Audio Classification of Capuchin Bird Clips

TASK AT HAND : ***The Challenge is to build a Machine Learning model and code to count the number of Capuchinbird calls within a given clip***

1. Loading Packages

In [1]:

```
import os
import csv
import tensorflow as tf
import matplotlib.pyplot as plt
import tensorflow_io as tfio
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Input,Conv2D, Dense, Flatten
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau
```

```
/opt/conda/lib/python3.10/site-packages/scipy/__init__.py:146: UserWarning: A NumPy version >=1.16.5 and <1.23.0 is required for this versi
on of SciPy (detected version 1.24.3
  warnings.warn(f"A NumPy version >={np_minversion} and <{np_maxversion}"
```

2. Method for Loading Data

In [2]:

```
CAPUCHIN_FILE = os.path.join('data','/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/Parsed_Capuchinbird_Clips','XC114131-0.wa
NOT_CAPUCHIN_FILE = os.path.join('data','/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/Parsed_Not_Capuchinbird_Clips', 'afte
```

2.1 Paths to Data Folders

In [3]:

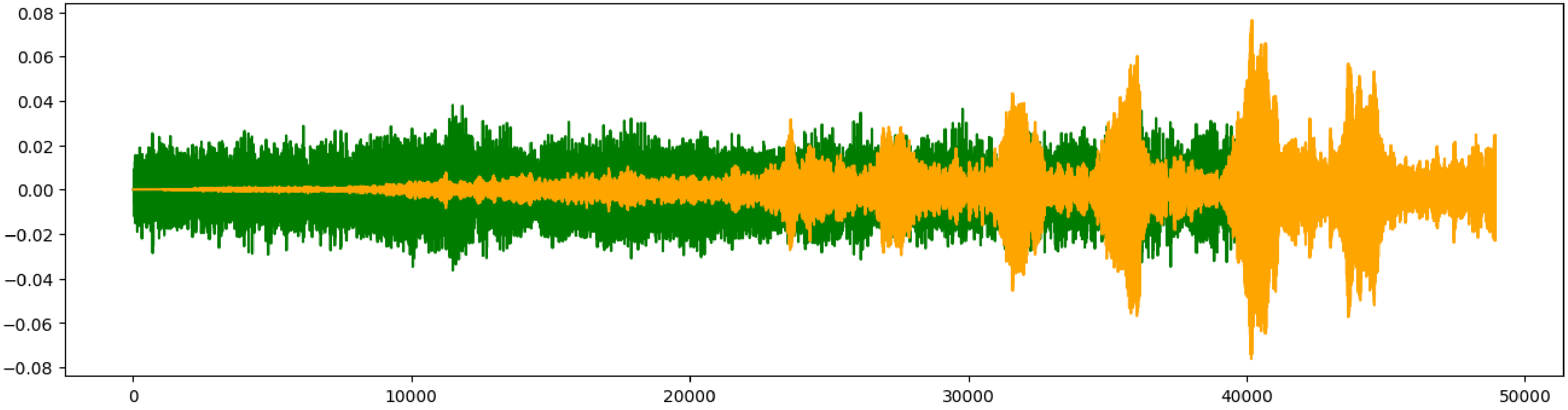
```
def load_wav_16k_mono(filename):

    file_contents = tf.io.read_file(filename)
    wav, sample_rate = tf.audio.decode_wav(file_contents, desired_channels=1)
    wav = tf.squeeze(wav, axis=-1)
    sample_rate = tf.cast(sample_rate, dtype=tf.int64)
    wav = tfio.audio.resample(wav, rate_in=sample_rate, rate_out=16000)
    return wav
```

In [4]:

```
capuchin = load_wav_16k_mono(CAPUCHIN_FILE)
not_capuchin = load_wav_16k_mono(NOT_CAPUCHIN_FILE)
```

In [5]:

```
plt.figure(figsize=(16,4))
plt.plot(capuchin,color='green')
plt.plot(not_capuchin,color='orange')
plt.show()
```



3. Tensorflow Dataset

In [6]:
```
Capuchin_folder = os.path.join('data','/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/Parsed_Capuchinbird_Clips')
not_Capuchin_folder = os.path.join('data','/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/Parsed_Not_Capuchinbird_Clips')
```

In [7]:
```
capuchin = tf.data.Dataset.list_files(Capuchin_folder + '/*-*.wav')
not_capuchin = tf.data.Dataset.list_files(not_Capuchin_folder + '/*-*.wav')
```

3.1 Adding labels to capuchin and not_capuchin samples

In [8]:
```
capuchins = tf.data.Dataset.zip((capuchin, tf.data.Dataset.from_tensor_slices(tf.ones(len(capuchin)))))
not_capuchins = tf.data.Dataset.zip((not_capuchin, tf.data.Dataset.from_tensor_slices(tf.zeros(len(not_capuchin)))))
```

In [9]:
```
data = capuchins.concatenate(not_capuchins)
```

4. Calculating the Avg Length of a Clip

4.1 calculate wave cycle length

In [10]:
```
lengths = []
for file in os.listdir(os.path.join('data','/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/Parsed_Capuchinbird_Clips')):
    file_path = os.path.join('data','/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/Parsed_Capuchinbird_Clips', file)
```

```
    tensor_wave = load_wav_16k_mono(file_path)
    lengths.append(len(tensor_wave))
```

In [11]:

```
max_length = tf.math.reduce_max(lengths)
mean_length = tf.math.reduce_mean(lengths)
min_length = tf.math.reduce_min(lengths)

print(f"Minimum Length : {min_length}")
print(f"Average Length : {mean_length}")
print(f"Maximum Length : {max_length}")
```

```
Minimum Length : 32000
Average Length : 54156
Maximum Length : 80000
```

5. Building Function to Convert wave to a Spectrogram

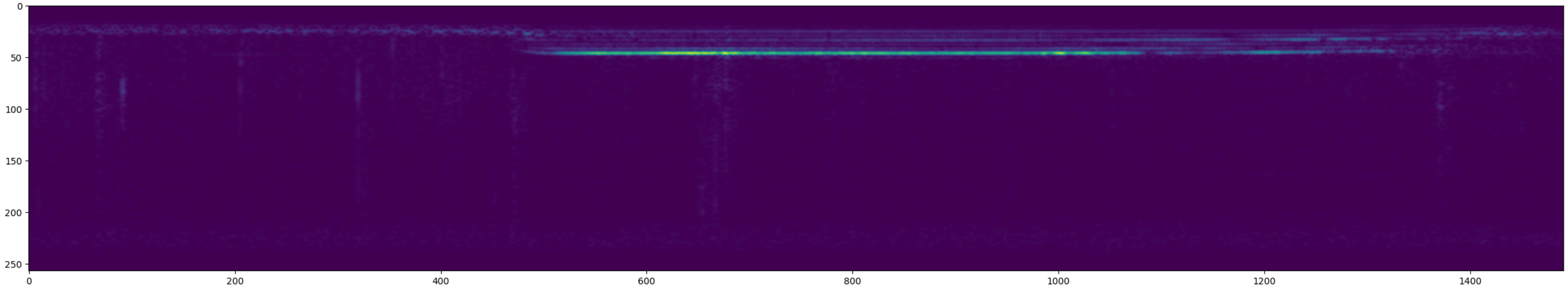
In [12]:

```
def preprocess(file_path, label):
    wav = load_wav_16k_mono(file_path)
    wav = wav[:48000]
    zero_padding = tf.zeros([48000] - tf.shape(wav), dtype=tf.float32)
    wav = tf.concat([zero_padding, wav],0)
    spectrogram = tf.signal.stft(wav, frame_length=320, frame_step=32)
    spectrogram = tf.abs(spectrogram)
    spectrogram = tf.expand_dims(spectrogram, axis=2)
    return spectrogram, label
```

5.1 Plot the Spectrogram

In [13]:

```
filepath, label = capuchins.shuffle(buffer_size=10000).as_numpy_iterator().next()
spectrogram, label = preprocess(filepath, label)

plt.figure(figsize=(30,20))
plt.imshow(tf.transpose(spectrogram)[0])
plt.show()
```



6. Training and Testing Splits

In [14]:

```
data = data.map(preprocess)
data = data.cache()
data = data.shuffle(buffer_size = 10000)
data = data.batch(16)
data = data.prefetch(8)
```

6.1. Split into training and testing data (70-30)

In [15]:

```
train = data.take(36)
test = data.skip(36).take(15)
```

In [16]:

```
samples, labels = train.as_numpy_iterator().next()
samples.shape
```

Out[16]:

```
(16, 1491, 257, 1)
```

7. Building Deep Learning Model

7.1. Convolutional Neural Network

```
In [17]: model = Sequential()
         model.add(Input(shape=(1491, 257, 1)))
         model.add(Conv2D(16, (3,3), activation='relu'))
         model.add(Conv2D(16, (3,3), activation='relu'))
         model.add(Flatten())
         model.add(Dense(128, activation='relu'))
         model.add(Dense(1, activation='sigmoid'))
```

```
In [18]: model.compile('Adam', loss='BinaryCrossentropy', metrics=[tf.keras.metrics.Recall(),tf.keras.metrics.Precision()])
         model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 1489, 255, 16)     160

 conv2d_1 (Conv2D)           (None, 1487, 253, 16)     2320

 flatten (Flatten)           (None, 6019376)           0

 dense (Dense)               (None, 128)               770480256

 dense_1 (Dense)             (None, 1)                 129

=================================================================
Total params: 770482865 (2.87 GB)
Trainable params: 770482865 (2.87 GB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
In [19]: earlystop = EarlyStopping(monitor='val_loss',
                                   min_delta=0,
                                   patience=5,
                                   verbose=1,
                                   restore_best_weights=True)

         # Callback to reduce learning rate
         reduce_lr = ReduceLROnPlateau(monitor='val_loss',
                                       factor=0.2,
                                       patience=6,
                                       verbose=1,
                                       min_delta=0.0001)

         callbacks = [earlystop, reduce_lr]
```

7.2. Model Fit

In [20]:

```
hist = model.fit(
    train,
    epochs=15,
    validation_data=test,
    callbacks=callbacks)
```

```
Epoch 1/15
36/36 [==============================] - 21s 424ms/step - loss: 2.0907 - recall: 0.8750 - precision: 0.7824 - val_loss: 0.0312 - val_recal
l: 0.9692 - val_precision: 1.0000 - lr: 0.0010
Epoch 2/15
36/36 [==============================] - 10s 292ms/step - loss: 0.1695 - recall: 0.9675 - precision: 0.9675 - val_loss: 0.0028 - val_recal
l: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 3/15
36/36 [==============================] - 6s 179ms/step - loss: 0.0281 - recall: 0.9801 - precision: 0.9933 - val_loss: 0.1185 - val_recall:
1.0000 - val_precision: 0.9831 - lr: 0.0010
Epoch 4/15
36/36 [==============================] - 10s 292ms/step - loss: 0.1161 - recall: 0.9809 - precision: 0.9872 - val_loss: 0.0014 - val_recal
l: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 5/15
36/36 [==============================] - 10s 290ms/step - loss: 0.0024 - recall: 1.0000 - precision: 0.9937 - val_loss: 5.6674e-04 - val_re
call: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 6/15
36/36 [==============================] - 10s 294ms/step - loss: 3.6977e-04 - recall: 1.0000 - precision: 1.0000 - val_loss: 1.9160e-04 - va
l_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 7/15
36/36 [==============================] - 6s 180ms/step - loss: 1.0143e-04 - recall: 1.0000 - precision: 1.0000 - val_loss: 2.6583e-04 - val
_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 8/15
36/36 [==============================] - 10s 290ms/step - loss: 1.3442e-04 - recall: 1.0000 - precision: 1.0000 - val_loss: 1.1126e-04 - va
l_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 9/15
36/36 [==============================] - 6s 179ms/step - loss: 5.1385e-05 - recall: 1.0000 - precision: 1.0000 - val_loss: 1.6098e-04 - val
_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 10/15
36/36 [==============================] - 10s 295ms/step - loss: 3.0267e-05 - recall: 1.0000 - precision: 1.0000 - val_loss: 3.2333e-05 - va
l_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 11/15
36/36 [==============================] - 10s 292ms/step - loss: 2.2182e-05 - recall: 1.0000 - precision: 1.0000 - val_loss: 2.7736e-05 - va
l_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 12/15
36/36 [==============================] - 7s 181ms/step - loss: 1.8129e-05 - recall: 1.0000 - precision: 1.0000 - val_loss: 2.7587e-04 - val
_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 13/15
36/36 [==============================] - 10s 292ms/step - loss: 1.2589e-05 - recall: 1.0000 - precision: 1.0000 - val_loss: 9.5401e-06 - va
l_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 14/15
36/36 [==============================] - 6s 179ms/step - loss: 1.5323e-04 - recall: 1.0000 - precision: 1.0000 - val_loss: 2.2469e-04 - val
_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
Epoch 15/15
36/36 [==============================] - 6s 180ms/step - loss: 1.8962e-04 - recall: 1.0000 - precision: 1.0000 - val_loss: 9.9462e-05 - val
_recall: 1.0000 - val_precision: 1.0000 - lr: 0.0010
```

In [22]:

```python
def plot_training_history(history):
    """
```

```
    Plots the training and validation accuracy and loss.
    """
    prec = history.history['precision']
    val_prec = history.history['val_precision']
    recall = history.history['recall']
    val_recall = history.history['val_recall']
    loss = history.history['loss']
    val_loss = history.history['val_loss']

    epochs_range = range(len(prec))

    plt.figure(figsize=(20, 5))

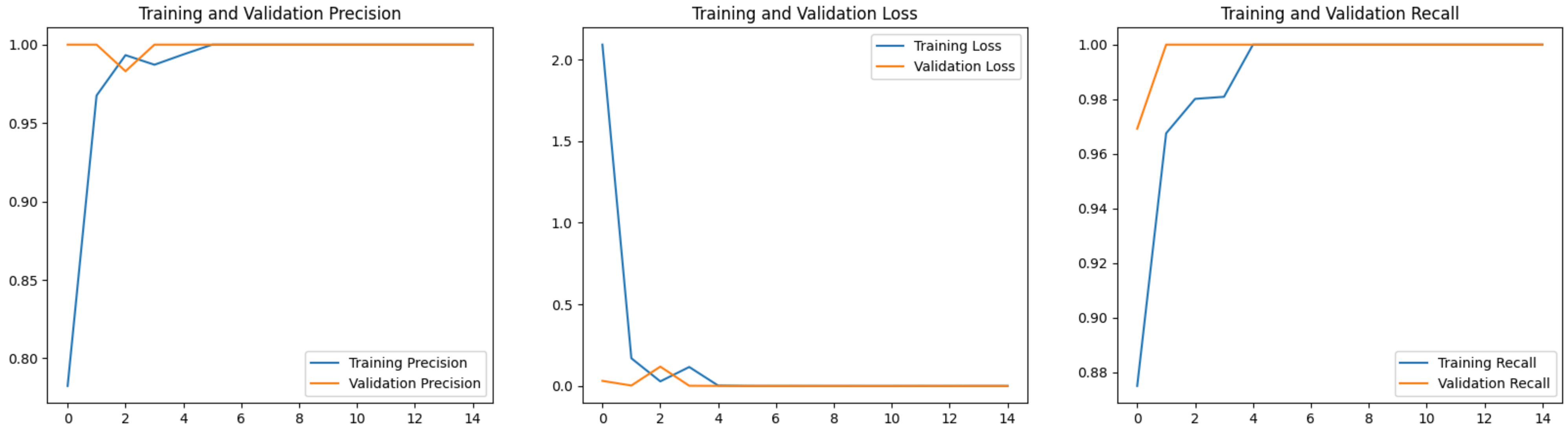
    # Plot training and validation Precision
    plt.subplot(1, 3, 1)
    plt.plot(epochs_range, prec, label='Training Precision')
    plt.plot(epochs_range, val_prec, label='Validation Precision')
    plt.legend(loc='lower right')
    plt.title('Training and Validation Precision')

    # Plot training and validation loss
    plt.subplot(1, 3, 2)
    plt.plot(epochs_range, loss, label='Training Loss')
    plt.plot(epochs_range, val_loss, label='Validation Loss')
    plt.legend(loc='upper right')
    plt.title('Training and Validation Loss')


    # Plot training and validation Recall
    plt.subplot(1, 3, 3)
    plt.plot(epochs_range, recall, label='Training Recall')
    plt.plot(epochs_range, val_recall, label='Validation Recall')
    plt.legend(loc='lower right')
    plt.title('Training and Validation Recall')

    plt.show()

plot_training_history(hist)
```



8. Predictions Time

In [23]:

```
X_test, y_test = test.as_numpy_iterator().next()
yhat = model.predict(X_test)
```

```
1/1 [==============================] - 0s 140ms/step
```

In [24]:

```
# Converting Probabilities to Classes
yhat = [1 if prediction > 0.5 else 0 for prediction in yhat]
```

In [30]:

```
y_test
```

Out[30]:

```
array([1., 0., 0., 1., 1., 0., 0., 0., 0., 1., 0., 1., 0., 1., 0., 0.],
      dtype=float32)
```

In [25]:

```
yhat
```

Out[25]:

```
[1, 0, 0, 1, 1, 0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0]
```

9. Forest Clips Parsing

In [31]:

```
def load_mp3_16k_mono(filename):
    """ Load a WAV file, convert it to a float tensor, resample to 16 kHz single-channel audio. """
    res = tfio.audio.AudioIOTensor(filename)
    # Convert to tensor and combine channels
    tensor = res.to_tensor()
```

```
    tensor = tf.math.reduce_sum(tensor, axis=1) / 2
    # Extract sample rate and cast
    sample_rate = res.rate
    sample_rate = tf.cast(sample_rate, dtype=tf.int64)
    # Resample to 16 kHz
    wav = tfio.audio.resample(tensor, rate_in=sample_rate, rate_out=16000)
    return wav
```

9.2 Build Function to convert clips into windowed spectrogram

In [37]:

```
def preprocess_mp3(sample, index):
    sample = sample[0]
    zero_padding = tf.zeros([48000] - tf.shape(sample), dtype=tf.float32)
    wav = tf.concat([zero_padding, sample],0)
    spectrogram = tf.signal.stft(wav, frame_length=320, frame_step=32)
    spectrogram = tf.abs(spectrogram)
    spectrogram = tf.expand_dims(spectrogram, axis=2)
    return spectrogram
```

10. Forect Clips Predictions

In [38]:

```
results = {}
for file in os.listdir(os.path.join('/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/', 'Forest Recordings')):
    FILEPATH = os.path.join('/kaggle/input/z-by-hp-unlocked-challenge-3-signal-processing/','Forest Recordings', file)

    wav = load_mp3_16k_mono(FILEPATH)
    audio_slices = tf.keras.utils.timeseries_dataset_from_array(wav, wav, sequence_length=48000, sequence_stride=48000, batch_size=1)
    audio_slices = audio_slices.map(preprocess_mp3)
    audio_slices = audio_slices.batch(64)

    yhat = model.predict(audio_slices)

    results[file] = yhat
```

```
1/1 [==============================] - 3s 3s/step
1/1 [==============================] - 1s 706ms/step
1/1 [==============================] - 1s 716ms/step
1/1 [==============================] - 1s 702ms/step
1/1 [==============================] - 1s 708ms/step
1/1 [==============================] - 1s 688ms/step
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1/1 [==============================] - 1s 706ms/step
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1/1 [==============================] - 1s 722ms/step
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```

```
1/1 [==============================] - 1s 688ms/step
1/1 [==============================] - 1s 705ms/step
1/1 [==============================] - 1s 688ms/step
1/1 [==============================] - 1s 684ms/step
```

In [43]:

```
# Convert Predictions into Classes

class_preds = {}
for file, logits in results.items():
    class_preds[file] = [1 if prediction > 0.99 else 0 for prediction in logits]
class_preds
```

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Out[43]: {'recording_76.mp3': [0,
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In [48]:

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# Grouping consequtive Detections

from itertools import groupby

postprocessed = {}
for file, scores in class_preds.items():
    postprocessed[file] = tf.math.reduce_sum([key for key, group in groupby(scores)]).numpy()

sorted_postprocessed = dict(sorted(postprocessed.items(), key=lambda item: item[1], reverse=True))

top_5 = dict(list(sorted_postprocessed.items())[:5])

print("Top 5 Recordings with most Capuchin Bird Sounds are : ",top_5)
```

```
Top 5 Recordings with most Capuchin Bird Sounds are :  {'recording_08.mp3': 24, 'recording_98.mp3': 21, 'recording_87.mp3': 20, 'recording_
28.mp3': 14, 'recording_59.mp3': 9}
```