```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import librosa
from glob import glob
import IPython.display as ipd
import tensorflow as tf
from PIL import Image

df =
pd.read_csv("C:/Users/raksh/Desktop/bird/bird_songs_metadata.csv")
df.head(3)
```

```
       id       genus   species subspecies           name  \
0  557838  Thryomanes  bewickii        NaN  Bewick's Wren
1  557838  Thryomanes  bewickii        NaN  Bewick's Wren
2  557838  Thryomanes  bewickii        NaN  Bewick's Wren

                recordist        country  \
0  Whitney Neufeld-Kaiser  United States
1  Whitney Neufeld-Kaiser  United States
2  Whitney Neufeld-Kaiser  United States

                                  location  latitude  longitude
altitude  \
0  Arlington, Snohomish County, Washington   48.0708  -122.1006
100
1  Arlington, Snohomish County, Washington   48.0708  -122.1006
100
2  Arlington, Snohomish County, Washington   48.0708  -122.1006
100

                   sound_type                    source_url   time
date  \
0  adult, sex uncertain, song  //www.xeno-canto.org/557838  11:51  14-
03-2020
1  adult, sex uncertain, song  //www.xeno-canto.org/557838  11:51  14-
03-2020
2  adult, sex uncertain, song  //www.xeno-canto.org/557838  11:51  14-
03-2020

                                             remarks      filename
0  Recorded with Voice Record Pro on iPhone7, nor...  557838-0.wav
1  Recorded with Voice Record Pro on iPhone7, nor...  557838-1.wav
2  Recorded with Voice Record Pro on iPhone7, nor...  557838-4.wav
```

```
class_names = df["name"].unique()
print(class_names)
```

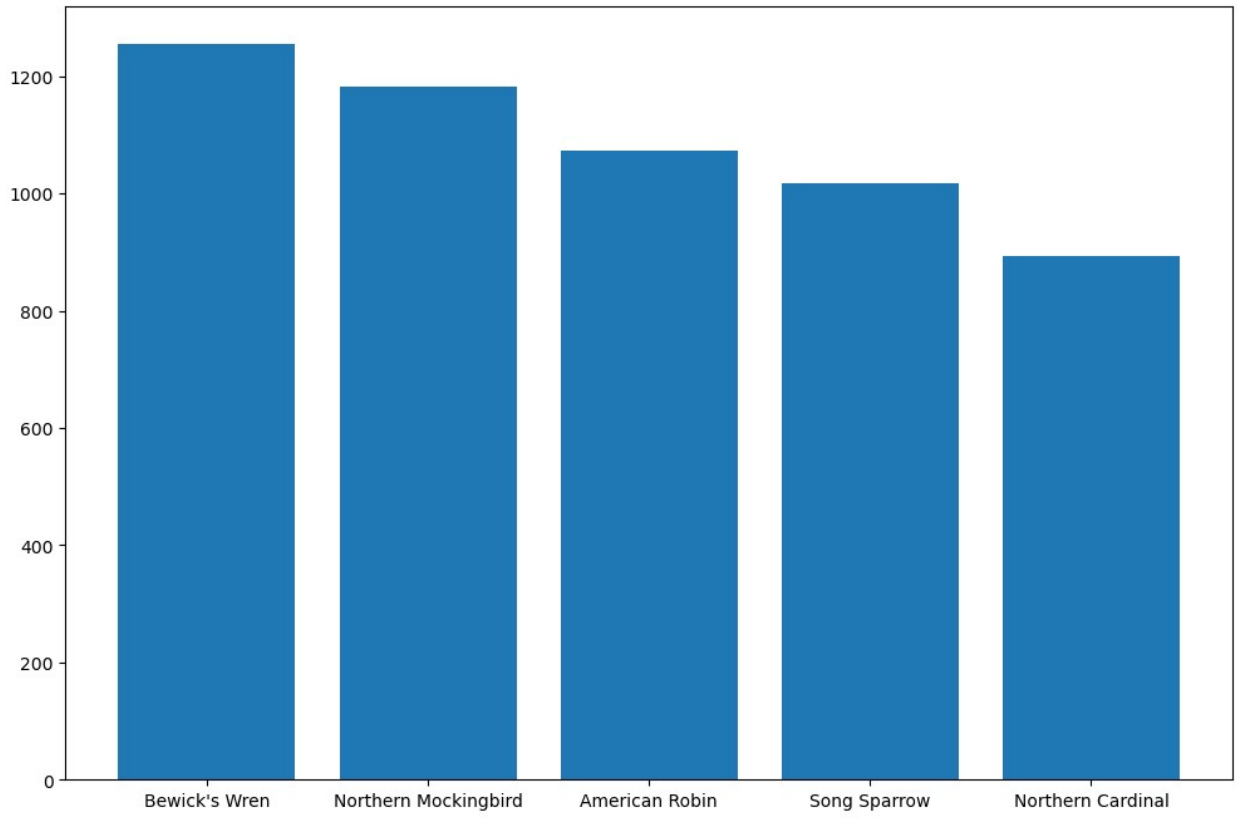
```
["Bewick's Wren" 'Northern Mockingbird' 'American Robin' 'Song
Sparrow'
 'Northern Cardinal']
```

```
df["name"].value_counts()
```

```
name
Song Sparrow             1256
Northern Mockingbird     1182
Northern Cardinal        1074
American Robin           1017
Bewick's Wren             893
Name: count, dtype: int64
```

```
fig, ax = plt.subplots(figsize=(12, 8))
ax.bar(df["name"].unique(), df["name"].value_counts())
```

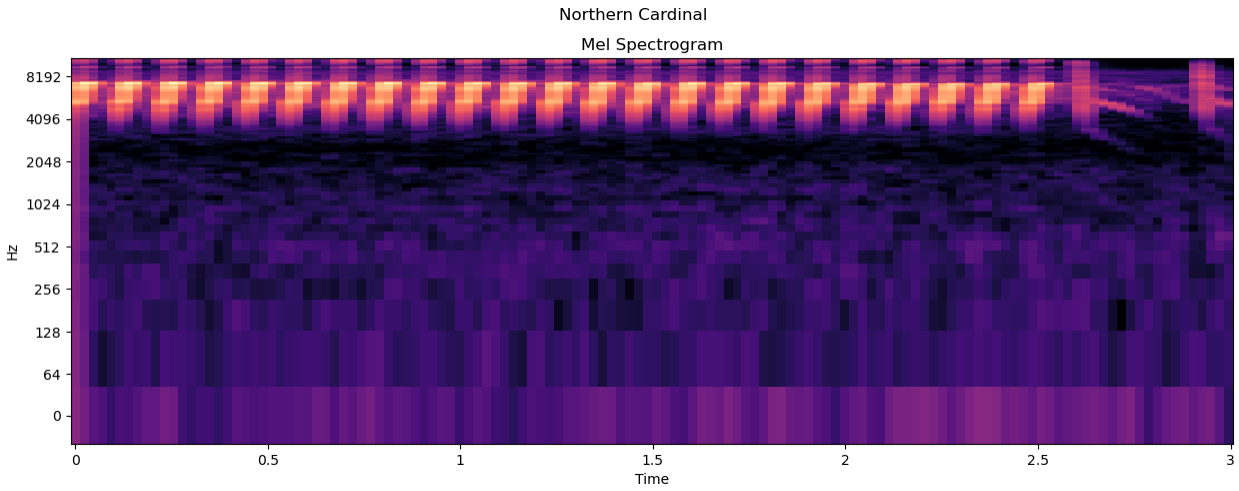
```
<BarContainer object of 5 artists>
```



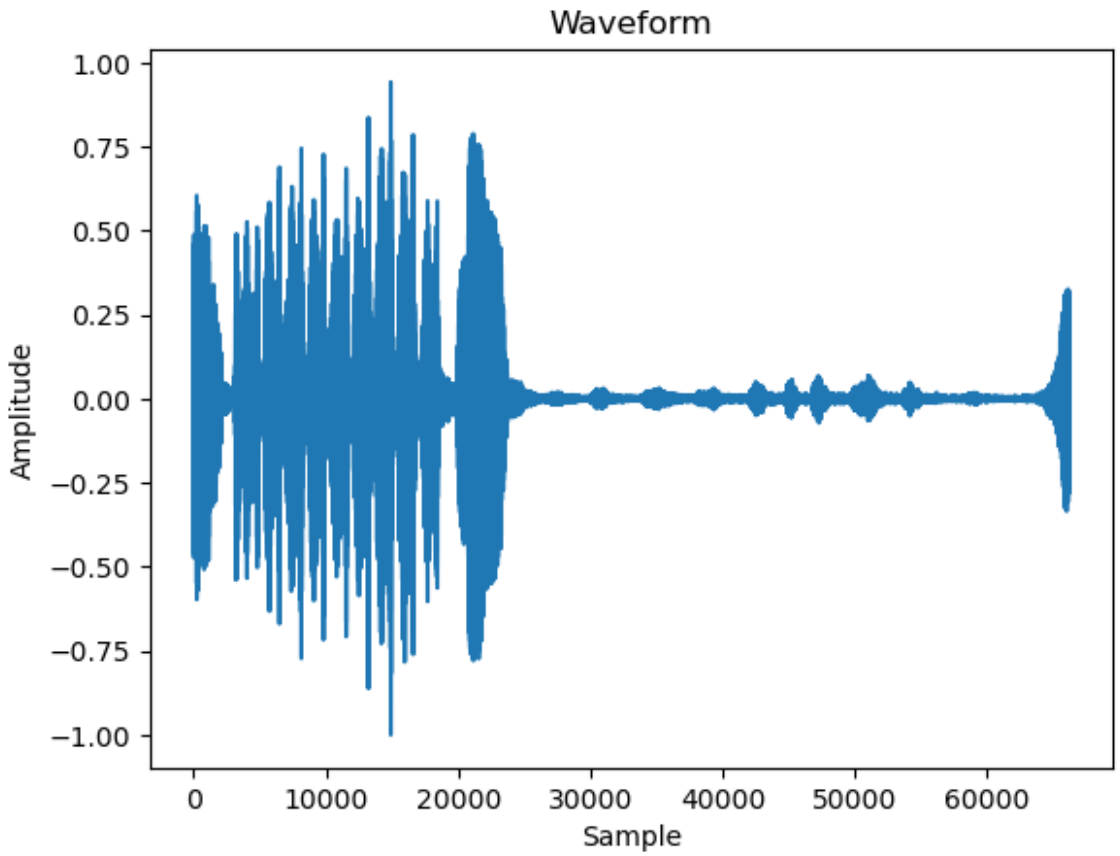

```
path_to_wav = "C:/Users/raksh/Desktop/bird/wavfiles (1)/"

datafiles = glob(path_to_wav + "*")

def generate_spectrogram(file_audio, identifier):
    audio_data, sample_rate = librosa.load(path_to_wav + file_audio)
```

```
    spec_mel = librosa.feature.melspectrogram(y=audio_data,
sr=sample_rate)
    spec_mel = librosa.power_to_db(spec_mel, ref=np.max)
    figure, axis = plt.subplots(figsize=(15, 5))
    axis.set_title("Mel Spectrogram")
    plt.suptitle(identifier)
    librosa.display.specshow(spec_mel, x_axis='time', y_axis='log',
ax=axis)
    return ipd.Audio(path_to_wav + file_audio, rate=sample_rate)

i = np.random.randint(0, df.shape[0])
generate_spectrogram(df.loc[i, "filename"], df.loc[i, "name"])
```

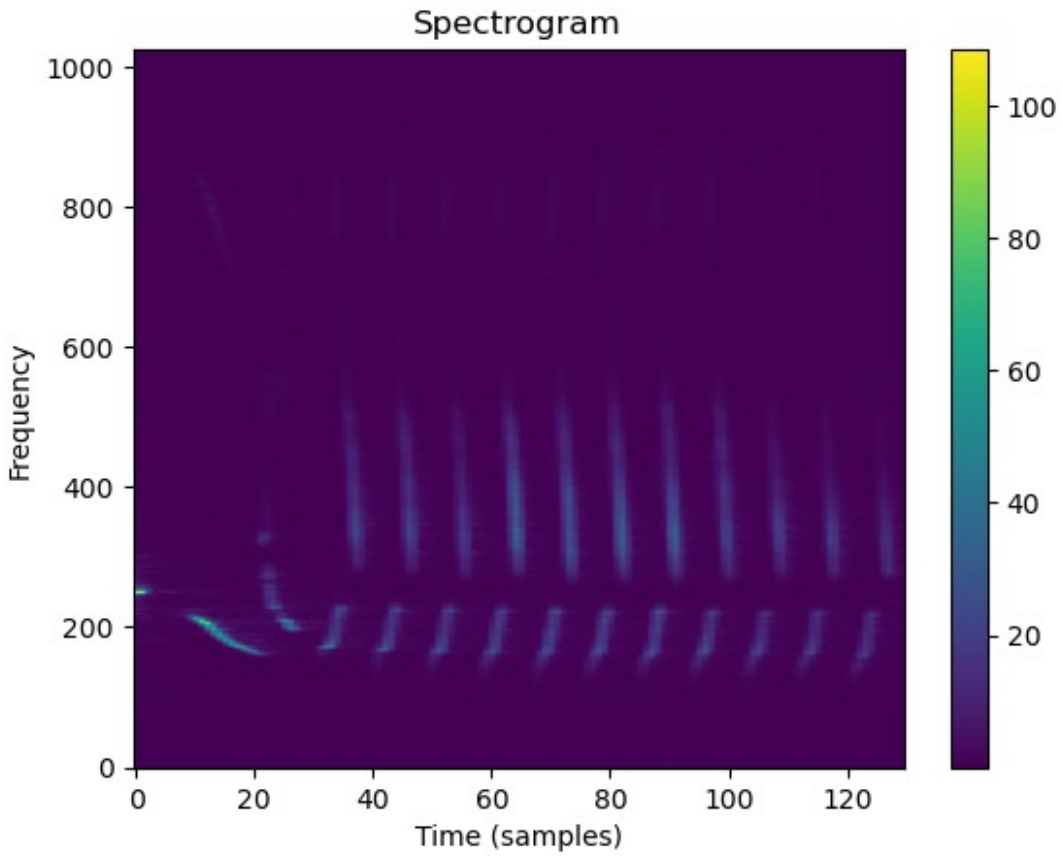
```
<IPython.lib.display.Audio object>
```




```
filename = "C:/Users/raksh/Desktop/bird/wavfiles (1)/12578-8.wav"
audio_data, sample_rate = librosa.load(filename)

plt.plot(audio_data)
plt.title("Waveform")
plt.xlabel("Sample")
plt.ylabel("Amplitude")
plt.show()
```




```
filename ="C:/Users/raksh/Desktop/bird/wavfiles (1)/11713-6.wav"
audio_data, sample_rate = librosa.load(filename)
spectrogram = librosa.stft(audio_data)
spectrogram = np.abs(spectrogram)

plt.imshow(spectrogram, origin='lower', aspect='auto')
plt.title("Spectrogram")
plt.xlabel("Time (samples)")
plt.ylabel("Frequency")
plt.colorbar()
plt.show()
```




```
def process_audio(audio_file):
    audio_data, sample_rate = librosa.load(audio_file, duration=10)
    mel_spec = librosa.feature.melspectrogram(y=audio_data,
sr=sample_rate)
    mel_spec = librosa.power_to_db(mel_spec, ref=np.max)
    return mel_spec

filename = "C:/Users/raksh/Desktop/bird/wavfiles (1)/11713-6.wav"
print(len(process_audio(filename)))
print(len(process_audio(filename)[0]))
```

```
128
130
```

```
df_train = pd.DataFrame({"name": df["name"], "audiopath": path_to_wav
+ df["filename"]})

# Assuming `process_audio` is a function that generates mel
spectrograms
df_train["mel_spec"] = df_train["audiopath"].apply(lambda x:
process_audio(x))

# Using factorize to encode class labels
df_train["class"] = df_train["name"].factorize()[0]
```

```
from sklearn.utils import shuffle

df_train = shuffle(df_train)
df_train.shape
```

```
(5422, 4)
```

```
(train_x, train_y) = df_train["mel_spec"][:5000].values,
df_train["class"][:5000].values
(test_x, test_y) = df_train["mel_spec"][5000:].values,
df_train["class"][5000:].values

from keras.utils import to_categorical

test_y = to_categorical(test_y, num_classes=len(class_names))
train_y = to_categorical(train_y, num_classes=len(class_names))

train_x = np.stack(train_x[:])
test_x = np.stack(test_x[:])

train_x = tf.keras.utils.normalize(train_x)
test_x = tf.keras.utils.normalize(test_x)

train_dataset = tf.data.Dataset.from_tensor_slices((train_x, train_y))
test_dataset = tf.data.Dataset.from_tensor_slices((test_x, test_y))

train_dataset = train_dataset.batch(10)
test_dataset = test_dataset.batch(10)
train_dataset = train_dataset.prefetch(tf.data.AUTOTUNE)
test_dataset = test_dataset.prefetch(tf.data.AUTOTUNE)

import keras
from keras.layers import Conv2D, MaxPooling2D, BatchNormalization,
Flatten, Dense, Reshape, InputLayer, Dropout
from keras.models import Sequential

model = keras.models.Sequential()

model.add(InputLayer(input_shape=(128,130)))
model.add(Reshape((128,130,1)))
model.add(Conv2D(64, (8, 8), input_shape=(128, 130),
activation='relu'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Conv2D(16, (2,2), activation='relu'))
model.add(Flatten())
model.add(Dropout(0.5))
model.add(Dense(128, activation='relu'))
model.add(Dense(5, activation='softmax'))
```

```
C:\Users\raksh\Documents\program\Lib\site-packages\keras\src\layers\
core\input_layer.py:25: UserWarning: Argument `input_shape` is
```

```
deprecated. Use `shape` instead.
  warnings.warn(
C:\Users\raksh\Documents\program\Lib\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)
```

```
model.summary()
```

```
Model: "sequential"
```

Layer (type)	Output Shape	Param #
reshape (Reshape)	(None, 128, 130, 1)	0
conv2d (Conv2D)	(None, 121, 123, 64)	4,160
batch_normalization (BatchNormalization)	(None, 121, 123, 64)	256
max_pooling2d (MaxPooling2D)	(None, 60, 61, 64)	0
conv2d_1 (Conv2D)	(None, 59, 60, 16)	4,112
flatten (Flatten)	(None, 56640)	0
dropout (Dropout)	(None, 56640)	0

```
| dense (Dense)                        | (None, 128)                 |
7,250,048 |
├──────────────────────────────────────┼─────────────────────────────┼
──────────────────┤
| dense_1 (Dense)                      | (None, 5)                   |
645 |
└──────────────────────────────────────┴─────────────────────────────┴
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 Total params: 7,259,221 (27.69 MB)

 Trainable params: 7,259,093 (27.69 MB)

 Non-trainable params: 128 (512.00 B)
```

```
model.compile('adam', loss='categorical_crossentropy',
metrics=[tf.keras.metrics.Recall(),tf.keras.metrics.Precision(),
'accuracy'])

hist = model.fit(train_dataset, epochs=10,
validation_data=test_dataset)
```

```
Epoch 1/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 168s 321ms/step - accuracy: 0.5586 -
loss: 1.0562 - precision: 0.6357 - recall: 0.4041 - val_accuracy:
0.2488 - val_loss: 1.6515 - val_precision: 0.2833 - val_recall: 0.2417
Epoch 2/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 152s 303ms/step - accuracy: 0.8148 -
loss: 0.5025 - precision: 0.8446 - recall: 0.7641 - val_accuracy:
0.5190 - val_loss: 2.2613 - val_precision: 0.5293 - val_recall: 0.5142
Epoch 3/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 150s 299ms/step - accuracy: 0.9210 -
loss: 0.2269 - precision: 0.9316 - recall: 0.9027 - val_accuracy:
0.4621 - val_loss: 6.5809 - val_precision: 0.4697 - val_recall: 0.4597
Epoch 4/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 149s 298ms/step - accuracy: 0.9549 -
loss: 0.1328 - precision: 0.9580 - recall: 0.9518 - val_accuracy:
0.7796 - val_loss: 0.7927 - val_precision: 0.7956 - val_recall: 0.7749
Epoch 5/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 148s 297ms/step - accuracy: 0.9652 -
loss: 0.1058 - precision: 0.9660 - recall: 0.9635 - val_accuracy:
0.6967 - val_loss: 1.6839 - val_precision: 0.6986 - val_recall: 0.6919
Epoch 6/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 149s 298ms/step - accuracy: 0.9831 -
loss: 0.0505 - precision: 0.9838 - recall: 0.9831 - val_accuracy:
0.4431 - val_loss: 6.9870 - val_precision: 0.4439 - val_recall: 0.4408
Epoch 7/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 148s 297ms/step - accuracy: 0.9774 -
loss: 0.0677 - precision: 0.9775 - recall: 0.9773 - val_accuracy:
0.7227 - val_loss: 1.3816 - val_precision: 0.7314 - val_recall: 0.7227
Epoch 8/10
```

```
500/500 ━━━━━━━━━━━━━━━━━━━━ 147s 294ms/step - accuracy: 0.9807 -
loss: 0.0626 - precision: 0.9818 - recall: 0.9807 - val_accuracy:
0.4502 - val_loss: 11.9156 - val_precision: 0.4487 - val_recall:
0.4455
Epoch 9/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 150s 300ms/step - accuracy: 0.9856 -
loss: 0.0454 - precision: 0.9861 - recall: 0.9854 - val_accuracy:
0.6777 - val_loss: 2.2371 - val_precision: 0.6827 - val_recall: 0.6730
Epoch 10/10
500/500 ━━━━━━━━━━━━━━━━━━━━ 152s 303ms/step - accuracy: 0.9899 -
loss: 0.0356 - precision: 0.9899 - recall: 0.9897 - val_accuracy:
0.3531 - val_loss: 14.6638 - val_precision: 0.3515 - val_recall:
0.3507

# Save the model to a file
model.save('bird_sound_classification_model.h5')

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

model.evaluate(test_dataset)

43/43 ━━━━━━━━━━━━━━━━━━━━ 2s 40ms/step - accuracy: 0.3472 - loss:
14.0894 - precision: 0.3458 - recall: 0.3450

[14.663841247558594,
 0.3507108986377716,
 0.35154393315315247,
 0.3530805706977844]

pred_y = model.predict(test_x)
true_y = test_y.argmax(axis=1, keepdims=True)

14/14 ━━━━━━━━━━━━━━━━━━━━ 2s 129ms/step

print(pred_y)
print(true_y)

[[6.9032223e-14 1.1925868e-15 5.9674535e-14 1.0000000e+00 5.9552114e-
09]
 [3.9875583e-22 5.1240882e-16 2.2828763e-14 1.0000000e+00 7.4895344e-
14]
 [8.2445224e-18 5.2689821e-18 1.3873992e-11 1.0000000e+00 1.5736290e-
15]
 ...
 [4.5625557e-16 6.8809799e-14 7.0644930e-09 1.0000000e+00 2.5091005e-
14]
 [3.0444321e-15 3.5197277e-15 1.2094655e-06 9.9999881e-01 1.5353808e-
```

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 [2.2554762e-17 3.8286978e-09 2.0808821e-15 1.0000000e+00 3.3472818e-
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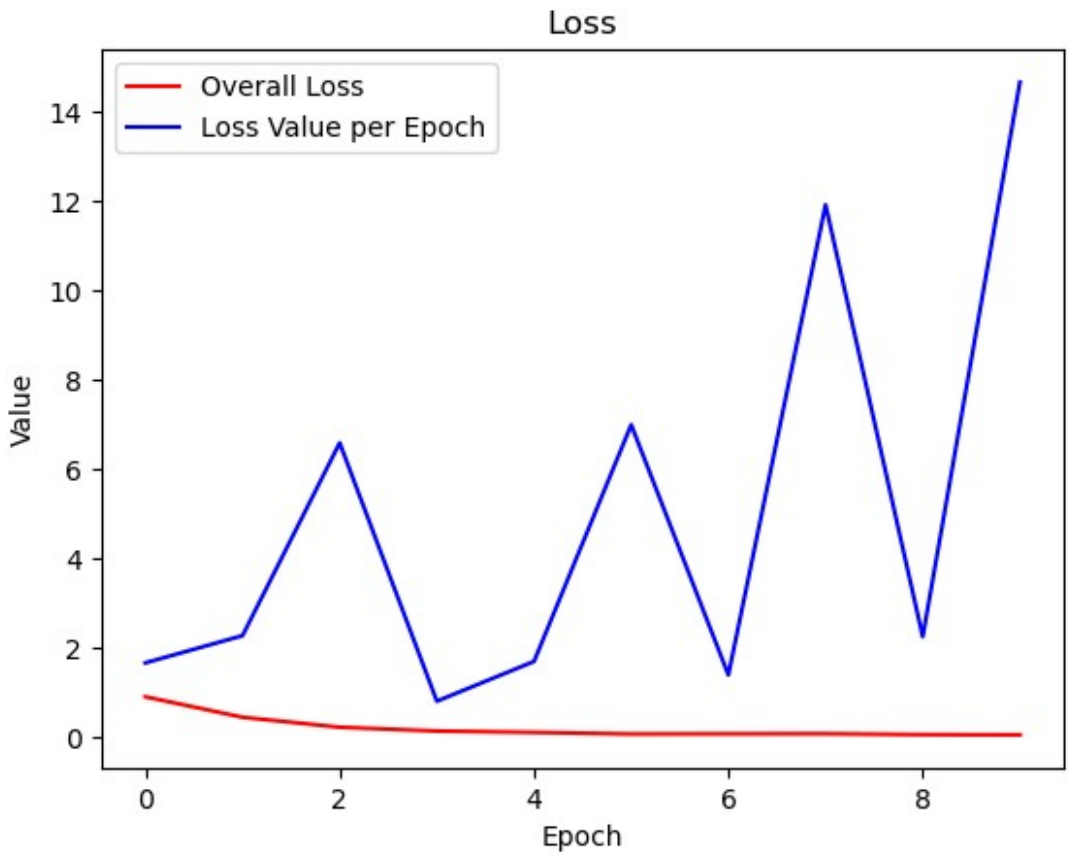
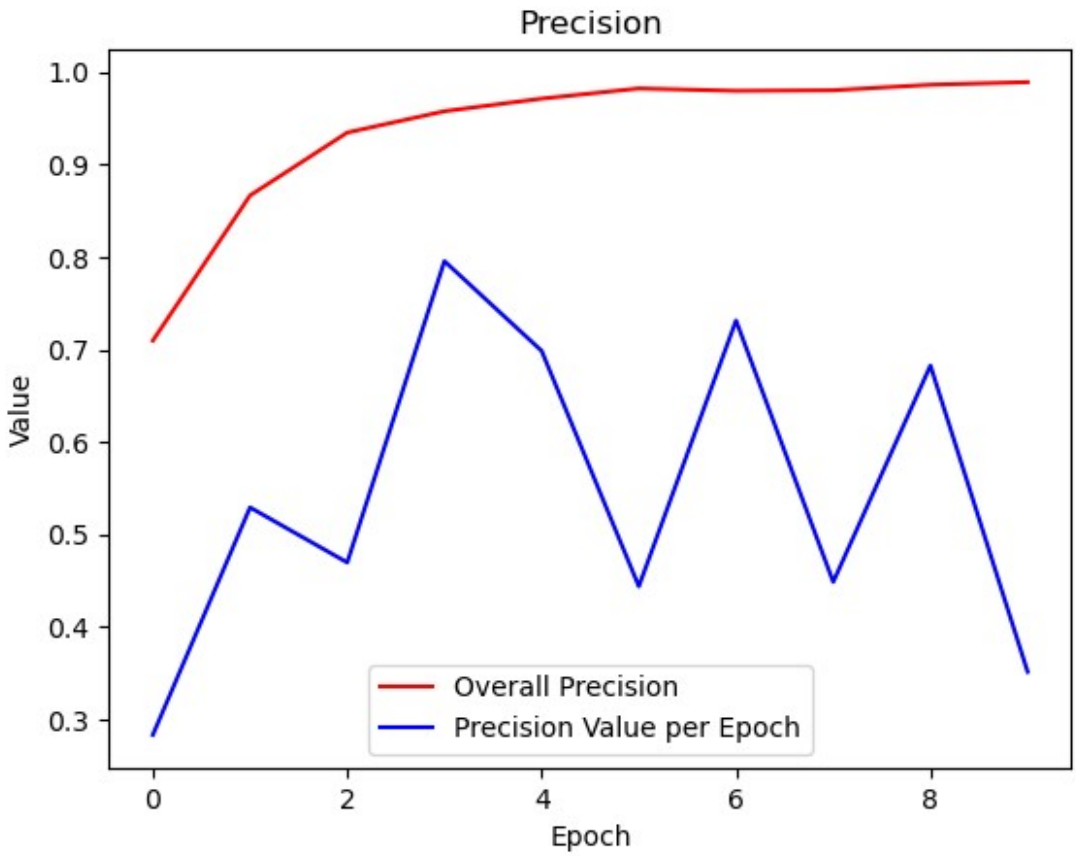
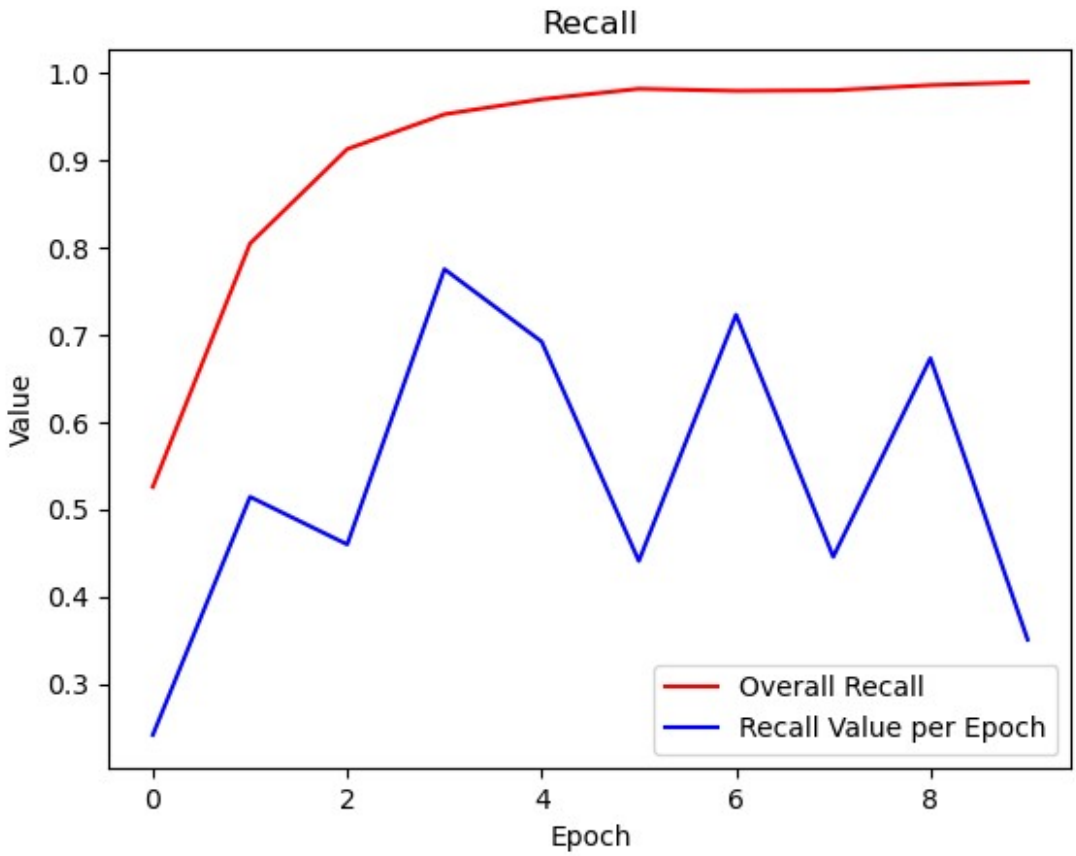
```
plt.title('Loss')
plt.plot(hist.history['loss'], 'r', label='Overall Loss')
plt.plot(hist.history['val_loss'], 'b', label='Loss Value per Epoch')
plt.xlabel('Epoch')
plt.ylabel('Value')
plt.legend()
plt.show()
```



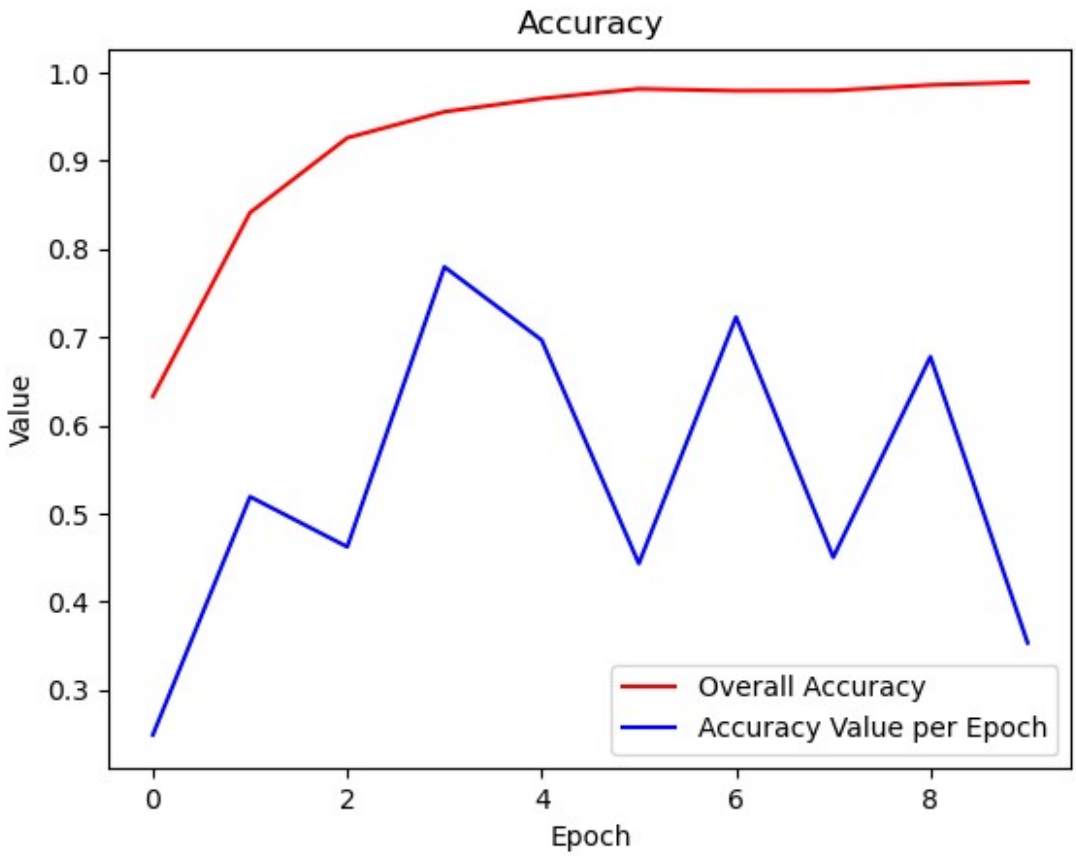

```
plt.title('Precision')
plt.plot(hist.history['precision'], 'r', label='Overall Precision')
plt.plot(hist.history['val_precision'], 'b', label='Precision Value
per Epoch')
plt.xlabel('Epoch')
plt.ylabel('Value')
plt.legend()
plt.show()
```




```
plt.title('Recall')
plt.plot(hist.history['recall'], 'r', label='Overall Recall')
plt.plot(hist.history['val_recall'], 'b', label='Recall Value per
Epoch')
plt.xlabel('Epoch')
plt.ylabel('Value')
plt.legend()
plt.show()
```




```
plt.title('Accuracy')
plt.plot(hist.history['accuracy'], 'r', label='Overall Accuracy')
plt.plot(hist.history['val_accuracy'], 'b', label='Accuracy Value per
Epoch')
plt.xlabel('Epoch')
plt.ylabel('Value')
plt.legend()
plt.show()
```




```
audio_file = "C:/Users/raksh/Desktop/bird/wavfiles (1)/11713-6.wav"
audio_data, sample_rate = librosa.load(audio_file, duration=3)
mel_spec = librosa.feature.melspectrogram(y=audio_data,
sr=sample_rate)
mel_spec = librosa.power_to_db(mel_spec, ref=np.max)
mel_spec = tf.expand_dims(mel_spec, axis=0)


# Make a prediction
prediction = model.predict(mel_spec)

# Get the predicted class index
predicted_class_index = np.argmax(prediction, axis=1)[0]

# Get the corresponding bird name
bird_name = class_names[predicted_class_index]

# Print the prediction and bird name
print(f"Predicted Class Index: {predicted_class_index}")
print(f"Predicted Bird Name: {bird_name}")
print(f"Prediction Scores: {prediction}")
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 40ms/step
Predicted Class Index: 3
```

```
Predicted Bird Name: Song Sparrow
Prediction Scores: [[0. 0. 0. 1. 0.]]
```