step -
accuracy: 0.9873 - auc: 0.9997 - loss: 0.0419 - precision: 0.9880 - recall:
0.9857 - val_accuracy: 0.9233 - val_auc: 0.9859 - val_loss: 0.4465 -
val_precision: 0.9253 - val_recall: 0.9222
```

[15]:
```
print(model.evaluate(xtest,ytest));
```

```
55/55             0s 1ms/step -
accuracy: 0.9034 - auc: 0.9843 - loss: 0.6079 - precision: 0.9050 - recall:
0.9031
[0.44645383954048157, 0.923297107219696, 0.9253302812576294, 0.9221522808074951,
0.9859354496002197]
```

[16]:
```
print(model.summary());
```

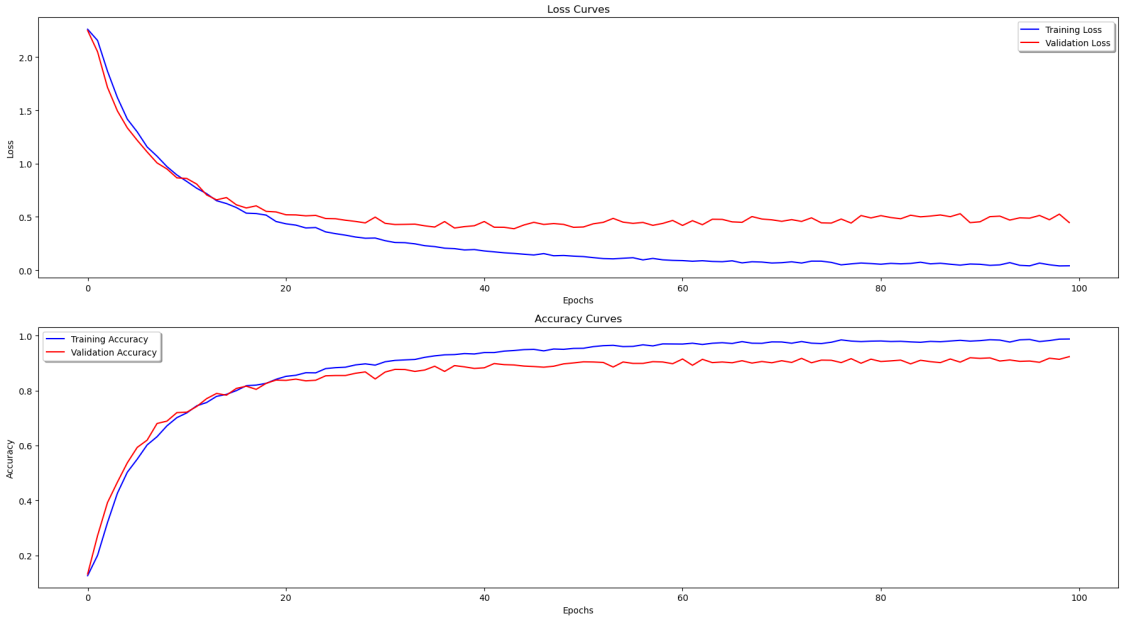
```
Model: "sequential"
```

Layer (type)	Output Shape	Param #
conv1d (Conv1D)	(None, 36, 64)	384
max_pooling1d (MaxPooling1D)	(None, 18, 64)	0
conv1d_1 (Conv1D)	(None, 14, 64)	20,544
max_pooling1d_1 (MaxPooling1D)	(None, 7, 64)	0
flatten (Flatten)	(None, 448)	0
dense (Dense)	(None, 256)	114,944
dropout (Dropout)	(None, 256)	0
dense_1 (Dense)	(None, 128)	32,896
dropout_1 (Dropout)	(None, 128)	0
dense_2 (Dense)	(None, 64)	8,256
dense_3 (Dense)	(None, 10)	650

```
Total params: 533,024 (2.03 MB)

Trainable params: 177,674 (694.04 KB)

Non-trainable params: 0 (0.00 B)

Optimizer params: 355,350 (1.36 MB)
```

None

[17]:
```
from matplotlib import pyplot as plt
fig,ax = plt.subplots(2,1,figsize = (18,10));
ax[0].plot(history.history["loss"],color = "b",label = "Training Loss");
ax[0].plot(history.history["val_loss"],color = "r",label = "Validation Loss");
ax[0].set_xlabel("Epochs");
ax[0].set_ylabel("Loss");
ax[0].set_title("Loss Curves");
ax[0].legend(loc = "best",shadow = True);
ax[1].plot(history.history["accuracy"],color = "b",label = "Training Accuracy");
ax[1].plot(history.history["val_accuracy"],color = "r",label = "Validation␣
 ↪Accuracy");
ax[1].set_xlabel("Epochs");
ax[1].set_ylabel("Accuracy");
ax[1].set_title("Accuracy Curves");
ax[1].legend(loc = "best",shadow = True);
plt.tight_layout();
```



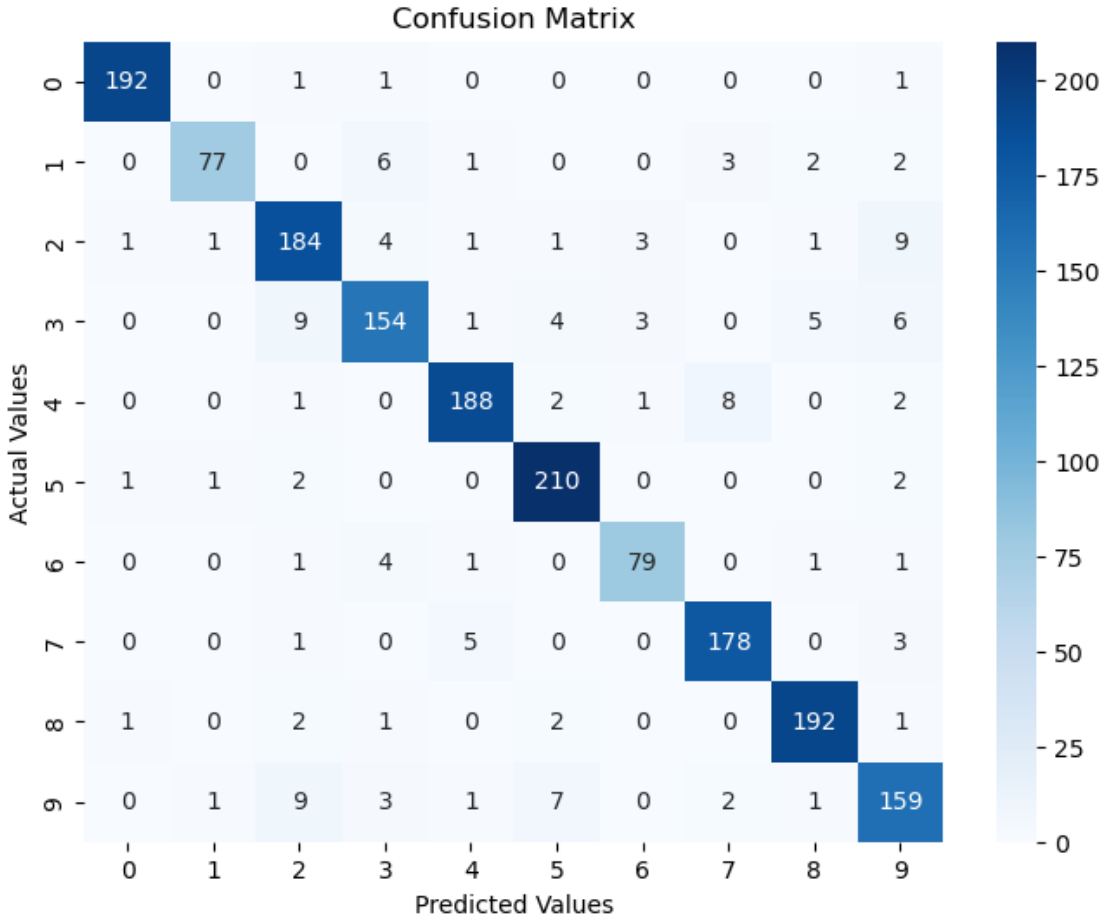
[18]:
```
ypred = model.predict(xtest);
ypred = np.argmax(ypred,axis = 1);
ytest = np.argmax(ytest,axis = 1);
print(ytest.shape,ypred.shape);
```

```
55/55             0s 1ms/step
(1747,) (1747,)
```

[19]:
```
from sklearn.metrics import␣
 ↪accuracy_score,confusion_matrix,classification_report;
score = accuracy_score(ytest,ypred);
print(score);
```

0.9232970807097882

[20]:
```
import seaborn as sns
from matplotlib import pyplot as plt
plt.figure(figsize = (8,6));
cm = confusion_matrix(ytest,ypred);
sns.heatmap(cm,cmap = "Blues",fmt = "d",annot = True,xticklabels =␣
 ↪arr,yticklabels = arr);
plt.title("Confusion Matrix");
plt.xlabel("Predicted Values");
plt.ylabel("Actual Values");
```



[21]:
```
report = classification_report(ytest,ypred,output_dict = True,target_names =␣
 ↪arr);
df = pd.DataFrame(report).transpose();
plt.figure(figsize = (10,5));
sns.heatmap(df,fmt = ".2f",annot = True,cmap = "Blues");
plt.title("Classification Report");
```