# CNN Optuna Mels

June 9, 2022

### 0.0.1 Audio Load by Barney

[1]:
```
from barney_functions import *
import librosa
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt
import random
import re
import soundfile as sf
import itertools
from sklearn.metrics import confusion_matrix
from sklearn.model_selection import train_test_split
```

[2]:
```
mels = np.load('mels.npz')['data']
y = np.load('mels_lables.npz',allow_pickle=True)['data']
num_classes = len(np.unique(y))
mels, TEST_images, y, TEST_y = train_test_split(mels, y, test_size=0.2,␣
 ↪random_state=42)
```

[3]:
```
print(mels.shape)
print(y.shape)
print(TEST_images.shape)
print(TEST_y.shape)
```

```
(1804, 128, 51)
(1804,)
(452, 128, 51)
(452,)
```

## 1 CNN

[4]:
```
import keras
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense,␣
 ↪Dropout
```

```
from tensorflow.keras.losses import categorical_crossentropy
from tensorflow.keras.optimizers import Adadelta, Adam
from optuna.integration import TFKerasPruningCallback
tf.compat.v1.logging.set_verbosity(tf.compat.v1.logging.ERROR)
```

```
/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/tqdm/auto.py:22: TqdmWarning: IProgress not found. Please update
jupyter and ipywidgets. See
https://ipywidgets.readthedocs.io/en/stable/user_install.html
  from .autonotebook import tqdm as notebook_tqdm
```

[5]:
```
from sklearn.model_selection import KFold
```

[6]:
```
import optuna
```

[7]:
```
print("Num CPUs Available: ", len(tf.config.list_physical_devices('CPU')))
```

```
Num CPUs Available:  1
```

## 2 Optimising

[8]:
```
def objective(trial):
    n_epochs = trial.suggest_int("n_epochs", low=5, high=30, step=5)
    learning_rate = trial.suggest_float("learning_rate", 1e-5, 1e-3)
    optimiser = Adam(learning_rate=learning_rate)

    filters_1 = trial.suggest_int("filters_1",low=2,high=32,step=2)
    kernel_1 = trial.suggest_int("kernel_size_1",low=8,high=16,step=4)
    strides_1 = 1
    padding_1 = 'same'
    activation_1 = 'relu'
    input_shape = (img_rows, img_cols, 1)
    pool_size_1 = 2

    filters_2 = trial.suggest_int("filters_2",low=2,high=64,step=2)
    kernel_2 = trial.suggest_int("kernel_size_2",low=4,high=12,step=2)
    strides_2 = 1
    padding_2 = 'same'
    activation_2 = 'relu'
    pool_size_2 = 2

    dropout_rate = 0.4

    lin_1_n = trial.suggest_int("lin_1_n",low=4,high=128,step=1)

    batch_size = 128
```

```
    model = Sequential()
    model.add(Conv2D(filters=filters_1,
                     kernel_size=kernel_1,
                     strides=strides_1,
                     padding=padding_1,
                     activation=activation_1,
                     input_shape=input_shape))
    model.add(MaxPooling2D(pool_size=pool_size_1, strides=None))
    model.add(Conv2D(filters=filters_2,
                     kernel_size=kernel_2,
                     strides=strides_2,
                     padding=padding_2,
                     activation=activation_2))
    model.add(MaxPooling2D(pool_size=pool_size_2, strides=None))
    model.add(Dropout(rate=dropout_rate))
    model.add(Flatten())
    model.add(Dense(units=lin_1_n, activation='relu'))
    model.add(Dense(units=num_classes, activation='softmax'))

    model.compile(loss=categorical_crossentropy,
              optimizer=optimiser,
              metrics=['categorical_accuracy'])

    monitor = "val_categorical_accuracy"

    callbacks = [
        tf.keras.callbacks.EarlyStopping(patience=5)]
        #TFKerasPruningCallback(trial, monitor)]

    fitted = model.fit(X_train, y_train,
                       batch_size=batch_size,
                       epochs=n_epochs,
                       verbose=1,
                       validation_data=(X_test, y_test),
                       callbacks=callbacks)

    score = fitted.history[monitor][-1]

    return score
# changed trials to 50 from 10
# removed pruning but not callbacks
```

[9]:
```
train_images, val_images, train_labels, val_labels = train_test_split(mels, y,␣
 ↪test_size=0.2, random_state=42)
X_train, X_test, y_train, y_test, img_rows, img_cols =␣
 ↪format_for_CNN(train_images, val_images, train_labels, val_labels)
check_class_complete_gen(train_labels, val_labels,y)
```

OK

[10]:
```
study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=20)
```

```
[I 2022-06-09 20:25:33,179] A new study created in memory with name:
no-name-73798b03-847a-4993-af7f-7294cb16e92b

Epoch 1/25

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(
2022-06-09 20:25:33.191230: I tensorflow/core/platform/cpu_feature_guard.cc:151]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library
(oneDNN) to use the following CPU instructions in performance-critical
operations:  SSE4.1 SSE4.2 AVX AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate
compiler flags.

12/12 [==============================] - 6s 443ms/step - loss: 1.3022 -
categorical_accuracy: 0.4061 - val_loss: 1.2743 - val_categorical_accuracy:
0.3961
Epoch 2/25
12/12 [==============================] - 5s 431ms/step - loss: 1.1902 -
categorical_accuracy: 0.4650 - val_loss: 1.1877 - val_categorical_accuracy:
0.4515
Epoch 3/25
12/12 [==============================] - 5s 427ms/step - loss: 1.0843 -
categorical_accuracy: 0.5440 - val_loss: 1.0999 - val_categorical_accuracy:
0.4765
Epoch 4/25
12/12 [==============================] - 5s 438ms/step - loss: 0.9884 -
categorical_accuracy: 0.5752 - val_loss: 1.0030 - val_categorical_accuracy:
0.5596
Epoch 5/25
12/12 [==============================] - 5s 437ms/step - loss: 0.9073 -
categorical_accuracy: 0.5911 - val_loss: 0.9352 - val_categorical_accuracy:
0.5568
Epoch 6/25
12/12 [==============================] - 5s 438ms/step - loss: 0.8330 -
categorical_accuracy: 0.6348 - val_loss: 0.8726 - val_categorical_accuracy:
0.6094
Epoch 7/25
12/12 [==============================] - 5s 438ms/step - loss: 0.7706 -
categorical_accuracy: 0.6625 - val_loss: 0.8170 - val_categorical_accuracy:
0.6925
```

```
Epoch 8/25
12/12 [==============================] - 5s 443ms/step - loss: 0.7264 -
categorical_accuracy: 0.7006 - val_loss: 0.7923 - val_categorical_accuracy:
0.6620
Epoch 9/25
12/12 [==============================] - 5s 444ms/step - loss: 0.6854 -
categorical_accuracy: 0.7249 - val_loss: 0.7369 - val_categorical_accuracy:
0.7285
Epoch 10/25
12/12 [==============================] - 5s 442ms/step - loss: 0.6491 -
categorical_accuracy: 0.7484 - val_loss: 0.7071 - val_categorical_accuracy:
0.7258
Epoch 11/25
12/12 [==============================] - 5s 444ms/step - loss: 0.6234 -
categorical_accuracy: 0.7651 - val_loss: 0.6951 - val_categorical_accuracy:
0.7285
Epoch 12/25
12/12 [==============================] - 5s 455ms/step - loss: 0.6051 -
categorical_accuracy: 0.7512 - val_loss: 0.6726 - val_categorical_accuracy:
0.7258
Epoch 13/25
12/12 [==============================] - 6s 459ms/step - loss: 0.5737 -
categorical_accuracy: 0.7762 - val_loss: 0.6336 - val_categorical_accuracy:
0.7341
Epoch 14/25
12/12 [==============================] - 5s 449ms/step - loss: 0.5449 -
categorical_accuracy: 0.7769 - val_loss: 0.6132 - val_categorical_accuracy:
0.7729
Epoch 15/25
12/12 [==============================] - 6s 462ms/step - loss: 0.5334 -
categorical_accuracy: 0.7872 - val_loss: 0.5960 - val_categorical_accuracy:
0.7673
Epoch 16/25
12/12 [==============================] - 5s 448ms/step - loss: 0.5147 -
categorical_accuracy: 0.7990 - val_loss: 0.5770 - val_categorical_accuracy:
0.7867
Epoch 17/25
12/12 [==============================] - 6s 464ms/step - loss: 0.4943 -
categorical_accuracy: 0.8080 - val_loss: 0.5703 - val_categorical_accuracy:
0.7701
Epoch 18/25
12/12 [==============================] - 5s 451ms/step - loss: 0.4845 -
categorical_accuracy: 0.8115 - val_loss: 0.5545 - val_categorical_accuracy:
0.7867
Epoch 19/25
12/12 [==============================] - 5s 448ms/step - loss: 0.4634 -
categorical_accuracy: 0.8198 - val_loss: 0.5372 - val_categorical_accuracy:
0.8006
```

```
Epoch 20/25
12/12 [==============================] - 5s 453ms/step - loss: 0.4597 -
categorical_accuracy: 0.8191 - val_loss: 0.5276 - val_categorical_accuracy:
0.7895
Epoch 21/25
12/12 [==============================] - 5s 446ms/step - loss: 0.4396 -
categorical_accuracy: 0.8295 - val_loss: 0.5130 - val_categorical_accuracy:
0.8061
Epoch 22/25
12/12 [==============================] - 5s 449ms/step - loss: 0.4364 -
categorical_accuracy: 0.8378 - val_loss: 0.5001 - val_categorical_accuracy:
0.8172
Epoch 23/25
12/12 [==============================] - 5s 446ms/step - loss: 0.4161 -
categorical_accuracy: 0.8462 - val_loss: 0.4912 - val_categorical_accuracy:
0.8116
Epoch 24/25
12/12 [==============================] - 5s 447ms/step - loss: 0.4119 -
categorical_accuracy: 0.8344 - val_loss: 0.4808 - val_categorical_accuracy:
0.8310
Epoch 25/25
12/12 [==============================] - 5s 446ms/step - loss: 0.3934 -
categorical_accuracy: 0.8482 - val_loss: 0.4746 - val_categorical_accuracy:
0.8310

[I 2022-06-09 20:27:47,743] Trial 0 finished with value:
0.8310249447822571 and parameters: {'n_epochs': 25, 'learning_rate':
3.114668048184325e-05, 'filters_1': 28, 'kernel_size_1': 8, 'filters_2': 42,
'kernel_size_2': 4, 'lin_1_n': 68}. Best is trial 0 with value:
0.8310249447822571.

Epoch 1/15

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 6s 479ms/step - loss: 1.1692 -
categorical_accuracy: 0.4622 - val_loss: 0.9911 - val_categorical_accuracy:
0.5291
Epoch 2/15
12/12 [==============================] - 6s 481ms/step - loss: 0.8558 -
categorical_accuracy: 0.6078 - val_loss: 0.7993 - val_categorical_accuracy:
0.6066
Epoch 3/15
12/12 [==============================] - 6s 480ms/step - loss: 0.7287 -
categorical_accuracy: 0.6681 - val_loss: 0.7379 - val_categorical_accuracy:
0.6343
```

```
Epoch 4/15
12/12 [==============================] - 6s 475ms/step - loss: 0.6586 -
categorical_accuracy: 0.7027 - val_loss: 0.6700 - val_categorical_accuracy:
0.6898
Epoch 5/15
12/12 [==============================] - 6s 481ms/step - loss: 0.6099 -
categorical_accuracy: 0.7297 - val_loss: 0.6542 - val_categorical_accuracy:
0.6925
Epoch 6/15
12/12 [==============================] - 6s 476ms/step - loss: 0.6031 -
categorical_accuracy: 0.7353 - val_loss: 0.6060 - val_categorical_accuracy:
0.7562
Epoch 7/15
12/12 [==============================] - 6s 482ms/step - loss: 0.5627 -
categorical_accuracy: 0.7616 - val_loss: 0.5699 - val_categorical_accuracy:
0.7396
Epoch 8/15
12/12 [==============================] - 6s 472ms/step - loss: 0.5116 -
categorical_accuracy: 0.7782 - val_loss: 0.5457 - val_categorical_accuracy:
0.7424
Epoch 9/15
12/12 [==============================] - 6s 480ms/step - loss: 0.4959 -
categorical_accuracy: 0.7866 - val_loss: 0.5138 - val_categorical_accuracy:
0.7701
Epoch 10/15
12/12 [==============================] - 6s 477ms/step - loss: 0.4810 -
categorical_accuracy: 0.7872 - val_loss: 0.4952 - val_categorical_accuracy:
0.7895
Epoch 11/15
12/12 [==============================] - 6s 477ms/step - loss: 0.4479 -
categorical_accuracy: 0.8087 - val_loss: 0.4843 - val_categorical_accuracy:
0.7784
Epoch 12/15
12/12 [==============================] - 6s 482ms/step - loss: 0.4353 -
categorical_accuracy: 0.8143 - val_loss: 0.4665 - val_categorical_accuracy:
0.7895
Epoch 13/15
12/12 [==============================] - 6s 474ms/step - loss: 0.4413 -
categorical_accuracy: 0.8184 - val_loss: 0.4481 - val_categorical_accuracy:
0.7978
Epoch 14/15
12/12 [==============================] - 6s 484ms/step - loss: 0.4116 -
categorical_accuracy: 0.8198 - val_loss: 0.4238 - val_categorical_accuracy:
0.8061
Epoch 15/15
12/12 [==============================] - 6s 477ms/step - loss: 0.3800 -
categorical_accuracy: 0.8378 - val_loss: 0.4417 - val_categorical_accuracy:
0.7895
```

```
[I 2022-06-09 20:29:14,227] Trial 1 finished with value:
0.7894737124443054 and parameters: {'n_epochs': 15, 'learning_rate':
0.0008466695000589696, 'filters_1': 14, 'kernel_size_1': 12, 'filters_2': 2,
'kernel_size_2': 4, 'lin_1_n': 51}. Best is trial 0 with value:
0.8310249447822571.

Epoch 1/30

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 7s 565ms/step - loss: 1.2167 -
categorical_accuracy: 0.4511 - val_loss: 0.9868 - val_categorical_accuracy:
0.5014
Epoch 2/30
12/12 [==============================] - 7s 557ms/step - loss: 0.7425 -
categorical_accuracy: 0.6639 - val_loss: 0.7052 - val_categorical_accuracy:
0.7008
Epoch 3/30
12/12 [==============================] - 7s 587ms/step - loss: 0.5708 -
categorical_accuracy: 0.7595 - val_loss: 0.5798 - val_categorical_accuracy:
0.7452
Epoch 4/30
12/12 [==============================] - 7s 573ms/step - loss: 0.4934 -
categorical_accuracy: 0.7838 - val_loss: 0.4928 - val_categorical_accuracy:
0.8006
Epoch 5/30
12/12 [==============================] - 7s 586ms/step - loss: 0.4008 -
categorical_accuracy: 0.8413 - val_loss: 0.4520 - val_categorical_accuracy:
0.7922
Epoch 6/30
12/12 [==============================] - 7s 563ms/step - loss: 0.3425 -
categorical_accuracy: 0.8503 - val_loss: 0.3775 - val_categorical_accuracy:
0.8476
Epoch 7/30
12/12 [==============================] - 7s 565ms/step - loss: 0.3283 -
categorical_accuracy: 0.8621 - val_loss: 0.3668 - val_categorical_accuracy:
0.8199
Epoch 8/30
12/12 [==============================] - 7s 563ms/step - loss: 0.2884 -
categorical_accuracy: 0.8884 - val_loss: 0.3518 - val_categorical_accuracy:
0.8560
Epoch 9/30
12/12 [==============================] - 7s 558ms/step - loss: 0.2451 -
categorical_accuracy: 0.9002 - val_loss: 0.2755 - val_categorical_accuracy:
0.8698
```

```
Epoch 10/30
12/12 [==============================] - 7s 568ms/step - loss: 0.2198 -
categorical_accuracy: 0.9148 - val_loss: 0.2674 - val_categorical_accuracy:
0.8837
Epoch 11/30
12/12 [==============================] - 7s 561ms/step - loss: 0.2023 -
categorical_accuracy: 0.9182 - val_loss: 0.2807 - val_categorical_accuracy:
0.8920
Epoch 12/30
12/12 [==============================] - 7s 558ms/step - loss: 0.1849 -
categorical_accuracy: 0.9314 - val_loss: 0.2318 - val_categorical_accuracy:
0.8920
Epoch 13/30
12/12 [==============================] - 7s 556ms/step - loss: 0.1598 -
categorical_accuracy: 0.9494 - val_loss: 0.1997 - val_categorical_accuracy:
0.9114
Epoch 14/30
12/12 [==============================] - 7s 559ms/step - loss: 0.1409 -
categorical_accuracy: 0.9487 - val_loss: 0.1781 - val_categorical_accuracy:
0.9224
Epoch 15/30
12/12 [==============================] - 7s 561ms/step - loss: 0.1209 -
categorical_accuracy: 0.9626 - val_loss: 0.1551 - val_categorical_accuracy:
0.9474
Epoch 16/30
12/12 [==============================] - 7s 560ms/step - loss: 0.1102 -
categorical_accuracy: 0.9653 - val_loss: 0.1649 - val_categorical_accuracy:
0.9474
Epoch 17/30
12/12 [==============================] - 7s 559ms/step - loss: 0.1394 -
categorical_accuracy: 0.9411 - val_loss: 0.1223 - val_categorical_accuracy:
0.9584
Epoch 18/30
12/12 [==============================] - 7s 557ms/step - loss: 0.1117 -
categorical_accuracy: 0.9605 - val_loss: 0.1384 - val_categorical_accuracy:
0.9335
Epoch 19/30
12/12 [==============================] - 7s 560ms/step - loss: 0.0957 -
categorical_accuracy: 0.9744 - val_loss: 0.1250 - val_categorical_accuracy:
0.9529
Epoch 20/30
12/12 [==============================] - 7s 556ms/step - loss: 0.0738 -
categorical_accuracy: 0.9785 - val_loss: 0.1315 - val_categorical_accuracy:
0.9418
Epoch 21/30
12/12 [==============================] - 7s 558ms/step - loss: 0.0887 -
categorical_accuracy: 0.9709 - val_loss: 0.1061 - val_categorical_accuracy:
0.9751
```

```
Epoch 22/30
12/12 [==============================] - 7s 557ms/step - loss: 0.0680 -
categorical_accuracy: 0.9820 - val_loss: 0.1044 - val_categorical_accuracy:
0.9584
Epoch 23/30
12/12 [==============================] - 7s 572ms/step - loss: 0.0546 -
categorical_accuracy: 0.9841 - val_loss: 0.0840 - val_categorical_accuracy:
0.9695
Epoch 24/30
12/12 [==============================] - 7s 569ms/step - loss: 0.0491 -
categorical_accuracy: 0.9882 - val_loss: 0.0909 - val_categorical_accuracy:
0.9612
Epoch 25/30
12/12 [==============================] - 8s 651ms/step - loss: 0.0428 -
categorical_accuracy: 0.9924 - val_loss: 0.0857 - val_categorical_accuracy:
0.9695
Epoch 26/30
12/12 [==============================] - 8s 646ms/step - loss: 0.0463 -
categorical_accuracy: 0.9868 - val_loss: 0.0865 - val_categorical_accuracy:
0.9778
Epoch 27/30
12/12 [==============================] - 7s 613ms/step - loss: 0.0492 -
categorical_accuracy: 0.9868 - val_loss: 0.0821 - val_categorical_accuracy:
0.9751
Epoch 28/30
12/12 [==============================] - 7s 571ms/step - loss: 0.0373 -
categorical_accuracy: 0.9931 - val_loss: 0.0732 - val_categorical_accuracy:
0.9695
Epoch 29/30
12/12 [==============================] - 7s 588ms/step - loss: 0.0286 -
categorical_accuracy: 0.9972 - val_loss: 0.0706 - val_categorical_accuracy:
0.9751
Epoch 30/30
12/12 [==============================] - 7s 567ms/step - loss: 0.0331 -
categorical_accuracy: 0.9910 - val_loss: 0.0719 - val_categorical_accuracy:
0.9778

[I 2022-06-09 20:32:41,010] Trial 2 finished with value:
0.9778393507003784 and parameters: {'n_epochs': 30, 'learning_rate':
0.000499083419342223, 'filters_1': 10, 'kernel_size_1': 12, 'filters_2': 32,
'kernel_size_2': 7, 'lin_1_n': 92}. Best is trial 2 with value:
0.9778393507003784.

Epoch 1/5

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
```

```
  warnings.warn(

12/12 [==============================] - 7s 543ms/step - loss: 1.4940 -
categorical_accuracy: 0.3943 - val_loss: 1.0131 - val_categorical_accuracy:
0.5789
Epoch 2/5
12/12 [==============================] - 6s 526ms/step - loss: 0.8065 -
categorical_accuracy: 0.6694 - val_loss: 0.7378 - val_categorical_accuracy:
0.6759
Epoch 3/5
12/12 [==============================] - 6s 527ms/step - loss: 0.6066 -
categorical_accuracy: 0.7477 - val_loss: 0.5891 - val_categorical_accuracy:
0.7479
Epoch 4/5
12/12 [==============================] - 6s 529ms/step - loss: 0.5074 -
categorical_accuracy: 0.7872 - val_loss: 0.5313 - val_categorical_accuracy:
0.7618
Epoch 5/5
12/12 [==============================] - 6s 522ms/step - loss: 0.4249 -
categorical_accuracy: 0.8122 - val_loss: 0.4543 - val_categorical_accuracy:
0.7978

[I 2022-06-09 20:33:13,215] Trial 3 finished with value:
0.7977839112281799 and parameters: {'n_epochs': 5, 'learning_rate':
0.0009303770257400144, 'filters_1': 18, 'kernel_size_1': 8, 'filters_2': 38,
'kernel_size_2': 7, 'lin_1_n': 103}. Best is trial 2 with value:
0.9778393507003784.
/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

Epoch 1/5
12/12 [==============================] - 11s 849ms/step - loss: 1.1535 -
categorical_accuracy: 0.4941 - val_loss: 0.8678 - val_categorical_accuracy:
0.5540
Epoch 2/5
12/12 [==============================] - 10s 843ms/step - loss: 0.6613 -
categorical_accuracy: 0.7221 - val_loss: 0.6692 - val_categorical_accuracy:
0.7479
Epoch 3/5
12/12 [==============================] - 10s 854ms/step - loss: 0.5713 -
categorical_accuracy: 0.7533 - val_loss: 0.6787 - val_categorical_accuracy:
0.6953
Epoch 4/5
12/12 [==============================] - 10s 852ms/step - loss: 0.5039 -
categorical_accuracy: 0.7859 - val_loss: 0.5413 - val_categorical_accuracy:
0.7452
```

```
Epoch 5/5
12/12 [==============================] - 10s 848ms/step - loss: 0.4151 -
categorical_accuracy: 0.8143 - val_loss: 0.4603 - val_categorical_accuracy:
0.7756

[I 2022-06-09 20:34:04,859] Trial 4 finished with value:
0.7756232619285583 and parameters: {'n_epochs': 5, 'learning_rate':
0.0007807321186895806, 'filters_1': 8, 'kernel_size_1': 16, 'filters_2': 44,
'kernel_size_2': 7, 'lin_1_n': 59}. Best is trial 2 with value:
0.9778393507003784.

Epoch 1/30

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 7s 591ms/step - loss: 1.3142 -
categorical_accuracy: 0.3520 - val_loss: 1.2040 - val_categorical_accuracy:
0.4321
Epoch 2/30
12/12 [==============================] - 7s 589ms/step - loss: 1.0478 -
categorical_accuracy: 0.5586 - val_loss: 0.9717 - val_categorical_accuracy:
0.5512
Epoch 3/30
12/12 [==============================] - 7s 584ms/step - loss: 0.9148 -
categorical_accuracy: 0.5897 - val_loss: 0.8997 - val_categorical_accuracy:
0.6094
Epoch 4/30
12/12 [==============================] - 7s 591ms/step - loss: 0.8060 -
categorical_accuracy: 0.6514 - val_loss: 0.7504 - val_categorical_accuracy:
0.6953
Epoch 5/30
12/12 [==============================] - 7s 608ms/step - loss: 0.6884 -
categorical_accuracy: 0.7138 - val_loss: 0.6802 - val_categorical_accuracy:
0.7175
Epoch 6/30
12/12 [==============================] - 7s 580ms/step - loss: 0.6383 -
categorical_accuracy: 0.7283 - val_loss: 0.6280 - val_categorical_accuracy:
0.7285
Epoch 7/30
12/12 [==============================] - 8s 671ms/step - loss: 0.6082 -
categorical_accuracy: 0.7394 - val_loss: 0.6126 - val_categorical_accuracy:
0.7479
Epoch 8/30
12/12 [==============================] - 8s 675ms/step - loss: 0.5775 -
categorical_accuracy: 0.7637 - val_loss: 0.5798 - val_categorical_accuracy:
0.7562
```

```
Epoch 9/30
12/12 [==============================] - 8s 662ms/step - loss: 0.5337 -
categorical_accuracy: 0.7803 - val_loss: 0.4998 - val_categorical_accuracy:
0.7978
Epoch 10/30
12/12 [==============================] - 8s 658ms/step - loss: 0.5102 -
categorical_accuracy: 0.7872 - val_loss: 0.4792 - val_categorical_accuracy:
0.7922
Epoch 11/30
12/12 [==============================] - 8s 632ms/step - loss: 0.4817 -
categorical_accuracy: 0.7942 - val_loss: 0.4886 - val_categorical_accuracy:
0.7784
Epoch 12/30
12/12 [==============================] - 8s 633ms/step - loss: 0.4906 -
categorical_accuracy: 0.8032 - val_loss: 0.4844 - val_categorical_accuracy:
0.8033
Epoch 13/30
12/12 [==============================] - 8s 631ms/step - loss: 0.4363 -
categorical_accuracy: 0.8177 - val_loss: 0.4508 - val_categorical_accuracy:
0.7978
Epoch 14/30
12/12 [==============================] - 8s 639ms/step - loss: 0.4296 -
categorical_accuracy: 0.8170 - val_loss: 0.4078 - val_categorical_accuracy:
0.8172
Epoch 15/30
12/12 [==============================] - 8s 630ms/step - loss: 0.4221 -
categorical_accuracy: 0.8184 - val_loss: 0.3915 - val_categorical_accuracy:
0.8449
Epoch 16/30
12/12 [==============================] - 8s 631ms/step - loss: 0.3616 -
categorical_accuracy: 0.8517 - val_loss: 0.3690 - val_categorical_accuracy:
0.8476
Epoch 17/30
12/12 [==============================] - 8s 631ms/step - loss: 0.3609 -
categorical_accuracy: 0.8462 - val_loss: 0.3771 - val_categorical_accuracy:
0.8199
Epoch 18/30
12/12 [==============================] - 8s 643ms/step - loss: 0.3341 -
categorical_accuracy: 0.8607 - val_loss: 0.3314 - val_categorical_accuracy:
0.8615
Epoch 19/30
12/12 [==============================] - 8s 658ms/step - loss: 0.3374 -
categorical_accuracy: 0.8600 - val_loss: 0.3417 - val_categorical_accuracy:
0.8615
Epoch 20/30
12/12 [==============================] - 8s 647ms/step - loss: 0.2995 -
categorical_accuracy: 0.8773 - val_loss: 0.3003 - val_categorical_accuracy:
0.8920
```

```
Epoch 21/30
12/12 [==============================] - 8s 632ms/step - loss: 0.2913 -
categorical_accuracy: 0.8780 - val_loss: 0.2955 - val_categorical_accuracy:
0.8920
Epoch 22/30
12/12 [==============================] - 8s 634ms/step - loss: 0.2679 -
categorical_accuracy: 0.8960 - val_loss: 0.2739 - val_categorical_accuracy:
0.8920
Epoch 23/30
12/12 [==============================] - 8s 638ms/step - loss: 0.2623 -
categorical_accuracy: 0.8926 - val_loss: 0.2750 - val_categorical_accuracy:
0.8864
Epoch 24/30
12/12 [==============================] - 8s 646ms/step - loss: 0.2596 -
categorical_accuracy: 0.8884 - val_loss: 0.3023 - val_categorical_accuracy:
0.8587
Epoch 25/30
12/12 [==============================] - 8s 627ms/step - loss: 0.2321 -
categorical_accuracy: 0.9099 - val_loss: 0.3067 - val_categorical_accuracy:
0.8698
Epoch 26/30
12/12 [==============================] - 8s 632ms/step - loss: 0.2355 -
categorical_accuracy: 0.9168 - val_loss: 0.2504 - val_categorical_accuracy:
0.9003
Epoch 27/30
12/12 [==============================] - 8s 634ms/step - loss: 0.2294 -
categorical_accuracy: 0.9085 - val_loss: 0.2374 - val_categorical_accuracy:
0.9197
Epoch 28/30
12/12 [==============================] - 8s 638ms/step - loss: 0.2321 -
categorical_accuracy: 0.9106 - val_loss: 0.2409 - val_categorical_accuracy:
0.9058
Epoch 29/30
12/12 [==============================] - 8s 653ms/step - loss: 0.2304 -
categorical_accuracy: 0.9078 - val_loss: 0.2476 - val_categorical_accuracy:
0.8864
Epoch 30/30
12/12 [==============================] - 8s 637ms/step - loss: 0.2328 -
categorical_accuracy: 0.9092 - val_loss: 0.2326 - val_categorical_accuracy:
0.9141

[I 2022-06-09 20:37:52,657] Trial 5 finished with value:
0.9141274094581604 and parameters: {'n_epochs': 30, 'learning_rate':
0.0006408761013234266, 'filters_1': 32, 'kernel_size_1': 12, 'filters_2': 2,
'kernel_size_2': 4, 'lin_1_n': 82}. Best is trial 2 with value:
0.9778393507003784.

Epoch 1/30
```

```
/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(
12/12 [==============================] - 15s 1s/step - loss: 1.3743 -
categorical_accuracy: 0.3860 - val_loss: 0.9781 - val_categorical_accuracy:
0.5069
Epoch 2/30
12/12 [==============================] - 14s 1s/step - loss: 0.7881 -
categorical_accuracy: 0.6313 - val_loss: 0.6838 - val_categorical_accuracy:
0.7036
Epoch 3/30
12/12 [==============================] - 14s 1s/step - loss: 0.6487 -
categorical_accuracy: 0.7304 - val_loss: 0.6755 - val_categorical_accuracy:
0.6953
Epoch 4/30
12/12 [==============================] - 14s 1s/step - loss: 0.5721 -
categorical_accuracy: 0.7491 - val_loss: 0.5978 - val_categorical_accuracy:
0.7285
Epoch 5/30
12/12 [==============================] - 14s 1s/step - loss: 0.5357 -
categorical_accuracy: 0.7609 - val_loss: 0.5736 - val_categorical_accuracy:
0.7285
Epoch 6/30
12/12 [==============================] - 14s 1s/step - loss: 0.4793 -
categorical_accuracy: 0.7907 - val_loss: 0.4935 - val_categorical_accuracy:
0.7812
Epoch 7/30
12/12 [==============================] - 14s 1s/step - loss: 0.4347 -
categorical_accuracy: 0.8060 - val_loss: 0.4607 - val_categorical_accuracy:
0.7673
Epoch 8/30
12/12 [==============================] - 14s 1s/step - loss: 0.3752 -
categorical_accuracy: 0.8233 - val_loss: 0.4356 - val_categorical_accuracy:
0.8144
Epoch 9/30
12/12 [==============================] - 14s 1s/step - loss: 0.3470 -
categorical_accuracy: 0.8427 - val_loss: 0.3847 - val_categorical_accuracy:
0.8227
Epoch 10/30
12/12 [==============================] - 14s 1s/step - loss: 0.2968 -
categorical_accuracy: 0.8773 - val_loss: 0.3384 - val_categorical_accuracy:
0.8560
Epoch 11/30
12/12 [==============================] - 14s 1s/step - loss: 0.2597 -
categorical_accuracy: 0.8891 - val_loss: 0.2541 - val_categorical_accuracy:
```

```
0.9224
Epoch 12/30
12/12 [==============================] - 14s 1s/step - loss: 0.2087 -
categorical_accuracy: 0.9258 - val_loss: 0.2238 - val_categorical_accuracy:
0.9169
Epoch 13/30
12/12 [==============================] - 14s 1s/step - loss: 0.1800 -
categorical_accuracy: 0.9279 - val_loss: 0.2254 - val_categorical_accuracy:
0.8975
Epoch 14/30
12/12 [==============================] - 14s 1s/step - loss: 0.1406 -
categorical_accuracy: 0.9487 - val_loss: 0.1412 - val_categorical_accuracy:
0.9584
Epoch 15/30
12/12 [==============================] - 14s 1s/step - loss: 0.1277 -
categorical_accuracy: 0.9508 - val_loss: 0.1230 - val_categorical_accuracy:
0.9723
Epoch 16/30
12/12 [==============================] - 14s 1s/step - loss: 0.1037 -
categorical_accuracy: 0.9626 - val_loss: 0.1141 - val_categorical_accuracy:
0.9668
Epoch 17/30
12/12 [==============================] - 14s 1s/step - loss: 0.0847 -
categorical_accuracy: 0.9709 - val_loss: 0.0930 - val_categorical_accuracy:
0.9778
Epoch 18/30
12/12 [==============================] - 14s 1s/step - loss: 0.0861 -
categorical_accuracy: 0.9723 - val_loss: 0.1043 - val_categorical_accuracy:
0.9778
Epoch 19/30
12/12 [==============================] - 14s 1s/step - loss: 0.0704 -
categorical_accuracy: 0.9799 - val_loss: 0.0866 - val_categorical_accuracy:
0.9834
Epoch 20/30
12/12 [==============================] - 14s 1s/step - loss: 0.0587 -
categorical_accuracy: 0.9799 - val_loss: 0.0986 - val_categorical_accuracy:
0.9778
Epoch 21/30
12/12 [==============================] - 14s 1s/step - loss: 0.0543 -
categorical_accuracy: 0.9861 - val_loss: 0.0819 - val_categorical_accuracy:
0.9806
Epoch 22/30
12/12 [==============================] - 14s 1s/step - loss: 0.0477 -
categorical_accuracy: 0.9868 - val_loss: 0.0785 - val_categorical_accuracy:
0.9751
Epoch 23/30
12/12 [==============================] - 14s 1s/step - loss: 0.0456 -
categorical_accuracy: 0.9854 - val_loss: 0.1281 - val_categorical_accuracy:
```

```
0.9529
Epoch 24/30
12/12 [==============================] - 14s 1s/step - loss: 0.0513 -
categorical_accuracy: 0.9827 - val_loss: 0.0847 - val_categorical_accuracy:
0.9806
Epoch 25/30
12/12 [==============================] - 14s 1s/step - loss: 0.0313 -
categorical_accuracy: 0.9924 - val_loss: 0.0725 - val_categorical_accuracy:
0.9806
Epoch 26/30
12/12 [==============================] - 14s 1s/step - loss: 0.0246 -
categorical_accuracy: 0.9924 - val_loss: 0.0843 - val_categorical_accuracy:
0.9778
Epoch 27/30
12/12 [==============================] - 14s 1s/step - loss: 0.0236 -
categorical_accuracy: 0.9924 - val_loss: 0.0811 - val_categorical_accuracy:
0.9778
Epoch 28/30
12/12 [==============================] - 14s 1s/step - loss: 0.0237 -
categorical_accuracy: 0.9903 - val_loss: 0.0999 - val_categorical_accuracy:
0.9778
Epoch 29/30
12/12 [==============================] - 14s 1s/step - loss: 0.0244 -
categorical_accuracy: 0.9931 - val_loss: 0.0775 - val_categorical_accuracy:
0.9806
Epoch 30/30
12/12 [==============================] - 14s 1s/step - loss: 0.0178 -
categorical_accuracy: 0.9958 - val_loss: 0.0643 - val_categorical_accuracy:
0.9778

[I 2022-06-09 20:44:54,859] Trial 6 finished with value:
0.9778393507003784 and parameters: {'n_epochs': 30, 'learning_rate':
0.0007589730295466081, 'filters_1': 18, 'kernel_size_1': 12, 'filters_2': 56,
'kernel_size_2': 10, 'lin_1_n': 59}. Best is trial 2 with value:
0.9778393507003784.

Epoch 1/15

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 6s 466ms/step - loss: 1.1235 -
categorical_accuracy: 0.5177 - val_loss: 0.9196 - val_categorical_accuracy:
0.6427
Epoch 2/15
12/12 [==============================] - 6s 466ms/step - loss: 0.8142 -
categorical_accuracy: 0.6424 - val_loss: 0.8021 - val_categorical_accuracy:
```

```
0.6620
Epoch 3/15
12/12 [==============================] - 6s 465ms/step - loss: 0.6957 -
categorical_accuracy: 0.6888 - val_loss: 0.7177 - val_categorical_accuracy:
0.7313
Epoch 4/15
12/12 [==============================] - 6s 468ms/step - loss: 0.6022 -
categorical_accuracy: 0.7554 - val_loss: 0.6410 - val_categorical_accuracy:
0.7396
Epoch 5/15
12/12 [==============================] - 6s 468ms/step - loss: 0.5343 -
categorical_accuracy: 0.7970 - val_loss: 0.5964 - val_categorical_accuracy:
0.7535
Epoch 6/15
12/12 [==============================] - 6s 463ms/step - loss: 0.5007 -
categorical_accuracy: 0.7907 - val_loss: 0.5343 - val_categorical_accuracy:
0.7867
Epoch 7/15
12/12 [==============================] - 6s 463ms/step - loss: 0.4439 -
categorical_accuracy: 0.8261 - val_loss: 0.5366 - val_categorical_accuracy:
0.7396
Epoch 8/15
12/12 [==============================] - 6s 466ms/step - loss: 0.4165 -
categorical_accuracy: 0.8309 - val_loss: 0.4749 - val_categorical_accuracy:
0.8089
Epoch 9/15
12/12 [==============================] - 6s 464ms/step - loss: 0.3809 -
categorical_accuracy: 0.8510 - val_loss: 0.4370 - val_categorical_accuracy:
0.8476
Epoch 10/15
12/12 [==============================] - 6s 463ms/step - loss: 0.3475 -
categorical_accuracy: 0.8663 - val_loss: 0.4089 - val_categorical_accuracy:
0.8532
Epoch 11/15
12/12 [==============================] - 6s 460ms/step - loss: 0.3213 -
categorical_accuracy: 0.8843 - val_loss: 0.3836 - val_categorical_accuracy:
0.8615
Epoch 12/15
12/12 [==============================] - 6s 478ms/step - loss: 0.3007 -
categorical_accuracy: 0.8926 - val_loss: 0.3850 - val_categorical_accuracy:
0.8476
Epoch 13/15
12/12 [==============================] - 6s 487ms/step - loss: 0.2769 -
categorical_accuracy: 0.8981 - val_loss: 0.3838 - val_categorical_accuracy:
0.8560
Epoch 14/15
12/12 [==============================] - 6s 481ms/step - loss: 0.2741 -
categorical_accuracy: 0.8981 - val_loss: 0.3765 - val_categorical_accuracy:
```

```
0.8560
Epoch 15/15
12/12 [==============================] - 6s 467ms/step - loss: 0.2561 -
categorical_accuracy: 0.9023 - val_loss: 0.3741 - val_categorical_accuracy:
0.8532

[I 2022-06-09 20:46:19,743] Trial 7 finished with value:
0.8531855940818787 and parameters: {'n_epochs': 15, 'learning_rate':
0.00019474565965705304, 'filters_1': 2, 'kernel_size_1': 12, 'filters_2': 58,
'kernel_size_2': 4, 'lin_1_n': 117}. Best is trial 2 with value:
0.9778393507003784.

Epoch 1/25

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 22s 2s/step - loss: 1.1954 -
categorical_accuracy: 0.4532 - val_loss: 0.9357 - val_categorical_accuracy:
0.5346
Epoch 2/25
12/12 [==============================] - 22s 2s/step - loss: 0.7350 -
categorical_accuracy: 0.6958 - val_loss: 0.7045 - val_categorical_accuracy:
0.7258
Epoch 3/25
12/12 [==============================] - 22s 2s/step - loss: 0.5947 -
categorical_accuracy: 0.7484 - val_loss: 0.6346 - val_categorical_accuracy:
0.7036
Epoch 4/25
12/12 [==============================] - 22s 2s/step - loss: 0.5126 -
categorical_accuracy: 0.7796 - val_loss: 0.5342 - val_categorical_accuracy:
0.7812
Epoch 5/25
12/12 [==============================] - 22s 2s/step - loss: 0.4192 -
categorical_accuracy: 0.8247 - val_loss: 0.5539 - val_categorical_accuracy:
0.7175
Epoch 6/25
12/12 [==============================] - 24s 2s/step - loss: 0.3937 -
categorical_accuracy: 0.8371 - val_loss: 0.4239 - val_categorical_accuracy:
0.7978
Epoch 7/25
12/12 [==============================] - 23s 2s/step - loss: 0.3354 -
categorical_accuracy: 0.8475 - val_loss: 0.4741 - val_categorical_accuracy:
0.8199
Epoch 8/25
12/12 [==============================] - 22s 2s/step - loss: 0.2939 -
categorical_accuracy: 0.8739 - val_loss: 0.3240 - val_categorical_accuracy:
```

```
0.8837
Epoch 9/25
12/12 [==============================] - 22s 2s/step - loss: 0.2469 -
categorical_accuracy: 0.8967 - val_loss: 0.2726 - val_categorical_accuracy:
0.8837
Epoch 10/25
12/12 [==============================] - 22s 2s/step - loss: 0.2346 -
categorical_accuracy: 0.9023 - val_loss: 0.3149 - val_categorical_accuracy:
0.8449
Epoch 11/25
12/12 [==============================] - 22s 2s/step - loss: 0.2133 -
categorical_accuracy: 0.9155 - val_loss: 0.3323 - val_categorical_accuracy:
0.8449
Epoch 12/25
12/12 [==============================] - 22s 2s/step - loss: 0.2122 -
categorical_accuracy: 0.9141 - val_loss: 0.2232 - val_categorical_accuracy:
0.9003
Epoch 13/25
12/12 [==============================] - 22s 2s/step - loss: 0.1651 -
categorical_accuracy: 0.9446 - val_loss: 0.1921 - val_categorical_accuracy:
0.9280
Epoch 14/25
12/12 [==============================] - 22s 2s/step - loss: 0.1440 -
categorical_accuracy: 0.9466 - val_loss: 0.1544 - val_categorical_accuracy:
0.9529
Epoch 15/25
12/12 [==============================] - 22s 2s/step - loss: 0.1300 -
categorical_accuracy: 0.9550 - val_loss: 0.1458 - val_categorical_accuracy:
0.9501
Epoch 16/25
12/12 [==============================] - 22s 2s/step - loss: 0.1299 -
categorical_accuracy: 0.9536 - val_loss: 0.1528 - val_categorical_accuracy:
0.9474
Epoch 17/25
12/12 [==============================] - 22s 2s/step - loss: 0.1084 -
categorical_accuracy: 0.9647 - val_loss: 0.1312 - val_categorical_accuracy:
0.9640
Epoch 18/25
12/12 [==============================] - 22s 2s/step - loss: 0.0970 -
categorical_accuracy: 0.9688 - val_loss: 0.1428 - val_categorical_accuracy:
0.9335
Epoch 19/25
12/12 [==============================] - 22s 2s/step - loss: 0.0929 -
categorical_accuracy: 0.9716 - val_loss: 0.0950 - val_categorical_accuracy:
0.9723
Epoch 20/25
12/12 [==============================] - 22s 2s/step - loss: 0.0683 -
categorical_accuracy: 0.9799 - val_loss: 0.1049 - val_categorical_accuracy:
```

```
0.9695
Epoch 21/25
12/12 [==============================] - 22s 2s/step - loss: 0.0791 -
categorical_accuracy: 0.9764 - val_loss: 0.0919 - val_categorical_accuracy:
0.9668
Epoch 22/25
12/12 [==============================] - 22s 2s/step - loss: 0.0638 -
categorical_accuracy: 0.9820 - val_loss: 0.0952 - val_categorical_accuracy:
0.9668
Epoch 23/25
12/12 [==============================] - 22s 2s/step - loss: 0.0594 -
categorical_accuracy: 0.9813 - val_loss: 0.0783 - val_categorical_accuracy:
0.9695
Epoch 24/25
12/12 [==============================] - 22s 2s/step - loss: 0.0510 -
categorical_accuracy: 0.9848 - val_loss: 0.0793 - val_categorical_accuracy:
0.9778
Epoch 25/25
12/12 [==============================] - 22s 2s/step - loss: 0.0471 -
categorical_accuracy: 0.9854 - val_loss: 0.0648 - val_categorical_accuracy:
0.9806

[I 2022-06-09 20:55:31,247] Trial 8 finished with value:
0.9806094169616699 and parameters: {'n_epochs': 25, 'learning_rate':
0.0004077468450779683, 'filters_1': 32, 'kernel_size_1': 12, 'filters_2': 62,
'kernel_size_2': 10, 'lin_1_n': 102}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/15

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 16s 1s/step - loss: 1.0197 -
categorical_accuracy: 0.5482 - val_loss: 0.8524 - val_categorical_accuracy:
0.5568
Epoch 2/15
12/12 [==============================] - 15s 1s/step - loss: 0.6885 -
categorical_accuracy: 0.6930 - val_loss: 0.6928 - val_categorical_accuracy:
0.7202
Epoch 3/15
12/12 [==============================] - 15s 1s/step - loss: 0.5939 -
categorical_accuracy: 0.7561 - val_loss: 0.5913 - val_categorical_accuracy:
0.7535
Epoch 4/15
12/12 [==============================] - 15s 1s/step - loss: 0.5080 -
categorical_accuracy: 0.7838 - val_loss: 0.5334 - val_categorical_accuracy:
```

```
0.7673
Epoch 5/15
12/12 [==============================] - 15s 1s/step - loss: 0.4647 -
categorical_accuracy: 0.8039 - val_loss: 0.4743 - val_categorical_accuracy:
0.8006
Epoch 6/15
12/12 [==============================] - 15s 1s/step - loss: 0.4188 -
categorical_accuracy: 0.8254 - val_loss: 0.4394 - val_categorical_accuracy:
0.8061
Epoch 7/15
12/12 [==============================] - 15s 1s/step - loss: 0.3683 -
categorical_accuracy: 0.8510 - val_loss: 0.4099 - val_categorical_accuracy:
0.8089
Epoch 8/15
12/12 [==============================] - 15s 1s/step - loss: 0.3471 -
categorical_accuracy: 0.8496 - val_loss: 0.3786 - val_categorical_accuracy:
0.8532
Epoch 9/15
12/12 [==============================] - 16s 1s/step - loss: 0.2936 -
categorical_accuracy: 0.8808 - val_loss: 0.4753 - val_categorical_accuracy:
0.7784
Epoch 10/15
12/12 [==============================] - 16s 1s/step - loss: 0.3055 -
categorical_accuracy: 0.8711 - val_loss: 0.3496 - val_categorical_accuracy:
0.8587
Epoch 11/15
12/12 [==============================] - 15s 1s/step - loss: 0.2652 -
categorical_accuracy: 0.8933 - val_loss: 0.3018 - val_categorical_accuracy:
0.8864
Epoch 12/15
12/12 [==============================] - 15s 1s/step - loss: 0.2451 -
categorical_accuracy: 0.9037 - val_loss: 0.2788 - val_categorical_accuracy:
0.8947
Epoch 13/15
12/12 [==============================] - 16s 1s/step - loss: 0.2169 -
categorical_accuracy: 0.9127 - val_loss: 0.2948 - val_categorical_accuracy:
0.8643
Epoch 14/15
12/12 [==============================] - 15s 1s/step - loss: 0.2073 -
categorical_accuracy: 0.9203 - val_loss: 0.2282 - val_categorical_accuracy:
0.9224
Epoch 15/15
12/12 [==============================] - 15s 1s/step - loss: 0.1805 -
categorical_accuracy: 0.9404 - val_loss: 0.2251 - val_categorical_accuracy:
0.9086

[I 2022-06-09 20:59:23,564] Trial 9 finished with value:
0.9085872769355774 and parameters: {'n_epochs': 15, 'learning_rate':
```

```
0.00023170259915135085, 'filters_1': 16, 'kernel_size_1': 16, 'filters_2': 40,
'kernel_size_2': 10, 'lin_1_n': 76}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/20

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 18s 1s/step - loss: 1.0736 -
categorical_accuracy: 0.5211 - val_loss: 0.8121 - val_categorical_accuracy:
0.5706
Epoch 2/20
12/12 [==============================] - 18s 2s/step - loss: 0.6695 -
categorical_accuracy: 0.7027 - val_loss: 0.6235 - val_categorical_accuracy:
0.7285
Epoch 3/20
12/12 [==============================] - 17s 1s/step - loss: 0.5677 -
categorical_accuracy: 0.7547 - val_loss: 0.6619 - val_categorical_accuracy:
0.7036
Epoch 4/20
12/12 [==============================] - 17s 1s/step - loss: 0.5637 -
categorical_accuracy: 0.7519 - val_loss: 0.5936 - val_categorical_accuracy:
0.7313
Epoch 5/20
12/12 [==============================] - 17s 1s/step - loss: 0.5006 -
categorical_accuracy: 0.7789 - val_loss: 0.5471 - val_categorical_accuracy:
0.7479
Epoch 6/20
12/12 [==============================] - 17s 1s/step - loss: 0.4366 -
categorical_accuracy: 0.8226 - val_loss: 0.5372 - val_categorical_accuracy:
0.7424
Epoch 7/20
12/12 [==============================] - 17s 1s/step - loss: 0.4483 -
categorical_accuracy: 0.7976 - val_loss: 0.5645 - val_categorical_accuracy:
0.7645
Epoch 8/20
12/12 [==============================] - 17s 1s/step - loss: 0.4023 -
categorical_accuracy: 0.8164 - val_loss: 0.5286 - val_categorical_accuracy:
0.7922
Epoch 9/20
12/12 [==============================] - 17s 1s/step - loss: 0.3906 -
categorical_accuracy: 0.8053 - val_loss: 0.4224 - val_categorical_accuracy:
0.8199
Epoch 10/20
12/12 [==============================] - 17s 1s/step - loss: 0.3097 -
```

```
categorical_accuracy: 0.8683 - val_loss: 0.3553 - val_categorical_accuracy:
0.8532
Epoch 11/20
12/12 [==============================] - 17s 1s/step - loss: 0.2791 -
categorical_accuracy: 0.8850 - val_loss: 0.4035 - val_categorical_accuracy:
0.8144
Epoch 12/20
12/12 [==============================] - 17s 1s/step - loss: 0.2834 -
categorical_accuracy: 0.8815 - val_loss: 0.2746 - val_categorical_accuracy:
0.9141
Epoch 13/20
12/12 [==============================] - 17s 1s/step - loss: 0.2369 -
categorical_accuracy: 0.9071 - val_loss: 0.3134 - val_categorical_accuracy:
0.8615
Epoch 14/20
12/12 [==============================] - 17s 1s/step - loss: 0.2292 -
categorical_accuracy: 0.9085 - val_loss: 0.2459 - val_categorical_accuracy:
0.9003
Epoch 15/20
12/12 [==============================] - 17s 1s/step - loss: 0.2100 -
categorical_accuracy: 0.9217 - val_loss: 0.2618 - val_categorical_accuracy:
0.8837
Epoch 16/20
12/12 [==============================] - 17s 1s/step - loss: 0.2082 -
categorical_accuracy: 0.9196 - val_loss: 0.2163 - val_categorical_accuracy:
0.9086
Epoch 17/20
12/12 [==============================] - 17s 1s/step - loss: 0.1743 -
categorical_accuracy: 0.9411 - val_loss: 0.1763 - val_categorical_accuracy:
0.9391
Epoch 18/20
12/12 [==============================] - 17s 1s/step - loss: 0.1449 -
categorical_accuracy: 0.9494 - val_loss: 0.1682 - val_categorical_accuracy:
0.9446
Epoch 19/20
12/12 [==============================] - 17s 1s/step - loss: 0.1335 -
categorical_accuracy: 0.9529 - val_loss: 0.1450 - val_categorical_accuracy:
0.9529
Epoch 20/20
12/12 [==============================] - 19s 2s/step - loss: 0.1292 -
categorical_accuracy: 0.9494 - val_loss: 0.1682 - val_categorical_accuracy:
0.9307

[I 2022-06-09 21:05:07,679] Trial 10 finished with value:
0.930747926235199 and parameters: {'n_epochs': 20, 'learning_rate':
0.00046319989217264996, 'filters_1': 24, 'kernel_size_1': 16, 'filters_2': 22,
'kernel_size_2': 10, 'lin_1_n': 27}. Best is trial 8 with value:
0.9806094169616699.
```

```
Epoch 1/25
/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(
12/12 [==============================] - 5s 362ms/step - loss: 1.2028 -
categorical_accuracy: 0.4761 - val_loss: 1.0477 - val_categorical_accuracy:
0.4681
Epoch 2/25
12/12 [==============================] - 4s 343ms/step - loss: 0.8072 -
categorical_accuracy: 0.6341 - val_loss: 0.7505 - val_categorical_accuracy:
0.6787
Epoch 3/25
12/12 [==============================] - 4s 348ms/step - loss: 0.6125 -
categorical_accuracy: 0.7318 - val_loss: 0.6451 - val_categorical_accuracy:
0.7313
Epoch 4/25
12/12 [==============================] - 4s 345ms/step - loss: 0.5437 -
categorical_accuracy: 0.7574 - val_loss: 0.5795 - val_categorical_accuracy:
0.7645
Epoch 5/25
12/12 [==============================] - 4s 345ms/step - loss: 0.4772 -
categorical_accuracy: 0.7949 - val_loss: 0.5308 - val_categorical_accuracy:
0.7922
Epoch 6/25
12/12 [==============================] - 4s 338ms/step - loss: 0.4324 -
categorical_accuracy: 0.8025 - val_loss: 0.5166 - val_categorical_accuracy:
0.7978
Epoch 7/25
12/12 [==============================] - 4s 340ms/step - loss: 0.4084 -
categorical_accuracy: 0.8295 - val_loss: 0.4879 - val_categorical_accuracy:
0.8061
Epoch 8/25
12/12 [==============================] - 4s 341ms/step - loss: 0.3736 -
categorical_accuracy: 0.8468 - val_loss: 0.4181 - val_categorical_accuracy:
0.8310
Epoch 9/25
12/12 [==============================] - 4s 332ms/step - loss: 0.3239 -
categorical_accuracy: 0.8676 - val_loss: 0.3696 - val_categorical_accuracy:
0.8338
Epoch 10/25
12/12 [==============================] - 4s 338ms/step - loss: 0.2933 -
categorical_accuracy: 0.8760 - val_loss: 0.3419 - val_categorical_accuracy:
0.8809
Epoch 11/25
12/12 [==============================] - 4s 334ms/step - loss: 0.2752 -
```

```
categorical_accuracy: 0.8912 - val_loss: 0.3296 - val_categorical_accuracy:
0.8532
Epoch 12/25
12/12 [==============================] - 4s 337ms/step - loss: 0.2646 -
categorical_accuracy: 0.8905 - val_loss: 0.3906 - val_categorical_accuracy:
0.8338
Epoch 13/25
12/12 [==============================] - 4s 337ms/step - loss: 0.2657 -
categorical_accuracy: 0.8926 - val_loss: 0.2822 - val_categorical_accuracy:
0.8864
Epoch 14/25
12/12 [==============================] - 4s 354ms/step - loss: 0.2217 -
categorical_accuracy: 0.9203 - val_loss: 0.2530 - val_categorical_accuracy:
0.9169
Epoch 15/25
12/12 [==============================] - 4s 340ms/step - loss: 0.2124 -
categorical_accuracy: 0.9099 - val_loss: 0.2965 - val_categorical_accuracy:
0.8892
Epoch 16/25
12/12 [==============================] - 4s 339ms/step - loss: 0.2065 -
categorical_accuracy: 0.9182 - val_loss: 0.2708 - val_categorical_accuracy:
0.8809
Epoch 17/25
12/12 [==============================] - 4s 343ms/step - loss: 0.1945 -
categorical_accuracy: 0.9307 - val_loss: 0.2204 - val_categorical_accuracy:
0.9391
Epoch 18/25
12/12 [==============================] - 4s 332ms/step - loss: 0.1692 -
categorical_accuracy: 0.9342 - val_loss: 0.2076 - val_categorical_accuracy:
0.9224
Epoch 19/25
12/12 [==============================] - 4s 336ms/step - loss: 0.1541 -
categorical_accuracy: 0.9494 - val_loss: 0.1961 - val_categorical_accuracy:
0.9418
Epoch 20/25
12/12 [==============================] - 4s 335ms/step - loss: 0.1446 -
categorical_accuracy: 0.9522 - val_loss: 0.1780 - val_categorical_accuracy:
0.9391
Epoch 21/25
12/12 [==============================] - 4s 332ms/step - loss: 0.1356 -
categorical_accuracy: 0.9536 - val_loss: 0.1859 - val_categorical_accuracy:
0.9418
Epoch 22/25
12/12 [==============================] - 4s 336ms/step - loss: 0.1262 -
categorical_accuracy: 0.9584 - val_loss: 0.1692 - val_categorical_accuracy:
0.9335
Epoch 23/25
12/12 [==============================] - 4s 333ms/step - loss: 0.1244 -
```

```
categorical_accuracy: 0.9536 - val_loss: 0.1694 - val_categorical_accuracy:
0.9446
Epoch 24/25
12/12 [==============================] - 4s 333ms/step - loss: 0.1146 -
categorical_accuracy: 0.9612 - val_loss: 0.1598 - val_categorical_accuracy:
0.9474
Epoch 25/25
12/12 [==============================] - 4s 342ms/step - loss: 0.1070 -
categorical_accuracy: 0.9667 - val_loss: 0.1504 - val_categorical_accuracy:
0.9418

[I 2022-06-09 21:06:50,305] Trial 11 finished with value:
0.9418282508850098 and parameters: {'n_epochs': 25, 'learning_rate':
0.0004644989725160682, 'filters_1': 8, 'kernel_size_1': 8, 'filters_2': 20,
'kernel_size_2': 7, 'lin_1_n': 101}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/25

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 14s 1s/step - loss: 1.0629 -
categorical_accuracy: 0.5218 - val_loss: 0.7981 - val_categorical_accuracy:
0.6371
Epoch 2/25
12/12 [==============================] - 13s 1s/step - loss: 0.6772 -
categorical_accuracy: 0.7055 - val_loss: 0.6962 - val_categorical_accuracy:
0.7036
Epoch 3/25
12/12 [==============================] - 13s 1s/step - loss: 0.6069 -
categorical_accuracy: 0.7332 - val_loss: 0.5950 - val_categorical_accuracy:
0.7535
Epoch 4/25
12/12 [==============================] - 13s 1s/step - loss: 0.5207 -
categorical_accuracy: 0.7692 - val_loss: 0.5212 - val_categorical_accuracy:
0.7812
Epoch 5/25
12/12 [==============================] - 14s 1s/step - loss: 0.4518 -
categorical_accuracy: 0.8053 - val_loss: 0.4712 - val_categorical_accuracy:
0.7978
Epoch 6/25
12/12 [==============================] - 13s 1s/step - loss: 0.3721 -
categorical_accuracy: 0.8545 - val_loss: 0.4093 - val_categorical_accuracy:
0.8255
Epoch 7/25
12/12 [==============================] - 13s 1s/step - loss: 0.3445 -
```

```
categorical_accuracy: 0.8559 - val_loss: 0.3872 - val_categorical_accuracy:
0.8089
Epoch 8/25
12/12 [==============================] - 13s 1s/step - loss: 0.2877 -
categorical_accuracy: 0.8829 - val_loss: 0.3352 - val_categorical_accuracy:
0.8670
Epoch 9/25
12/12 [==============================] - 13s 1s/step - loss: 0.2641 -
categorical_accuracy: 0.8905 - val_loss: 0.3865 - val_categorical_accuracy:
0.7839
Epoch 10/25
12/12 [==============================] - 13s 1s/step - loss: 0.2443 -
categorical_accuracy: 0.8933 - val_loss: 0.2960 - val_categorical_accuracy:
0.8753
Epoch 11/25
12/12 [==============================] - 13s 1s/step - loss: 0.2113 -
categorical_accuracy: 0.9175 - val_loss: 0.2604 - val_categorical_accuracy:
0.8837
Epoch 12/25
12/12 [==============================] - 13s 1s/step - loss: 0.1877 -
categorical_accuracy: 0.9328 - val_loss: 0.2205 - val_categorical_accuracy:
0.9197
Epoch 13/25
12/12 [==============================] - 14s 1s/step - loss: 0.1544 -
categorical_accuracy: 0.9459 - val_loss: 0.2160 - val_categorical_accuracy:
0.9252
Epoch 14/25
12/12 [==============================] - 13s 1s/step - loss: 0.1452 -
categorical_accuracy: 0.9494 - val_loss: 0.1944 - val_categorical_accuracy:
0.9224
Epoch 15/25
12/12 [==============================] - 14s 1s/step - loss: 0.1360 -
categorical_accuracy: 0.9591 - val_loss: 0.1722 - val_categorical_accuracy:
0.9529
Epoch 16/25
12/12 [==============================] - 14s 1s/step - loss: 0.1125 -
categorical_accuracy: 0.9653 - val_loss: 0.1449 - val_categorical_accuracy:
0.9557
Epoch 17/25
12/12 [==============================] - 13s 1s/step - loss: 0.1045 -
categorical_accuracy: 0.9695 - val_loss: 0.1449 - val_categorical_accuracy:
0.9584
Epoch 18/25
12/12 [==============================] - 13s 1s/step - loss: 0.0938 -
categorical_accuracy: 0.9709 - val_loss: 0.1308 - val_categorical_accuracy:
0.9557
Epoch 19/25
12/12 [==============================] - 14s 1s/step - loss: 0.0893 -
```

```
categorical_accuracy: 0.9716 - val_loss: 0.1332 - val_categorical_accuracy:
0.9474
Epoch 20/25
12/12 [==============================] - 13s 1s/step - loss: 0.0816 -
categorical_accuracy: 0.9702 - val_loss: 0.1245 - val_categorical_accuracy:
0.9584
Epoch 21/25
12/12 [==============================] - 13s 1s/step - loss: 0.0881 -
categorical_accuracy: 0.9688 - val_loss: 0.1515 - val_categorical_accuracy:
0.9307
Epoch 22/25
12/12 [==============================] - 13s 1s/step - loss: 0.0841 -
categorical_accuracy: 0.9751 - val_loss: 0.1187 - val_categorical_accuracy:
0.9695
Epoch 23/25
12/12 [==============================] - 13s 1s/step - loss: 0.0689 -
categorical_accuracy: 0.9785 - val_loss: 0.1248 - val_categorical_accuracy:
0.9723
Epoch 24/25
12/12 [==============================] - 13s 1s/step - loss: 0.0763 -
categorical_accuracy: 0.9730 - val_loss: 0.0905 - val_categorical_accuracy:
0.9668
Epoch 25/25
12/12 [==============================] - 13s 1s/step - loss: 0.0497 -
categorical_accuracy: 0.9868 - val_loss: 0.1076 - val_categorical_accuracy:
0.9584

[I 2022-06-09 21:12:25,939] Trial 12 finished with value:
0.9584487676620483 and parameters: {'n_epochs': 25, 'learning_rate':
0.0003634667849786947, 'filters_1': 24, 'kernel_size_1': 12, 'filters_2': 28,
'kernel_size_2': 10, 'lin_1_n': 128}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/30

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 8s 645ms/step - loss: 1.0912 -
categorical_accuracy: 0.4976 - val_loss: 0.8393 - val_categorical_accuracy:
0.6205
Epoch 2/30
12/12 [==============================] - 8s 634ms/step - loss: 0.6434 -
categorical_accuracy: 0.7422 - val_loss: 0.6070 - val_categorical_accuracy:
0.7424
Epoch 3/30
12/12 [==============================] - 8s 631ms/step - loss: 0.4943 -
```

```
categorical_accuracy: 0.7845 - val_loss: 0.5343 - val_categorical_accuracy:
0.7618
Epoch 4/30
12/12 [==============================] - 8s 628ms/step - loss: 0.3904 -
categorical_accuracy: 0.8267 - val_loss: 0.4174 - val_categorical_accuracy:
0.8116
Epoch 5/30
12/12 [==============================] - 7s 625ms/step - loss: 0.3199 -
categorical_accuracy: 0.8773 - val_loss: 0.3888 - val_categorical_accuracy:
0.8089
Epoch 6/30
12/12 [==============================] - 7s 623ms/step - loss: 0.2604 -
categorical_accuracy: 0.9037 - val_loss: 0.3380 - val_categorical_accuracy:
0.8532
Epoch 7/30
12/12 [==============================] - 8s 633ms/step - loss: 0.2278 -
categorical_accuracy: 0.9141 - val_loss: 0.2670 - val_categorical_accuracy:
0.9003
Epoch 8/30
12/12 [==============================] - 8s 622ms/step - loss: 0.1868 -
categorical_accuracy: 0.9307 - val_loss: 0.2604 - val_categorical_accuracy:
0.8947
Epoch 9/30
12/12 [==============================] - 7s 618ms/step - loss: 0.1504 -
categorical_accuracy: 0.9494 - val_loss: 0.2444 - val_categorical_accuracy:
0.9030
Epoch 10/30
12/12 [==============================] - 7s 619ms/step - loss: 0.1458 -
categorical_accuracy: 0.9459 - val_loss: 0.2327 - val_categorical_accuracy:
0.9169
Epoch 11/30
12/12 [==============================] - 7s 620ms/step - loss: 0.1352 -
categorical_accuracy: 0.9556 - val_loss: 0.1846 - val_categorical_accuracy:
0.9252
Epoch 12/30
12/12 [==============================] - 7s 617ms/step - loss: 0.1049 -
categorical_accuracy: 0.9653 - val_loss: 0.1730 - val_categorical_accuracy:
0.9307
Epoch 13/30
12/12 [==============================] - 7s 620ms/step - loss: 0.1055 -
categorical_accuracy: 0.9619 - val_loss: 0.1596 - val_categorical_accuracy:
0.9529
Epoch 14/30
12/12 [==============================] - 7s 618ms/step - loss: 0.1023 -
categorical_accuracy: 0.9681 - val_loss: 0.1417 - val_categorical_accuracy:
0.9557
Epoch 15/30
12/12 [==============================] - 7s 622ms/step - loss: 0.0718 -
```

```
categorical_accuracy: 0.9813 - val_loss: 0.1517 - val_categorical_accuracy:
0.9474
Epoch 16/30
12/12 [==============================] - 7s 621ms/step - loss: 0.0683 -
categorical_accuracy: 0.9806 - val_loss: 0.0970 - val_categorical_accuracy:
0.9751
Epoch 17/30
12/12 [==============================] - 7s 621ms/step - loss: 0.0639 -
categorical_accuracy: 0.9806 - val_loss: 0.0958 - val_categorical_accuracy:
0.9695
Epoch 18/30
12/12 [==============================] - 8s 643ms/step - loss: 0.0466 -
categorical_accuracy: 0.9896 - val_loss: 0.1009 - val_categorical_accuracy:
0.9695
Epoch 19/30
12/12 [==============================] - 7s 621ms/step - loss: 0.0393 -
categorical_accuracy: 0.9938 - val_loss: 0.0869 - val_categorical_accuracy:
0.9723
Epoch 20/30
12/12 [==============================] - 8s 645ms/step - loss: 0.0350 -
categorical_accuracy: 0.9938 - val_loss: 0.0946 - val_categorical_accuracy:
0.9723
Epoch 21/30
12/12 [==============================] - 8s 634ms/step - loss: 0.0301 -
categorical_accuracy: 0.9951 - val_loss: 0.1050 - val_categorical_accuracy:
0.9723
Epoch 22/30
12/12 [==============================] - 8s 635ms/step - loss: 0.0328 -
categorical_accuracy: 0.9951 - val_loss: 0.0920 - val_categorical_accuracy:
0.9723
Epoch 23/30
12/12 [==============================] - 8s 629ms/step - loss: 0.0295 -
categorical_accuracy: 0.9931 - val_loss: 0.1016 - val_categorical_accuracy:
0.9778
Epoch 24/30
12/12 [==============================] - 7s 621ms/step - loss: 0.0307 -
categorical_accuracy: 0.9938 - val_loss: 0.0876 - val_categorical_accuracy:
0.9751

[I 2022-06-09 21:15:27,041] Trial 13 finished with value:
0.9750692248344421 and parameters: {'n_epochs': 30, 'learning_rate':
0.0006007988732901043, 'filters_1': 8, 'kernel_size_1': 12, 'filters_2': 62,
'kernel_size_2': 7, 'lin_1_n': 97}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/20

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
```

```
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(
12/12 [==============================] - 7s 484ms/step - loss: 1.2084 -
categorical_accuracy: 0.4546 - val_loss: 1.1025 - val_categorical_accuracy:
0.4654
Epoch 2/20
12/12 [==============================] - 6s 479ms/step - loss: 0.9312 -
categorical_accuracy: 0.5683 - val_loss: 0.9072 - val_categorical_accuracy:
0.5319
Epoch 3/20
12/12 [==============================] - 6s 486ms/step - loss: 0.7821 -
categorical_accuracy: 0.6244 - val_loss: 0.8041 - val_categorical_accuracy:
0.6150
Epoch 4/20
12/12 [==============================] - 6s 486ms/step - loss: 0.6906 -
categorical_accuracy: 0.6972 - val_loss: 0.7237 - val_categorical_accuracy:
0.7091
Epoch 5/20
12/12 [==============================] - 6s 481ms/step - loss: 0.6375 -
categorical_accuracy: 0.7380 - val_loss: 0.6887 - val_categorical_accuracy:
0.7175
Epoch 6/20
12/12 [==============================] - 6s 479ms/step - loss: 0.6057 -
categorical_accuracy: 0.7471 - val_loss: 0.6463 - val_categorical_accuracy:
0.7452
Epoch 7/20
12/12 [==============================] - 6s 478ms/step - loss: 0.5608 -
categorical_accuracy: 0.7678 - val_loss: 0.6228 - val_categorical_accuracy:
0.7729
Epoch 8/20
12/12 [==============================] - 6s 476ms/step - loss: 0.5310 -
categorical_accuracy: 0.7775 - val_loss: 0.5978 - val_categorical_accuracy:
0.7313
Epoch 9/20
12/12 [==============================] - 6s 479ms/step - loss: 0.5003 -
categorical_accuracy: 0.7907 - val_loss: 0.5591 - val_categorical_accuracy:
0.7701
Epoch 10/20
12/12 [==============================] - 6s 478ms/step - loss: 0.4777 -
categorical_accuracy: 0.8032 - val_loss: 0.5442 - val_categorical_accuracy:
0.7645
Epoch 11/20
12/12 [==============================] - 6s 479ms/step - loss: 0.4636 -
categorical_accuracy: 0.8184 - val_loss: 0.5314 - val_categorical_accuracy:
0.7645
Epoch 12/20
```

```
12/12 [==============================] - 6s 480ms/step - loss: 0.4339 -
categorical_accuracy: 0.8316 - val_loss: 0.5064 - val_categorical_accuracy:
0.7590
Epoch 13/20
12/12 [==============================] - 6s 495ms/step - loss: 0.4167 -
categorical_accuracy: 0.8247 - val_loss: 0.4824 - val_categorical_accuracy:
0.7756
Epoch 14/20
12/12 [==============================] - 6s 490ms/step - loss: 0.3918 -
categorical_accuracy: 0.8392 - val_loss: 0.4637 - val_categorical_accuracy:
0.8006
Epoch 15/20
12/12 [==============================] - 6s 487ms/step - loss: 0.3954 -
categorical_accuracy: 0.8441 - val_loss: 0.4717 - val_categorical_accuracy:
0.7729
Epoch 16/20
12/12 [==============================] - 6s 484ms/step - loss: 0.3583 -
categorical_accuracy: 0.8628 - val_loss: 0.4429 - val_categorical_accuracy:
0.7922
Epoch 17/20
12/12 [==============================] - 6s 482ms/step - loss: 0.3519 -
categorical_accuracy: 0.8517 - val_loss: 0.4275 - val_categorical_accuracy:
0.8476
Epoch 18/20
12/12 [==============================] - 6s 485ms/step - loss: 0.3354 -
categorical_accuracy: 0.8593 - val_loss: 0.4268 - val_categorical_accuracy:
0.8144
Epoch 19/20
12/12 [==============================] - 6s 482ms/step - loss: 0.3207 -
categorical_accuracy: 0.8780 - val_loss: 0.4383 - val_categorical_accuracy:
0.7784
Epoch 20/20
12/12 [==============================] - 6s 484ms/step - loss: 0.3212 -
categorical_accuracy: 0.8711 - val_loss: 0.3835 - val_categorical_accuracy:
0.8393

[I 2022-06-09 21:17:23,879] Trial 14 finished with value:
0.8393352031707764 and parameters: {'n_epochs': 20, 'learning_rate':
0.00028323738591291896, 'filters_1': 12, 'kernel_size_1': 8, 'filters_2': 50,
'kernel_size_2': 7, 'lin_1_n': 9}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/25

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(
```

```
12/12 [==============================] - 10s 815ms/step - loss: 1.0904 -
categorical_accuracy: 0.5128 - val_loss: 0.8519 - val_categorical_accuracy:
0.6122
Epoch 2/25
12/12 [==============================] - 10s 824ms/step - loss: 0.6580 -
categorical_accuracy: 0.7062 - val_loss: 0.6676 - val_categorical_accuracy:
0.7036
Epoch 3/25
12/12 [==============================] - 10s 832ms/step - loss: 0.5242 -
categorical_accuracy: 0.7748 - val_loss: 0.5411 - val_categorical_accuracy:
0.7673
Epoch 4/25
12/12 [==============================] - 10s 814ms/step - loss: 0.4799 -
categorical_accuracy: 0.8025 - val_loss: 0.5053 - val_categorical_accuracy:
0.7867
Epoch 5/25
12/12 [==============================] - 10s 813ms/step - loss: 0.4164 -
categorical_accuracy: 0.8330 - val_loss: 0.4573 - val_categorical_accuracy:
0.8006
Epoch 6/25
12/12 [==============================] - 10s 815ms/step - loss: 0.3627 -
categorical_accuracy: 0.8510 - val_loss: 0.4121 - val_categorical_accuracy:
0.8532
Epoch 7/25
12/12 [==============================] - 10s 809ms/step - loss: 0.3303 -
categorical_accuracy: 0.8676 - val_loss: 0.4146 - val_categorical_accuracy:
0.8255
Epoch 8/25
12/12 [==============================] - 10s 813ms/step - loss: 0.3040 -
categorical_accuracy: 0.8808 - val_loss: 0.3653 - val_categorical_accuracy:
0.8670
Epoch 9/25
12/12 [==============================] - 10s 815ms/step - loss: 0.2467 -
categorical_accuracy: 0.9120 - val_loss: 0.3181 - val_categorical_accuracy:
0.8920
Epoch 10/25
12/12 [==============================] - 10s 811ms/step - loss: 0.2461 -
categorical_accuracy: 0.9203 - val_loss: 0.3425 - val_categorical_accuracy:
0.8476
Epoch 11/25
12/12 [==============================] - 10s 821ms/step - loss: 0.2226 -
categorical_accuracy: 0.9231 - val_loss: 0.2914 - val_categorical_accuracy:
0.9058
Epoch 12/25
12/12 [==============================] - 10s 851ms/step - loss: 0.1947 -
categorical_accuracy: 0.9328 - val_loss: 0.2943 - val_categorical_accuracy:
0.8920
Epoch 13/25
```

```
12/12 [==============================] - 10s 816ms/step - loss: 0.1955 -
categorical_accuracy: 0.9286 - val_loss: 0.2616 - val_categorical_accuracy:
0.9197
Epoch 14/25
12/12 [==============================] - 10s 830ms/step - loss: 0.1801 -
categorical_accuracy: 0.9376 - val_loss: 0.2405 - val_categorical_accuracy:
0.9418
Epoch 15/25
12/12 [==============================] - 10s 818ms/step - loss: 0.1530 -
categorical_accuracy: 0.9556 - val_loss: 0.2376 - val_categorical_accuracy:
0.9446
Epoch 16/25
12/12 [==============================] - 10s 813ms/step - loss: 0.1442 -
categorical_accuracy: 0.9522 - val_loss: 0.2246 - val_categorical_accuracy:
0.9391
Epoch 17/25
12/12 [==============================] - 10s 815ms/step - loss: 0.1322 -
categorical_accuracy: 0.9591 - val_loss: 0.2195 - val_categorical_accuracy:
0.9529
Epoch 18/25
12/12 [==============================] - 10s 818ms/step - loss: 0.1239 -
categorical_accuracy: 0.9653 - val_loss: 0.2153 - val_categorical_accuracy:
0.9418
Epoch 19/25
12/12 [==============================] - 10s 815ms/step - loss: 0.1121 -
categorical_accuracy: 0.9681 - val_loss: 0.1991 - val_categorical_accuracy:
0.9584
Epoch 20/25
12/12 [==============================] - 10s 818ms/step - loss: 0.1175 -
categorical_accuracy: 0.9640 - val_loss: 0.1980 - val_categorical_accuracy:
0.9446
Epoch 21/25
12/12 [==============================] - 10s 869ms/step - loss: 0.1089 -
categorical_accuracy: 0.9688 - val_loss: 0.2386 - val_categorical_accuracy:
0.9307
Epoch 22/25
12/12 [==============================] - 11s 933ms/step - loss: 0.0965 -
categorical_accuracy: 0.9716 - val_loss: 0.1855 - val_categorical_accuracy:
0.9446
Epoch 23/25
12/12 [==============================] - 11s 890ms/step - loss: 0.0918 -
categorical_accuracy: 0.9737 - val_loss: 0.1843 - val_categorical_accuracy:
0.9529
Epoch 24/25
12/12 [==============================] - 10s 860ms/step - loss: 0.0797 -
categorical_accuracy: 0.9757 - val_loss: 0.1705 - val_categorical_accuracy:
0.9612
Epoch 25/25
```

```
12/12 [==============================] - 10s 834ms/step - loss: 0.0723 -
categorical_accuracy: 0.9820 - val_loss: 0.1725 - val_categorical_accuracy:
0.9529

[I 2022-06-09 21:21:33,877] Trial 15 finished with value:
0.9529085755348206 and parameters: {'n_epochs': 25, 'learning_rate':
0.0005928207268080963, 'filters_1': 2, 'kernel_size_1': 16, 'filters_2': 14,
'kernel_size_2': 10, 'lin_1_n': 92}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/30

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 10s 803ms/step - loss: 1.1618 -
categorical_accuracy: 0.4962 - val_loss: 0.9594 - val_categorical_accuracy:
0.5069
Epoch 2/30
12/12 [==============================] - 10s 795ms/step - loss: 0.7394 -
categorical_accuracy: 0.6743 - val_loss: 0.6309 - val_categorical_accuracy:
0.7424
Epoch 3/30
12/12 [==============================] - 10s 792ms/step - loss: 0.5644 -
categorical_accuracy: 0.7422 - val_loss: 0.5783 - val_categorical_accuracy:
0.7424
Epoch 4/30
12/12 [==============================] - 10s 805ms/step - loss: 0.5109 -
categorical_accuracy: 0.7838 - val_loss: 0.5023 - val_categorical_accuracy:
0.7673
Epoch 5/30
12/12 [==============================] - 10s 821ms/step - loss: 0.4468 -
categorical_accuracy: 0.8150 - val_loss: 0.4784 - val_categorical_accuracy:
0.7479
Epoch 6/30
12/12 [==============================] - 10s 810ms/step - loss: 0.3904 -
categorical_accuracy: 0.8226 - val_loss: 0.4390 - val_categorical_accuracy:
0.8061
Epoch 7/30
12/12 [==============================] - 10s 800ms/step - loss: 0.3525 -
categorical_accuracy: 0.8482 - val_loss: 0.4291 - val_categorical_accuracy:
0.8089
Epoch 8/30
12/12 [==============================] - 10s 795ms/step - loss: 0.3214 -
categorical_accuracy: 0.8739 - val_loss: 0.3543 - val_categorical_accuracy:
0.8560
Epoch 9/30
```

```
12/12 [==============================] - 10s 793ms/step - loss: 0.2995 -
categorical_accuracy: 0.8711 - val_loss: 0.3317 - val_categorical_accuracy:
0.8809
Epoch 10/30
12/12 [==============================] - 10s 796ms/step - loss: 0.2587 -
categorical_accuracy: 0.8995 - val_loss: 0.2896 - val_categorical_accuracy:
0.8892
Epoch 11/30
12/12 [==============================] - 10s 795ms/step - loss: 0.2190 -
categorical_accuracy: 0.9231 - val_loss: 0.2538 - val_categorical_accuracy:
0.9058
Epoch 12/30
12/12 [==============================] - 10s 797ms/step - loss: 0.1931 -
categorical_accuracy: 0.9245 - val_loss: 0.2513 - val_categorical_accuracy:
0.8947
Epoch 13/30
12/12 [==============================] - 10s 792ms/step - loss: 0.1996 -
categorical_accuracy: 0.9203 - val_loss: 0.2716 - val_categorical_accuracy:
0.8809
Epoch 14/30
12/12 [==============================] - 10s 809ms/step - loss: 0.1792 -
categorical_accuracy: 0.9307 - val_loss: 0.1824 - val_categorical_accuracy:
0.9391
Epoch 15/30
12/12 [==============================] - 10s 794ms/step - loss: 0.1570 -
categorical_accuracy: 0.9425 - val_loss: 0.1663 - val_categorical_accuracy:
0.9474
Epoch 16/30
12/12 [==============================] - 10s 799ms/step - loss: 0.1396 -
categorical_accuracy: 0.9570 - val_loss: 0.1721 - val_categorical_accuracy:
0.9252
Epoch 17/30
12/12 [==============================] - 9s 792ms/step - loss: 0.1245 -
categorical_accuracy: 0.9536 - val_loss: 0.1583 - val_categorical_accuracy:
0.9446
Epoch 18/30
12/12 [==============================] - 10s 799ms/step - loss: 0.1045 -
categorical_accuracy: 0.9640 - val_loss: 0.1315 - val_categorical_accuracy:
0.9501
Epoch 19/30
12/12 [==============================] - 10s 811ms/step - loss: 0.0958 -
categorical_accuracy: 0.9695 - val_loss: 0.1427 - val_categorical_accuracy:
0.9474
Epoch 20/30
12/12 [==============================] - 10s 800ms/step - loss: 0.0896 -
categorical_accuracy: 0.9737 - val_loss: 0.1167 - val_categorical_accuracy:
0.9668
Epoch 21/30
```

```
12/12 [==============================] - 10s 797ms/step - loss: 0.0896 -
categorical_accuracy: 0.9716 - val_loss: 0.1009 - val_categorical_accuracy:
0.9751
Epoch 22/30
12/12 [==============================] - 10s 795ms/step - loss: 0.0809 -
categorical_accuracy: 0.9764 - val_loss: 0.1246 - val_categorical_accuracy:
0.9612
Epoch 23/30
12/12 [==============================] - 10s 806ms/step - loss: 0.0699 -
categorical_accuracy: 0.9785 - val_loss: 0.0840 - val_categorical_accuracy:
0.9668
Epoch 24/30
12/12 [==============================] - 10s 810ms/step - loss: 0.0633 -
categorical_accuracy: 0.9806 - val_loss: 0.1135 - val_categorical_accuracy:
0.9584
Epoch 25/30
12/12 [==============================] - 10s 813ms/step - loss: 0.0606 -
categorical_accuracy: 0.9841 - val_loss: 0.1197 - val_categorical_accuracy:
0.9612
Epoch 26/30
12/12 [==============================] - 9s 790ms/step - loss: 0.0592 -
categorical_accuracy: 0.9778 - val_loss: 0.1030 - val_categorical_accuracy:
0.9695
Epoch 27/30
12/12 [==============================] - 10s 795ms/step - loss: 0.0469 -
categorical_accuracy: 0.9882 - val_loss: 0.0871 - val_categorical_accuracy:
0.9778
Epoch 28/30
12/12 [==============================] - 10s 795ms/step - loss: 0.0390 -
categorical_accuracy: 0.9931 - val_loss: 0.0665 - val_categorical_accuracy:
0.9695
Epoch 29/30
12/12 [==============================] - 10s 809ms/step - loss: 0.0354 -
categorical_accuracy: 0.9924 - val_loss: 0.0866 - val_categorical_accuracy:
0.9695
Epoch 30/30
12/12 [==============================] - 10s 803ms/step - loss: 0.0307 -
categorical_accuracy: 0.9945 - val_loss: 0.0747 - val_categorical_accuracy:
0.9778

[I 2022-06-09 21:26:22,395] Trial 16 finished with value:
0.9778393507003784 and parameters: {'n_epochs': 30, 'learning_rate':
0.00038271740143620294, 'filters_1': 22, 'kernel_size_1': 12, 'filters_2': 28,
'kernel_size_2': 7, 'lin_1_n': 115}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/20

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
```

```
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(

12/12 [==============================] - 18s 2s/step - loss: 1.2034 -
categorical_accuracy: 0.4761 - val_loss: 0.9669 - val_categorical_accuracy:
0.4820
Epoch 2/20
12/12 [==============================] - 18s 1s/step - loss: 0.7751 -
categorical_accuracy: 0.6126 - val_loss: 0.7748 - val_categorical_accuracy:
0.5817
Epoch 3/20
12/12 [==============================] - 18s 1s/step - loss: 0.6360 -
categorical_accuracy: 0.6764 - val_loss: 0.6954 - val_categorical_accuracy:
0.6205
Epoch 4/20
12/12 [==============================] - 19s 2s/step - loss: 0.5684 -
categorical_accuracy: 0.7076 - val_loss: 0.6026 - val_categorical_accuracy:
0.7424
Epoch 5/20
12/12 [==============================] - 19s 2s/step - loss: 0.5286 -
categorical_accuracy: 0.7644 - val_loss: 0.5697 - val_categorical_accuracy:
0.7368
Epoch 6/20
12/12 [==============================] - 18s 2s/step - loss: 0.4705 -
categorical_accuracy: 0.7997 - val_loss: 0.5134 - val_categorical_accuracy:
0.7590
Epoch 7/20
12/12 [==============================] - 18s 2s/step - loss: 0.4034 -
categorical_accuracy: 0.8267 - val_loss: 0.4600 - val_categorical_accuracy:
0.7756
Epoch 8/20
12/12 [==============================] - 18s 2s/step - loss: 0.3376 -
categorical_accuracy: 0.8496 - val_loss: 0.3754 - val_categorical_accuracy:
0.8560
Epoch 9/20
12/12 [==============================] - 18s 2s/step - loss: 0.2831 -
categorical_accuracy: 0.8794 - val_loss: 0.3120 - val_categorical_accuracy:
0.8698
Epoch 10/20
12/12 [==============================] - 18s 2s/step - loss: 0.2655 -
categorical_accuracy: 0.9009 - val_loss: 0.2984 - val_categorical_accuracy:
0.8837
Epoch 11/20
12/12 [==============================] - 18s 2s/step - loss: 0.2262 -
categorical_accuracy: 0.9134 - val_loss: 0.2512 - val_categorical_accuracy:
0.9114
```

```
Epoch 12/20
12/12 [==============================] - 19s 2s/step - loss: 0.2106 -
categorical_accuracy: 0.9161 - val_loss: 0.2275 - val_categorical_accuracy:
0.9224
Epoch 13/20
12/12 [==============================] - 19s 2s/step - loss: 0.1884 -
categorical_accuracy: 0.9265 - val_loss: 0.2044 - val_categorical_accuracy:
0.9391
Epoch 14/20
12/12 [==============================] - 18s 2s/step - loss: 0.1630 -
categorical_accuracy: 0.9335 - val_loss: 0.1807 - val_categorical_accuracy:
0.9307
Epoch 15/20
12/12 [==============================] - 18s 2s/step - loss: 0.1370 -
categorical_accuracy: 0.9508 - val_loss: 0.1784 - val_categorical_accuracy:
0.9280
Epoch 16/20
12/12 [==============================] - 18s 2s/step - loss: 0.1311 -
categorical_accuracy: 0.9584 - val_loss: 0.1577 - val_categorical_accuracy:
0.9612
Epoch 17/20
12/12 [==============================] - 18s 2s/step - loss: 0.1277 -
categorical_accuracy: 0.9543 - val_loss: 0.1283 - val_categorical_accuracy:
0.9529
Epoch 18/20
12/12 [==============================] - 18s 2s/step - loss: 0.1150 -
categorical_accuracy: 0.9570 - val_loss: 0.1163 - val_categorical_accuracy:
0.9751
Epoch 19/20
12/12 [==============================] - 18s 2s/step - loss: 0.0910 -
categorical_accuracy: 0.9709 - val_loss: 0.1046 - val_categorical_accuracy:
0.9751
Epoch 20/20
12/12 [==============================] - 18s 2s/step - loss: 0.0788 -
categorical_accuracy: 0.9723 - val_loss: 0.1232 - val_categorical_accuracy:
0.9584

[I 2022-06-09 21:32:29,018] Trial 17 finished with value:
0.9584487676620483 and parameters: {'n_epochs': 20, 'learning_rate':
0.0007462441458716158, 'filters_1': 32, 'kernel_size_1': 8, 'filters_2': 54,
'kernel_size_2': 10, 'lin_1_n': 43}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/10

/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
```

```
  warnings.warn(

12/12 [==============================] - 8s 624ms/step - loss: 1.1448 -
categorical_accuracy: 0.4712 - val_loss: 0.9604 - val_categorical_accuracy:
0.4820
Epoch 2/10
12/12 [==============================] - 7s 618ms/step - loss: 0.7829 -
categorical_accuracy: 0.6556 - val_loss: 0.7637 - val_categorical_accuracy:
0.6759
Epoch 3/10
12/12 [==============================] - 7s 619ms/step - loss: 0.6417 -
categorical_accuracy: 0.7297 - val_loss: 0.6671 - val_categorical_accuracy:
0.7341
Epoch 4/10
12/12 [==============================] - 7s 618ms/step - loss: 0.5544 -
categorical_accuracy: 0.7616 - val_loss: 0.5911 - val_categorical_accuracy:
0.7812
Epoch 5/10
12/12 [==============================] - 8s 626ms/step - loss: 0.4860 -
categorical_accuracy: 0.7956 - val_loss: 0.5331 - val_categorical_accuracy:
0.7673
Epoch 6/10
12/12 [==============================] - 7s 619ms/step - loss: 0.4255 -
categorical_accuracy: 0.8240 - val_loss: 0.5082 - val_categorical_accuracy:
0.7590
Epoch 7/10
12/12 [==============================] - 7s 617ms/step - loss: 0.3991 -
categorical_accuracy: 0.8399 - val_loss: 0.4602 - val_categorical_accuracy:
0.8061
Epoch 8/10
12/12 [==============================] - 7s 621ms/step - loss: 0.3707 -
categorical_accuracy: 0.8482 - val_loss: 0.4262 - val_categorical_accuracy:
0.8227
Epoch 9/10
12/12 [==============================] - 8s 629ms/step - loss: 0.3346 -
categorical_accuracy: 0.8649 - val_loss: 0.4029 - val_categorical_accuracy:
0.8227
Epoch 10/10
12/12 [==============================] - 8s 636ms/step - loss: 0.3381 -
categorical_accuracy: 0.8579 - val_loss: 0.3820 - val_categorical_accuracy:
0.8476

[I 2022-06-09 21:33:44,390] Trial 18 finished with value:
0.8476454019546509 and parameters: {'n_epochs': 10, 'learning_rate':
0.00016475573379123537, 'filters_1': 12, 'kernel_size_1': 12, 'filters_2': 32,
'kernel_size_2': 7, 'lin_1_n': 84}. Best is trial 8 with value:
0.9806094169616699.

Epoch 1/25
```

```
/Users/barnabyemmens/opt/anaconda3/envs/appml/lib/python3.8/site-
packages/optuna/distributions.py:560: UserWarning: The distribution is specified
by [4, 12] and step=3, but the range is not divisible by `step`. It will be
replaced by [4, 10].
  warnings.warn(
12/12 [==============================] - 13s 1s/step - loss: 1.0823 -
categorical_accuracy: 0.5031 - val_loss: 0.8609 - val_categorical_accuracy:
0.6316
Epoch 2/25
12/12 [==============================] - 13s 1s/step - loss: 0.7114 -
categorical_accuracy: 0.6930 - val_loss: 0.6765 - val_categorical_accuracy:
0.7064
Epoch 3/25
12/12 [==============================] - 13s 1s/step - loss: 0.5911 -
categorical_accuracy: 0.7471 - val_loss: 0.5839 - val_categorical_accuracy:
0.7618
Epoch 4/25
12/12 [==============================] - 14s 1s/step - loss: 0.5328 -
categorical_accuracy: 0.7706 - val_loss: 0.5430 - val_categorical_accuracy:
0.7618
Epoch 5/25
12/12 [==============================] - 13s 1s/step - loss: 0.4681 -
categorical_accuracy: 0.8080 - val_loss: 0.5304 - val_categorical_accuracy:
0.7922
Epoch 6/25
12/12 [==============================] - 13s 1s/step - loss: 0.4320 -
categorical_accuracy: 0.8122 - val_loss: 0.4585 - val_categorical_accuracy:
0.7895
Epoch 7/25
12/12 [==============================] - 13s 1s/step - loss: 0.4109 -
categorical_accuracy: 0.8170 - val_loss: 0.4475 - val_categorical_accuracy:
0.8089
Epoch 8/25
12/12 [==============================] - 13s 1s/step - loss: 0.3670 -
categorical_accuracy: 0.8475 - val_loss: 0.4350 - val_categorical_accuracy:
0.8061
Epoch 9/25
12/12 [==============================] - 13s 1s/step - loss: 0.3131 -
categorical_accuracy: 0.8711 - val_loss: 0.3961 - val_categorical_accuracy:
0.8172
Epoch 10/25
12/12 [==============================] - 13s 1s/step - loss: 0.3076 -
categorical_accuracy: 0.8766 - val_loss: 0.3268 - val_categorical_accuracy:
0.8670
Epoch 11/25
12/12 [==============================] - 13s 1s/step - loss: 0.2672 -
categorical_accuracy: 0.8926 - val_loss: 0.2878 - val_categorical_accuracy:
```

```
0.9058
Epoch 12/25
12/12 [==============================] - 12s 1s/step - loss: 0.2308 -
categorical_accuracy: 0.9099 - val_loss: 0.2736 - val_categorical_accuracy:
0.8837
Epoch 13/25
12/12 [==============================] - 12s 994ms/step - loss: 0.2161 -
categorical_accuracy: 0.9141 - val_loss: 0.2528 - val_categorical_accuracy:
0.8837
Epoch 14/25
12/12 [==============================] - 13s 1s/step - loss: 0.1938 -
categorical_accuracy: 0.9175 - val_loss: 0.2510 - val_categorical_accuracy:
0.8947
Epoch 15/25
12/12 [==============================] - 13s 1s/step - loss: 0.1931 -
categorical_accuracy: 0.9217 - val_loss: 0.2378 - val_categorical_accuracy:
0.9030
Epoch 16/25
12/12 [==============================] - 13s 1s/step - loss: 0.1993 -
categorical_accuracy: 0.9272 - val_loss: 0.2096 - val_categorical_accuracy:
0.9224
Epoch 17/25
12/12 [==============================] - 12s 1s/step - loss: 0.1600 -
categorical_accuracy: 0.9439 - val_loss: 0.2446 - val_categorical_accuracy:
0.8975
Epoch 18/25
12/12 [==============================] - 12s 993ms/step - loss: 0.1490 -
categorical_accuracy: 0.9453 - val_loss: 0.1560 - val_categorical_accuracy:
0.9418
Epoch 19/25
12/12 [==============================] - 12s 991ms/step - loss: 0.1377 -
categorical_accuracy: 0.9515 - val_loss: 0.1404 - val_categorical_accuracy:
0.9612
Epoch 20/25
12/12 [==============================] - 12s 1s/step - loss: 0.1132 -
categorical_accuracy: 0.9633 - val_loss: 0.1398 - val_categorical_accuracy:
0.9474
Epoch 21/25
12/12 [==============================] - 12s 998ms/step - loss: 0.1214 -
categorical_accuracy: 0.9570 - val_loss: 0.1204 - val_categorical_accuracy:
0.9668
Epoch 22/25
12/12 [==============================] - 12s 1s/step - loss: 0.0932 -
categorical_accuracy: 0.9695 - val_loss: 0.1112 - val_categorical_accuracy:
0.9529
Epoch 23/25
12/12 [==============================] - 12s 996ms/step - loss: 0.0882 -
categorical_accuracy: 0.9730 - val_loss: 0.1162 - val_categorical_accuracy:
```

```
0.9668
Epoch 24/25
12/12 [==============================] - 12s 996ms/step - loss: 0.0884 -
categorical_accuracy: 0.9723 - val_loss: 0.1037 - val_categorical_accuracy:
0.9668
Epoch 25/25
12/12 [==============================] - 12s 1000ms/step - loss: 0.0820 -
categorical_accuracy: 0.9744 - val_loss: 0.1157 - val_categorical_accuracy:
0.9557

[I 2022-06-09 21:38:58,242] Trial 19 finished with value:
0.9556786417961121 and parameters: {'n_epochs': 25, 'learning_rate':
0.0003631528616661671, 'filters_1': 22, 'kernel_size_1': 16, 'filters_2': 12,
'kernel_size_2': 7, 'lin_1_n': 116}. Best is trial 8 with value:
0.9806094169616699.
```

[11]:
```
optimised_params = study.best_params
print(optimised_params)
```

```
{'n_epochs': 25, 'learning_rate': 0.0004077468450779683, 'filters_1': 32,
'kernel_size_1': 12, 'filters_2': 62, 'kernel_size_2': 10, 'lin_1_n': 102}
```

[12]:
```
def opt_model(optimised_params):
    n_epochs = optimised_params['n_epochs']
    learning_rate = optimised_params['learning_rate']
    optimiser = Adam(learning_rate=learning_rate)
    # Conv 1
    filters_1 = optimised_params['filters_1']
    kernel_size_1 = optimised_params['kernel_size_1']
    strides_1 = 1
    padding_1 = 'same'
    activation_1 = 'relu'
    input_shape = (img_rows, img_cols, 1)
    # Pool 1
    pool_size_1 = 2
    # Conv 2
    filters_2 = optimised_params['filters_2']
    kernel_size_2 = optimised_params['kernel_size_2']
    strides_2 = 1
    padding_2 = 'same'
    activation_2 = 'relu'
    # Pool 2
    pool_size_2 = 2
    # Droput
    dropout_rate = 0.4
    # Lin 1
    lin_1_n = optimised_params['lin_1_n']
```

```
    model = Sequential()
    model.add(Conv2D(filters=filters_1,
                     kernel_size=kernel_size_1,
                     strides=strides_1,
                     padding=padding_1,
                     activation=activation_1,
                     input_shape=input_shape))
    model.add(MaxPooling2D(pool_size=pool_size_1, strides=None))
    model.add(Conv2D(filters=filters_2,
                     kernel_size=kernel_size_2,
                     strides=strides_2,
                     padding=padding_2,
                     activation=activation_2))
    model.add(MaxPooling2D(pool_size=pool_size_2, strides=None))
    model.add(Dropout(rate=dropout_rate))
    model.add(Flatten())
    model.add(Dense(units=lin_1_n, activation='relu'))
    model.add(Dense(units=num_classes, activation='softmax'))

    model.compile(loss=categorical_crossentropy,
              optimizer=optimiser,
              metrics=['categorical_accuracy'])

    return model
```

## 3 Folding

[13]:
```
n_folds = 5
kfold = KFold(n_splits=n_folds, shuffle=True)
X = mels
y = y
# Human Optimisation...
check_class_complete(kfold,X,y)
#optimised_params['learning_rate'] = 0.0014280245429123698/2
#optimised_params['n_epochs'] = 30
n_epochs = optimised_params['n_epochs']
fold_loss = np.zeros((n_folds,n_epochs))
np.save('optimised_params',optimised_params)
print(optimised_params)
```

```
ALL CLASSES PRESENT
{'n_epochs': 25, 'learning_rate': 0.0004077468450779683, 'filters_1': 32,
'kernel_size_1': 12, 'filters_2': 62, 'kernel_size_2': 10, 'lin_1_n': 102}
```

[14]:
```
fold_no = 1
for train_index, test_index in kfold.split(X, y):
```

```
    print("------------------------------------")
    print("FOLD "+str(fold_no))
    print("------------------------------------")

    X_train, X_test = X[train_index], X[test_index]
    y_train, y_test = y[train_index], y[test_index]
    X_train,X_test,y_train,y_test, img_rows, img_cols =␣
↪format_for_CNN(X_train,X_test,y_train,y_test)

    model = opt_model(optimised_params)

    history = model.fit(X_train, y_train,
                        batch_size=128,
                        epochs=n_epochs,
                        verbose=1,
                        validation_data=(X_test, y_test))

    fold_loss[fold_no-1] = history.history['val_categorical_accuracy']
    fold_no += 1
```

```
------------------------------------
FOLD 1
------------------------------------
Epoch 1/25
12/12 [==============================] - 20s 2s/step - loss: 0.9755 -
categorical_accuracy: 0.5343 - val_loss: 0.6320 - val_categorical_accuracy:
0.7313
Epoch 2/25
12/12 [==============================] - 20s 2s/step - loss: 0.6111 -
categorical_accuracy: 0.7588 - val_loss: 0.5397 - val_categorical_accuracy:
0.7396
Epoch 3/25
12/12 [==============================] - 20s 2s/step - loss: 0.4938 -
categorical_accuracy: 0.7921 - val_loss: 0.4141 - val_categorical_accuracy:
0.8006
Epoch 4/25
12/12 [==============================] - 20s 2s/step - loss: 0.4238 -
categorical_accuracy: 0.8219 - val_loss: 0.3748 - val_categorical_accuracy:
0.8144
Epoch 5/25
12/12 [==============================] - 20s 2s/step - loss: 0.3431 -
categorical_accuracy: 0.8552 - val_loss: 0.3402 - val_categorical_accuracy:
0.8476
Epoch 6/25
12/12 [==============================] - 20s 2s/step - loss: 0.2962 -
categorical_accuracy: 0.8732 - val_loss: 0.2876 - val_categorical_accuracy:
```

```
0.9030
Epoch 7/25
12/12 [==============================] - 20s 2s/step - loss: 0.3052 -
categorical_accuracy: 0.8697 - val_loss: 0.2557 - val_categorical_accuracy:
0.8947
Epoch 8/25
12/12 [==============================] - 22s 2s/step - loss: 0.2492 -
categorical_accuracy: 0.9120 - val_loss: 0.2136 - val_categorical_accuracy:
0.9169
Epoch 9/25
12/12 [==============================] - 22s 2s/step - loss: 0.2048 -
categorical_accuracy: 0.9148 - val_loss: 0.2759 - val_categorical_accuracy:
0.8753
Epoch 10/25
12/12 [==============================] - 22s 2s/step - loss: 0.1907 -
categorical_accuracy: 0.9293 - val_loss: 0.1630 - val_categorical_accuracy:
0.9418
Epoch 11/25
12/12 [==============================] - 22s 2s/step - loss: 0.1564 -
categorical_accuracy: 0.9439 - val_loss: 0.1549 - val_categorical_accuracy:
0.9391
Epoch 12/25
12/12 [==============================] - 22s 2s/step - loss: 0.1288 -
categorical_accuracy: 0.9584 - val_loss: 0.1231 - val_categorical_accuracy:
0.9668
Epoch 13/25
12/12 [==============================] - 22s 2s/step - loss: 0.1043 -
categorical_accuracy: 0.9612 - val_loss: 0.1724 - val_categorical_accuracy:
0.9418
Epoch 14/25
12/12 [==============================] - 22s 2s/step - loss: 0.1167 -
categorical_accuracy: 0.9598 - val_loss: 0.1345 - val_categorical_accuracy:
0.9446
Epoch 15/25
12/12 [==============================] - 22s 2s/step - loss: 0.1048 -
categorical_accuracy: 0.9619 - val_loss: 0.0813 - val_categorical_accuracy:
0.9861
Epoch 16/25
12/12 [==============================] - 22s 2s/step - loss: 0.0860 -
categorical_accuracy: 0.9744 - val_loss: 0.0930 - val_categorical_accuracy:
0.9529
Epoch 17/25
12/12 [==============================] - 22s 2s/step - loss: 0.0624 -
categorical_accuracy: 0.9834 - val_loss: 0.0763 - val_categorical_accuracy:
0.9695
Epoch 18/25
12/12 [==============================] - 22s 2s/step - loss: 0.0613 -
categorical_accuracy: 0.9827 - val_loss: 0.0801 - val_categorical_accuracy:
```

```
0.9695
Epoch 19/25
12/12 [==============================] - 22s 2s/step - loss: 0.0467 -
categorical_accuracy: 0.9861 - val_loss: 0.0568 - val_categorical_accuracy:
0.9861
Epoch 20/25
12/12 [==============================] - 22s 2s/step - loss: 0.0365 -
categorical_accuracy: 0.9910 - val_loss: 0.0495 - val_categorical_accuracy:
0.9889
Epoch 21/25
12/12 [==============================] - 22s 2s/step - loss: 0.0319 -
categorical_accuracy: 0.9931 - val_loss: 0.0526 - val_categorical_accuracy:
0.9834
Epoch 22/25
12/12 [==============================] - 22s 2s/step - loss: 0.0301 -
categorical_accuracy: 0.9917 - val_loss: 0.0433 - val_categorical_accuracy:
0.9917
Epoch 23/25
12/12 [==============================] - 20s 2s/step - loss: 0.0382 -
categorical_accuracy: 0.9917 - val_loss: 0.0507 - val_categorical_accuracy:
0.9834
Epoch 24/25
12/12 [==============================] - 20s 2s/step - loss: 0.0446 -
categorical_accuracy: 0.9896 - val_loss: 0.1122 - val_categorical_accuracy:
0.9446
Epoch 25/25
12/12 [==============================] - 24s 2s/step - loss: 0.0332 -
categorical_accuracy: 0.9938 - val_loss: 0.0787 - val_categorical_accuracy:
0.9751
---------------------------------
FOLD 2
---------------------------------
Epoch 1/25
12/12 [==============================] - 25s 2s/step - loss: 1.3500 -
categorical_accuracy: 0.4366 - val_loss: 0.8843 - val_categorical_accuracy:
0.5789
Epoch 2/25
12/12 [==============================] - 21s 2s/step - loss: 0.7481 -
categorical_accuracy: 0.6431 - val_loss: 0.6425 - val_categorical_accuracy:
0.7452
Epoch 3/25
12/12 [==============================] - 20s 2s/step - loss: 0.6114 -
categorical_accuracy: 0.7380 - val_loss: 0.5568 - val_categorical_accuracy:
0.7895
Epoch 4/25
12/12 [==============================] - 20s 2s/step - loss: 0.5285 -
categorical_accuracy: 0.7755 - val_loss: 0.5172 - val_categorical_accuracy:
0.7950
```

```
Epoch 5/25
12/12 [==============================] - 20s 2s/step - loss: 0.4741 -
categorical_accuracy: 0.7949 - val_loss: 0.4800 - val_categorical_accuracy:
0.7784
Epoch 6/25
12/12 [==============================] - 20s 2s/step - loss: 0.4442 -
categorical_accuracy: 0.8011 - val_loss: 0.4510 - val_categorical_accuracy:
0.8116
Epoch 7/25
12/12 [==============================] - 21s 2s/step - loss: 0.3959 -
categorical_accuracy: 0.8254 - val_loss: 0.4992 - val_categorical_accuracy:
0.8006
Epoch 8/25
12/12 [==============================] - 20s 2s/step - loss: 0.4057 -
categorical_accuracy: 0.8274 - val_loss: 0.3273 - val_categorical_accuracy:
0.8698
Epoch 9/25
12/12 [==============================] - 21s 2s/step - loss: 0.2981 -
categorical_accuracy: 0.8725 - val_loss: 0.2780 - val_categorical_accuracy:
0.8892
Epoch 10/25
12/12 [==============================] - 21s 2s/step - loss: 0.2364 -
categorical_accuracy: 0.9099 - val_loss: 0.2495 - val_categorical_accuracy:
0.8947
Epoch 11/25
12/12 [==============================] - 20s 2s/step - loss: 0.1976 -
categorical_accuracy: 0.9286 - val_loss: 0.1865 - val_categorical_accuracy:
0.9446
Epoch 12/25
12/12 [==============================] - 20s 2s/step - loss: 0.1702 -
categorical_accuracy: 0.9397 - val_loss: 0.1683 - val_categorical_accuracy:
0.9363
Epoch 13/25
12/12 [==============================] - 20s 2s/step - loss: 0.1440 -
categorical_accuracy: 0.9543 - val_loss: 0.1610 - val_categorical_accuracy:
0.9224
Epoch 14/25
12/12 [==============================] - 20s 2s/step - loss: 0.1380 -
categorical_accuracy: 0.9383 - val_loss: 0.1462 - val_categorical_accuracy:
0.9584
Epoch 15/25
12/12 [==============================] - 23s 2s/step - loss: 0.1256 -
categorical_accuracy: 0.9522 - val_loss: 0.1239 - val_categorical_accuracy:
0.9584
Epoch 16/25
12/12 [==============================] - 22s 2s/step - loss: 0.1049 -
categorical_accuracy: 0.9626 - val_loss: 0.1212 - val_categorical_accuracy:
0.9584
```

```
Epoch 17/25
12/12 [==============================] - 21s 2s/step - loss: 0.0950 -
categorical_accuracy: 0.9730 - val_loss: 0.1187 - val_categorical_accuracy:
0.9584
Epoch 18/25
12/12 [==============================] - 20s 2s/step - loss: 0.0917 -
categorical_accuracy: 0.9660 - val_loss: 0.0809 - val_categorical_accuracy:
0.9806
Epoch 19/25
12/12 [==============================] - 21s 2s/step - loss: 0.0702 -
categorical_accuracy: 0.9792 - val_loss: 0.1243 - val_categorical_accuracy:
0.9640
Epoch 20/25
12/12 [==============================] - 22s 2s/step - loss: 0.0694 -
categorical_accuracy: 0.9785 - val_loss: 0.0666 - val_categorical_accuracy:
0.9834
Epoch 21/25
12/12 [==============================] - 22s 2s/step - loss: 0.0568 -
categorical_accuracy: 0.9848 - val_loss: 0.0694 - val_categorical_accuracy:
0.9806
Epoch 22/25
12/12 [==============================] - 21s 2s/step - loss: 0.0632 -
categorical_accuracy: 0.9778 - val_loss: 0.0743 - val_categorical_accuracy:
0.9834
Epoch 23/25
12/12 [==============================] - 21s 2s/step - loss: 0.0485 -
categorical_accuracy: 0.9868 - val_loss: 0.0678 - val_categorical_accuracy:
0.9806
Epoch 24/25
12/12 [==============================] - 20s 2s/step - loss: 0.0397 -
categorical_accuracy: 0.9889 - val_loss: 0.0503 - val_categorical_accuracy:
0.9778
Epoch 25/25
12/12 [==============================] - 25s 2s/step - loss: 0.0239 -
categorical_accuracy: 0.9958 - val_loss: 0.0499 - val_categorical_accuracy:
0.9889
----------------------------------
FOLD 3
----------------------------------
Epoch 1/25
12/12 [==============================] - 21s 2s/step - loss: 1.2415 -
categorical_accuracy: 0.4664 - val_loss: 0.8772 - val_categorical_accuracy:
0.5900
Epoch 2/25
12/12 [==============================] - 21s 2s/step - loss: 0.7539 -
categorical_accuracy: 0.6473 - val_loss: 0.7382 - val_categorical_accuracy:
0.7452
Epoch 3/25
```

```
12/12 [==============================] - 21s 2s/step - loss: 0.6269 -
categorical_accuracy: 0.7242 - val_loss: 0.6463 - val_categorical_accuracy:
0.6953
Epoch 4/25
12/12 [==============================] - 20s 2s/step - loss: 0.5834 -
categorical_accuracy: 0.7471 - val_loss: 0.5312 - val_categorical_accuracy:
0.7867
Epoch 5/25
12/12 [==============================] - 20s 2s/step - loss: 0.5195 -
categorical_accuracy: 0.7817 - val_loss: 0.4960 - val_categorical_accuracy:
0.8061
Epoch 6/25
12/12 [==============================] - 20s 2s/step - loss: 0.4705 -
categorical_accuracy: 0.7956 - val_loss: 0.4714 - val_categorical_accuracy:
0.8089
Epoch 7/25
12/12 [==============================] - 20s 2s/step - loss: 0.4317 -
categorical_accuracy: 0.8108 - val_loss: 0.4079 - val_categorical_accuracy:
0.8476
Epoch 8/25
12/12 [==============================] - 20s 2s/step - loss: 0.3757 -
categorical_accuracy: 0.8441 - val_loss: 0.3923 - val_categorical_accuracy:
0.7978
Epoch 9/25
12/12 [==============================] - 21s 2s/step - loss: 0.3424 -
categorical_accuracy: 0.8510 - val_loss: 0.3579 - val_categorical_accuracy:
0.8698
Epoch 10/25
12/12 [==============================] - 22s 2s/step - loss: 0.3132 -
categorical_accuracy: 0.8586 - val_loss: 0.3144 - val_categorical_accuracy:
0.8753
Epoch 11/25
12/12 [==============================] - 22s 2s/step - loss: 0.2470 -
categorical_accuracy: 0.9071 - val_loss: 0.2724 - val_categorical_accuracy:
0.8809
Epoch 12/25
12/12 [==============================] - 21s 2s/step - loss: 0.2085 -
categorical_accuracy: 0.9196 - val_loss: 0.2809 - val_categorical_accuracy:
0.8892
Epoch 13/25
12/12 [==============================] - 26s 2s/step - loss: 0.1991 -
categorical_accuracy: 0.9238 - val_loss: 0.2431 - val_categorical_accuracy:
0.9114
Epoch 14/25
12/12 [==============================] - 27s 2s/step - loss: 0.1751 -
categorical_accuracy: 0.9335 - val_loss: 0.2089 - val_categorical_accuracy:
0.9224
Epoch 15/25
```

```
12/12 [==============================] - 25s 2s/step - loss: 0.1506 -
categorical_accuracy: 0.9508 - val_loss: 0.2048 - val_categorical_accuracy:
0.9335
Epoch 16/25
12/12 [==============================] - 21s 2s/step - loss: 0.1266 -
categorical_accuracy: 0.9577 - val_loss: 0.1753 - val_categorical_accuracy:
0.9307
Epoch 17/25
12/12 [==============================] - 22s 2s/step - loss: 0.1105 -
categorical_accuracy: 0.9619 - val_loss: 0.1614 - val_categorical_accuracy:
0.9280
Epoch 18/25
12/12 [==============================] - 23s 2s/step - loss: 0.0939 -
categorical_accuracy: 0.9681 - val_loss: 0.1742 - val_categorical_accuracy:
0.9391
Epoch 19/25
12/12 [==============================] - 22s 2s/step - loss: 0.1072 -
categorical_accuracy: 0.9591 - val_loss: 0.1835 - val_categorical_accuracy:
0.9363
Epoch 20/25
12/12 [==============================] - 22s 2s/step - loss: 0.0893 -
categorical_accuracy: 0.9681 - val_loss: 0.1969 - val_categorical_accuracy:
0.9252
Epoch 21/25
12/12 [==============================] - 21s 2s/step - loss: 0.0746 -
categorical_accuracy: 0.9764 - val_loss: 0.1607 - val_categorical_accuracy:
0.9474
Epoch 22/25
12/12 [==============================] - 23s 2s/step - loss: 0.0712 -
categorical_accuracy: 0.9778 - val_loss: 0.1409 - val_categorical_accuracy:
0.9391
Epoch 23/25
12/12 [==============================] - 22s 2s/step - loss: 0.0511 -
categorical_accuracy: 0.9848 - val_loss: 0.1442 - val_categorical_accuracy:
0.9501
Epoch 24/25
12/12 [==============================] - 21s 2s/step - loss: 0.0489 -
categorical_accuracy: 0.9841 - val_loss: 0.1247 - val_categorical_accuracy:
0.9557
Epoch 25/25
12/12 [==============================] - 20s 2s/step - loss: 0.0489 -
categorical_accuracy: 0.9841 - val_loss: 0.1241 - val_categorical_accuracy:
0.9640
---------------------------------
FOLD 4
---------------------------------
Epoch 1/25
12/12 [==============================] - 22s 2s/step - loss: 0.9925 -
```

```
categorical_accuracy: 0.5211 - val_loss: 0.8483 - val_categorical_accuracy:
0.5956
Epoch 2/25
12/12 [==============================] - 22s 2s/step - loss: 0.6864 -
categorical_accuracy: 0.7235 - val_loss: 0.6418 - val_categorical_accuracy:
0.7341
Epoch 3/25
12/12 [==============================] - 20s 2s/step - loss: 0.5814 -
categorical_accuracy: 0.7540 - val_loss: 0.5275 - val_categorical_accuracy:
0.7756
Epoch 4/25
12/12 [==============================] - 23s 2s/step - loss: 0.4604 -
categorical_accuracy: 0.8039 - val_loss: 0.4548 - val_categorical_accuracy:
0.8144
Epoch 5/25
12/12 [==============================] - 22s 2s/step - loss: 0.3869 -
categorical_accuracy: 0.8323 - val_loss: 0.3721 - val_categorical_accuracy:
0.8532
Epoch 6/25
12/12 [==============================] - 21s 2s/step - loss: 0.3165 -
categorical_accuracy: 0.8766 - val_loss: 0.3138 - val_categorical_accuracy:
0.8837
Epoch 7/25
12/12 [==============================] - 20s 2s/step - loss: 0.2680 -
categorical_accuracy: 0.8947 - val_loss: 0.2744 - val_categorical_accuracy:
0.8698
Epoch 8/25
12/12 [==============================] - 21s 2s/step - loss: 0.2228 -
categorical_accuracy: 0.9175 - val_loss: 0.2140 - val_categorical_accuracy:
0.9391
Epoch 9/25
12/12 [==============================] - 20s 2s/step - loss: 0.1831 -
categorical_accuracy: 0.9272 - val_loss: 0.1916 - val_categorical_accuracy:
0.9307
Epoch 10/25
12/12 [==============================] - 21s 2s/step - loss: 0.1433 -
categorical_accuracy: 0.9584 - val_loss: 0.1735 - val_categorical_accuracy:
0.9474
Epoch 11/25
12/12 [==============================] - 22s 2s/step - loss: 0.1349 -
categorical_accuracy: 0.9508 - val_loss: 0.1503 - val_categorical_accuracy:
0.9474
Epoch 12/25
12/12 [==============================] - 23s 2s/step - loss: 0.1239 -
categorical_accuracy: 0.9598 - val_loss: 0.1389 - val_categorical_accuracy:
0.9751
Epoch 13/25
12/12 [==============================] - 22s 2s/step - loss: 0.1176 -
```

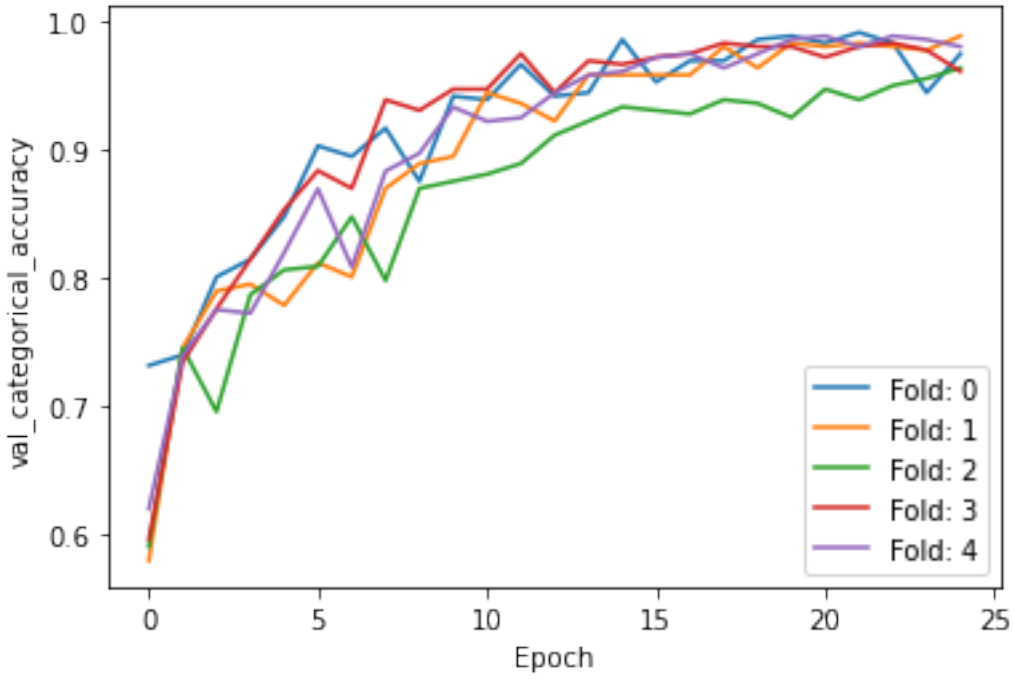
```
categorical_accuracy: 0.9570 - val_loss: 0.1456 - val_categorical_accuracy:
0.9446
Epoch 14/25
12/12 [==============================] - 22s 2s/step - loss: 0.1085 -
categorical_accuracy: 0.9640 - val_loss: 0.1322 - val_categorical_accuracy:
0.9695
Epoch 15/25
12/12 [==============================] - 23s 2s/step - loss: 0.0798 -
categorical_accuracy: 0.9757 - val_loss: 0.1102 - val_categorical_accuracy:
0.9668
Epoch 16/25
12/12 [==============================] - 22s 2s/step - loss: 0.0610 -
categorical_accuracy: 0.9827 - val_loss: 0.1022 - val_categorical_accuracy:
0.9723
Epoch 17/25
12/12 [==============================] - 21s 2s/step - loss: 0.0488 -
categorical_accuracy: 0.9889 - val_loss: 0.0923 - val_categorical_accuracy:
0.9751
Epoch 18/25
12/12 [==============================] - 21s 2s/step - loss: 0.0390 -
categorical_accuracy: 0.9903 - val_loss: 0.0906 - val_categorical_accuracy:
0.9834
Epoch 19/25
12/12 [==============================] - 22s 2s/step - loss: 0.0319 -
categorical_accuracy: 0.9945 - val_loss: 0.0858 - val_categorical_accuracy:
0.9806
Epoch 20/25
12/12 [==============================] - 22s 2s/step - loss: 0.0264 -
categorical_accuracy: 0.9965 - val_loss: 0.0835 - val_categorical_accuracy:
0.9806
Epoch 21/25
12/12 [==============================] - 21s 2s/step - loss: 0.0293 -
categorical_accuracy: 0.9924 - val_loss: 0.0938 - val_categorical_accuracy:
0.9723
Epoch 22/25
12/12 [==============================] - 22s 2s/step - loss: 0.0295 -
categorical_accuracy: 0.9924 - val_loss: 0.0768 - val_categorical_accuracy:
0.9806
Epoch 23/25
12/12 [==============================] - 22s 2s/step - loss: 0.0247 -
categorical_accuracy: 0.9945 - val_loss: 0.0816 - val_categorical_accuracy:
0.9834
Epoch 24/25
12/12 [==============================] - 21s 2s/step - loss: 0.0212 -
categorical_accuracy: 0.9945 - val_loss: 0.0888 - val_categorical_accuracy:
0.9778
Epoch 25/25
12/12 [==============================] - 21s 2s/step - loss: 0.0306 -
```

```
categorical_accuracy: 0.9882 - val_loss: 0.1333 - val_categorical_accuracy:
0.9612
----------------------------------
FOLD 5
----------------------------------
Epoch 1/25
12/12 [==============================] - 23s 2s/step - loss: 1.0997 -
categorical_accuracy: 0.4993 - val_loss: 0.7815 - val_categorical_accuracy:
0.6194
Epoch 2/25
12/12 [==============================] - 21s 2s/step - loss: 0.6757 -
categorical_accuracy: 0.7244 - val_loss: 0.5960 - val_categorical_accuracy:
0.7389
Epoch 3/25
12/12 [==============================] - 20s 2s/step - loss: 0.5508 -
categorical_accuracy: 0.7597 - val_loss: 0.4929 - val_categorical_accuracy:
0.7750
Epoch 4/25
12/12 [==============================] - 22s 2s/step - loss: 0.4719 -
categorical_accuracy: 0.7922 - val_loss: 0.4864 - val_categorical_accuracy:
0.7722
Epoch 5/25
12/12 [==============================] - 21s 2s/step - loss: 0.4285 -
categorical_accuracy: 0.8193 - val_loss: 0.3824 - val_categorical_accuracy:
0.8194
Epoch 6/25
12/12 [==============================] - 20s 2s/step - loss: 0.3559 -
categorical_accuracy: 0.8511 - val_loss: 0.3284 - val_categorical_accuracy:
0.8694
Epoch 7/25
12/12 [==============================] - 21s 2s/step - loss: 0.3242 -
categorical_accuracy: 0.8747 - val_loss: 0.3596 - val_categorical_accuracy:
0.8083
Epoch 8/25
12/12 [==============================] - 21s 2s/step - loss: 0.2858 -
categorical_accuracy: 0.8802 - val_loss: 0.2776 - val_categorical_accuracy:
0.8833
Epoch 9/25
12/12 [==============================] - 20s 2s/step - loss: 0.2461 -
categorical_accuracy: 0.9044 - val_loss: 0.2360 - val_categorical_accuracy:
0.8972
Epoch 10/25
12/12 [==============================] - 21s 2s/step - loss: 0.2219 -
categorical_accuracy: 0.9183 - val_loss: 0.2030 - val_categorical_accuracy:
0.9333
Epoch 11/25
12/12 [==============================] - 21s 2s/step - loss: 0.1766 -
categorical_accuracy: 0.9349 - val_loss: 0.2033 - val_categorical_accuracy:
```

```
0.9222
Epoch 12/25
12/12 [==============================] - 20s 2s/step - loss: 0.1757 -
categorical_accuracy: 0.9321 - val_loss: 0.1874 - val_categorical_accuracy:
0.9250
Epoch 13/25
12/12 [==============================] - 20s 2s/step - loss: 0.1436 -
categorical_accuracy: 0.9515 - val_loss: 0.1314 - val_categorical_accuracy:
0.9444
Epoch 14/25
12/12 [==============================] - 20s 2s/step - loss: 0.1109 -
categorical_accuracy: 0.9647 - val_loss: 0.1204 - val_categorical_accuracy:
0.9583
Epoch 15/25
12/12 [==============================] - 21s 2s/step - loss: 0.1108 -
categorical_accuracy: 0.9564 - val_loss: 0.1103 - val_categorical_accuracy:
0.9611
Epoch 16/25
12/12 [==============================] - 21s 2s/step - loss: 0.0912 -
categorical_accuracy: 0.9765 - val_loss: 0.0986 - val_categorical_accuracy:
0.9722
Epoch 17/25
12/12 [==============================] - 21s 2s/step - loss: 0.0693 -
categorical_accuracy: 0.9841 - val_loss: 0.0760 - val_categorical_accuracy:
0.9750
Epoch 18/25
12/12 [==============================] - 21s 2s/step - loss: 0.0552 -
categorical_accuracy: 0.9848 - val_loss: 0.0809 - val_categorical_accuracy:
0.9639
Epoch 19/25
12/12 [==============================] - 21s 2s/step - loss: 0.0625 -
categorical_accuracy: 0.9806 - val_loss: 0.0684 - val_categorical_accuracy:
0.9750
Epoch 20/25
12/12 [==============================] - 21s 2s/step - loss: 0.0444 -
categorical_accuracy: 0.9910 - val_loss: 0.0629 - val_categorical_accuracy:
0.9861
Epoch 21/25
12/12 [==============================] - 21s 2s/step - loss: 0.0358 -
categorical_accuracy: 0.9931 - val_loss: 0.0521 - val_categorical_accuracy:
0.9889
Epoch 22/25
12/12 [==============================] - 21s 2s/step - loss: 0.0325 -
categorical_accuracy: 0.9917 - val_loss: 0.0627 - val_categorical_accuracy:
0.9806
Epoch 23/25
12/12 [==============================] - 21s 2s/step - loss: 0.0310 -
categorical_accuracy: 0.9938 - val_loss: 0.0442 - val_categorical_accuracy:
```

```
0.9889
Epoch 24/25
12/12 [==============================] - 20s 2s/step - loss: 0.0281 -
categorical_accuracy: 0.9952 - val_loss: 0.0456 - val_categorical_accuracy:
0.9861
Epoch 25/25
12/12 [==============================] - 20s 2s/step - loss: 0.0214 -
categorical_accuracy: 0.9993 - val_loss: 0.0462 - val_categorical_accuracy:
0.9806
```

[15]:
```
for i in range(n_folds):
    plt.plot(fold_loss[i], label='Fold: '+str(i))
plt.xlabel('Epoch')
plt.ylabel('val_categorical_accuracy')
plt.legend()
plt.show()
mean_acc = np.mean(fold_loss[:,-1])
print('Mean val_categorical_accuracy: ',np.around(mean_acc,5))
```




```
Mean val_categorical_accuracy:  0.97395
```

[16]:
```
# model.layers will print a list of layer parameters/values
filters1, biases1 = model.layers[0].get_weights()
filters2, biases2 = model.layers[2].get_weights()
```

```
# normalize filter values to range 0-1 for better colormapping during plotting
def norm_filter(kernel):
    return (kernel - np.min(kernel)) / (np.max(kernel) - np.min(kernel))

n_1 = optimised_params['filters_1']
print('1st convolution layer:')
fig, axs = plt.subplots(1,n_1, figsize=(10, 6))
axs = axs.ravel()
for i in range(n_1):
    axs[i].imshow(norm_filter(filters1[:,:,0,i]), cmap=plt.cm.binary)
    axs[i].set_xticks([]); axs[i].set_yticks([]); axs[i].grid(False)
plt.show()

n_2 = optimised_params['filters_2']
print('2nd convolution layer:')
fig, axs = plt.subplots(1,n_2, figsize=(10, 6))
axs = axs.ravel()
for i in range(n_2):
    axs[i].imshow(norm_filter(filters2[:,:,0,i]), cmap=plt.cm.binary)
    axs[i].set_xticks([]); axs[i].set_yticks([]); axs[i].grid(False)
```

```
1st convolution layer:
```

```
2nd convolution layer:
```

### 3.0.1 Evaluation

[17]:
```
predicted_prob = model.predict(TEST_images)
predictions = np.argmax(predicted_prob, axis=1)
```

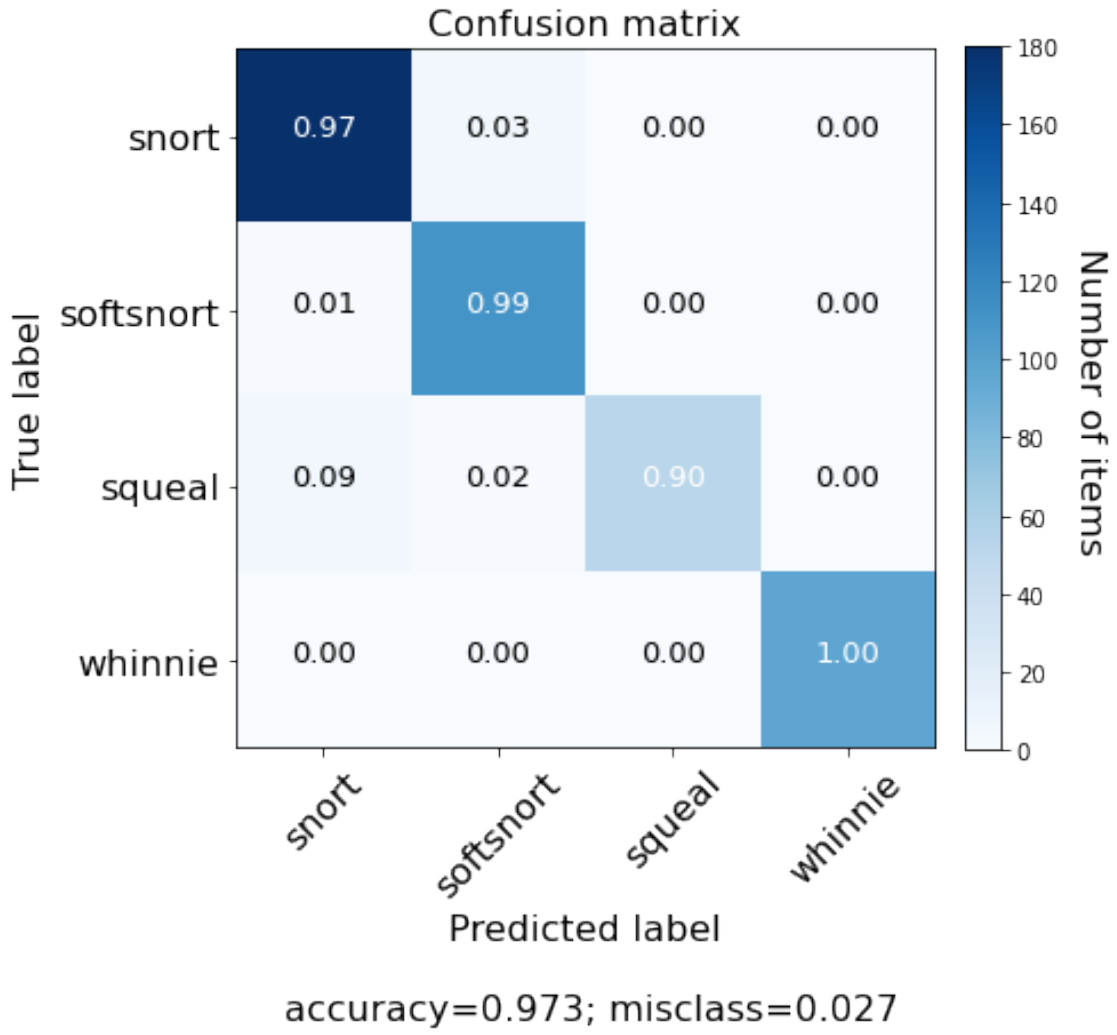
[18]:
```
print(predictions.shape)
print(TEST_y.shape)
```

```
(452,)
(452,)
```

[19]:
```
labels_list = np.unique(TEST_y)
onehot_v = pd.get_dummies(TEST_y)
```

```
onehot_y = onehot_v.to_numpy()
truths = np.argmax(onehot_y, axis=1)
cm = confusion_matrix(truths, predictions, labels=range(num_classes))
print(cm)
plot_confusion_matrix(cm,labels_list)
```

```
[[180   5   0   0]
 [  1 111   0   0]
 [  5   1  52   0]
 [  0   0   0  97]]
```




[ ]: