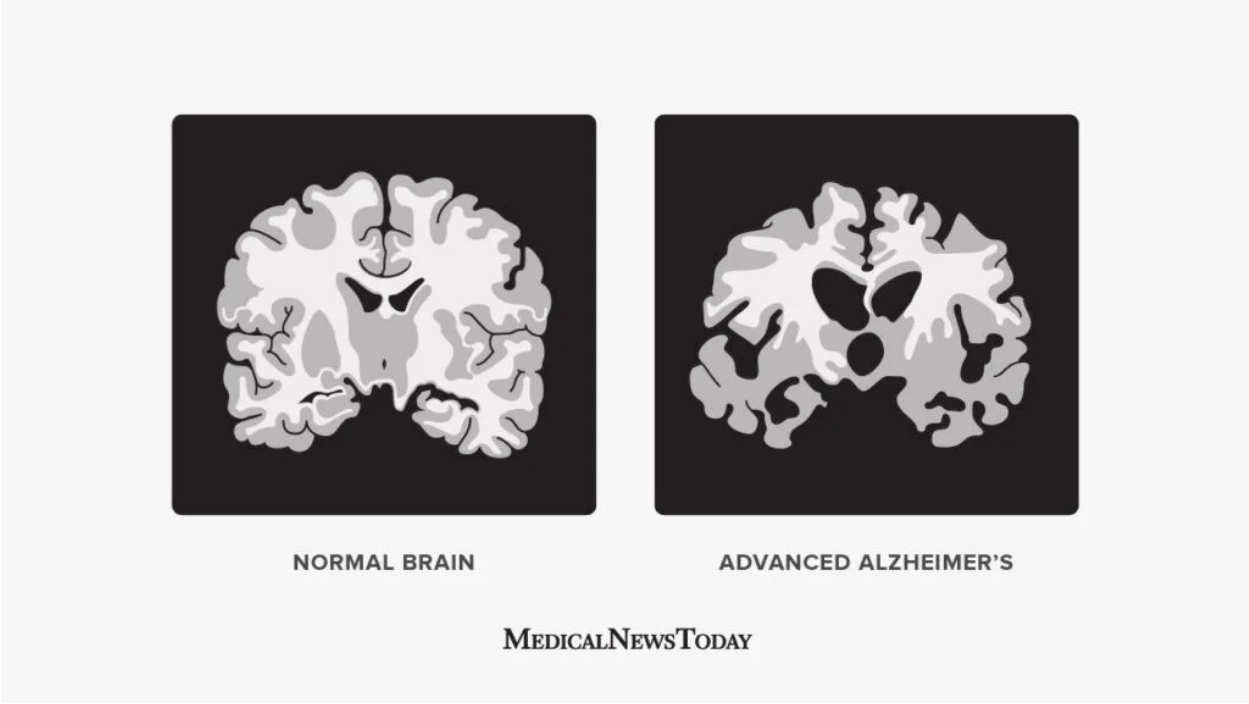
Alzheimer's Disease Classification Using a Novel Bidirectional CNN!




```
import numpy as np
import pandas as pd
import os

base_path =
"/kaggle/input/augmented-alzheimer-mri-dataset/AugmentedAlzheimerDatas
et/"
categories = ["MildDemented","ModerateDemented", "NonDemented",
"VeryMildDemented"]

image_paths = []
labels = []

for category in categories:
    category_path = os.path.join(base_path, category)
    for image_name in os.listdir(category_path):
        image_path = os.path.join(category_path, image_name)
        image_paths.append(image_path)
        labels.append(category)

df = pd.DataFrame({
    "image_path": image_paths,
```

```
    "label": labels
})

df.head()
```

```
                                          image_path         label
0  /kaggle/input/augmented-alzheimer-mri-dataset/...  MildDemented
1  /kaggle/input/augmented-alzheimer-mri-dataset/...  MildDemented
2  /kaggle/input/augmented-alzheimer-mri-dataset/...  MildDemented
3  /kaggle/input/augmented-alzheimer-mri-dataset/...  MildDemented
4  /kaggle/input/augmented-alzheimer-mri-dataset/...  MildDemented
```

```
df.tail()
```

```
                                                image_path
label
33979  /kaggle/input/augmented-alzheimer-mri-dataset/...
VeryMildDemented
33980  /kaggle/input/augmented-alzheimer-mri-dataset/...
VeryMildDemented
33981  /kaggle/input/augmented-alzheimer-mri-dataset/...
VeryMildDemented
33982  /kaggle/input/augmented-alzheimer-mri-dataset/...
VeryMildDemented
33983  /kaggle/input/augmented-alzheimer-mri-dataset/...
VeryMildDemented
```

```
df.shape
```

```
(33984, 2)
```

```
df.columns
```

```
Index(['image_path', 'label'], dtype='object')
```

```
df.duplicated().sum()
```

```
0
```

```
df.isnull().sum()
```

```
image_path    0
label         0
dtype: int64
```

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 33984 entries, 0 to 33983
Data columns (total 2 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
```

```
 0   image_path  33984 non-null  object
 1   label       33984 non-null  object
dtypes: object(2)
memory usage: 531.1+ KB
```

```
df['label'].unique()
```

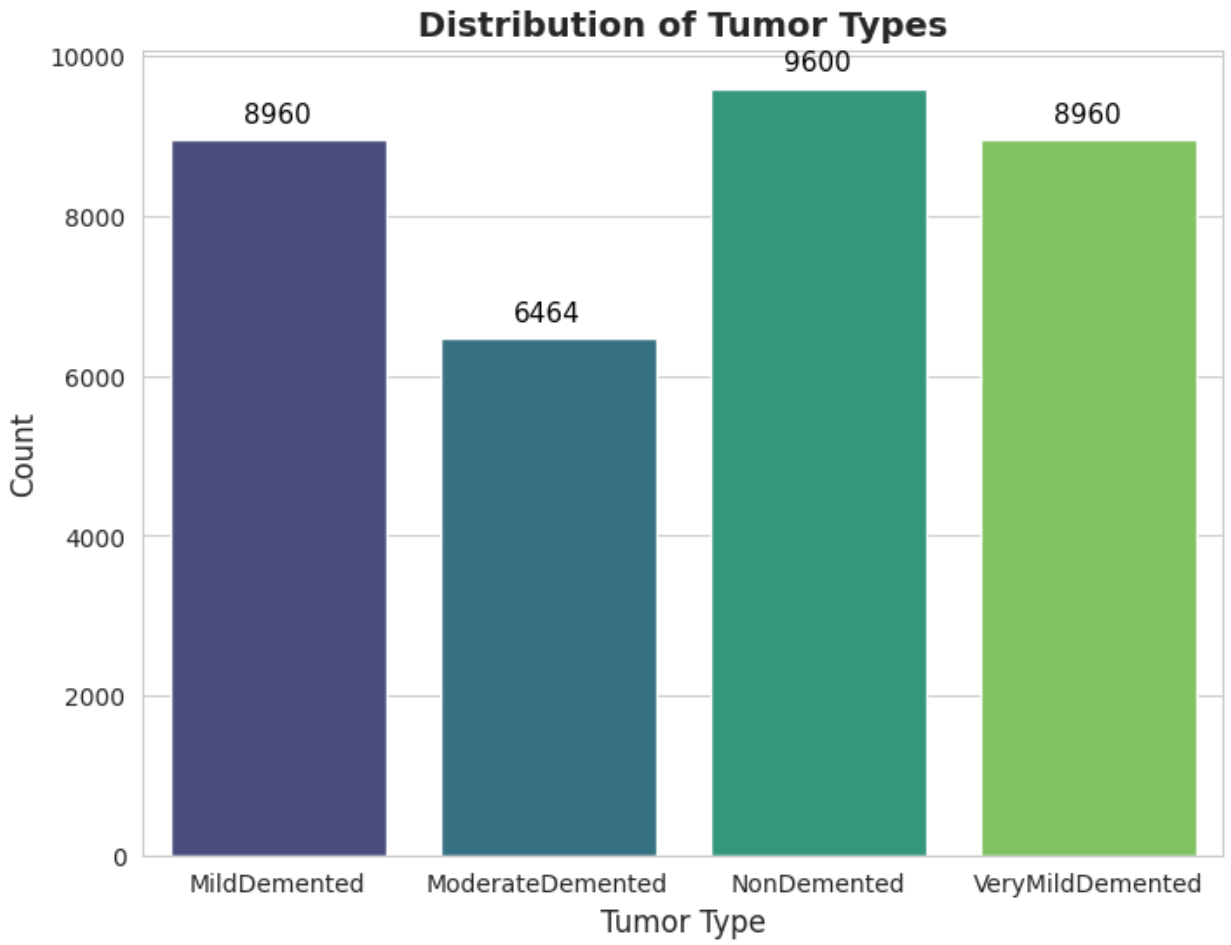
```
array(['MildDemented', 'ModerateDemented', 'NonDemented',
       'VeryMildDemented'], dtype=object)
```

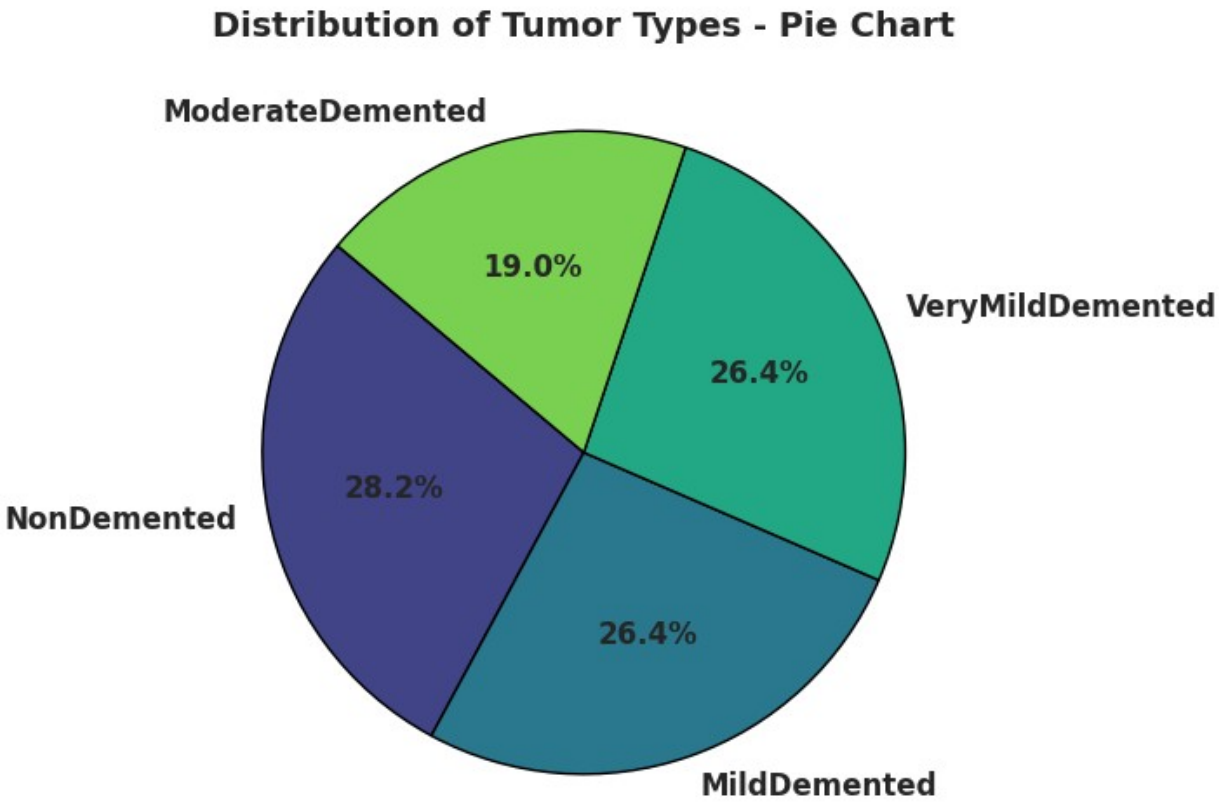
```
df['label'].value_counts()
```

```
label
NonDemented          9600
MildDemented         8960
VeryMildDemented     8960
ModerateDemented     6464
Name: count, dtype: int64
```

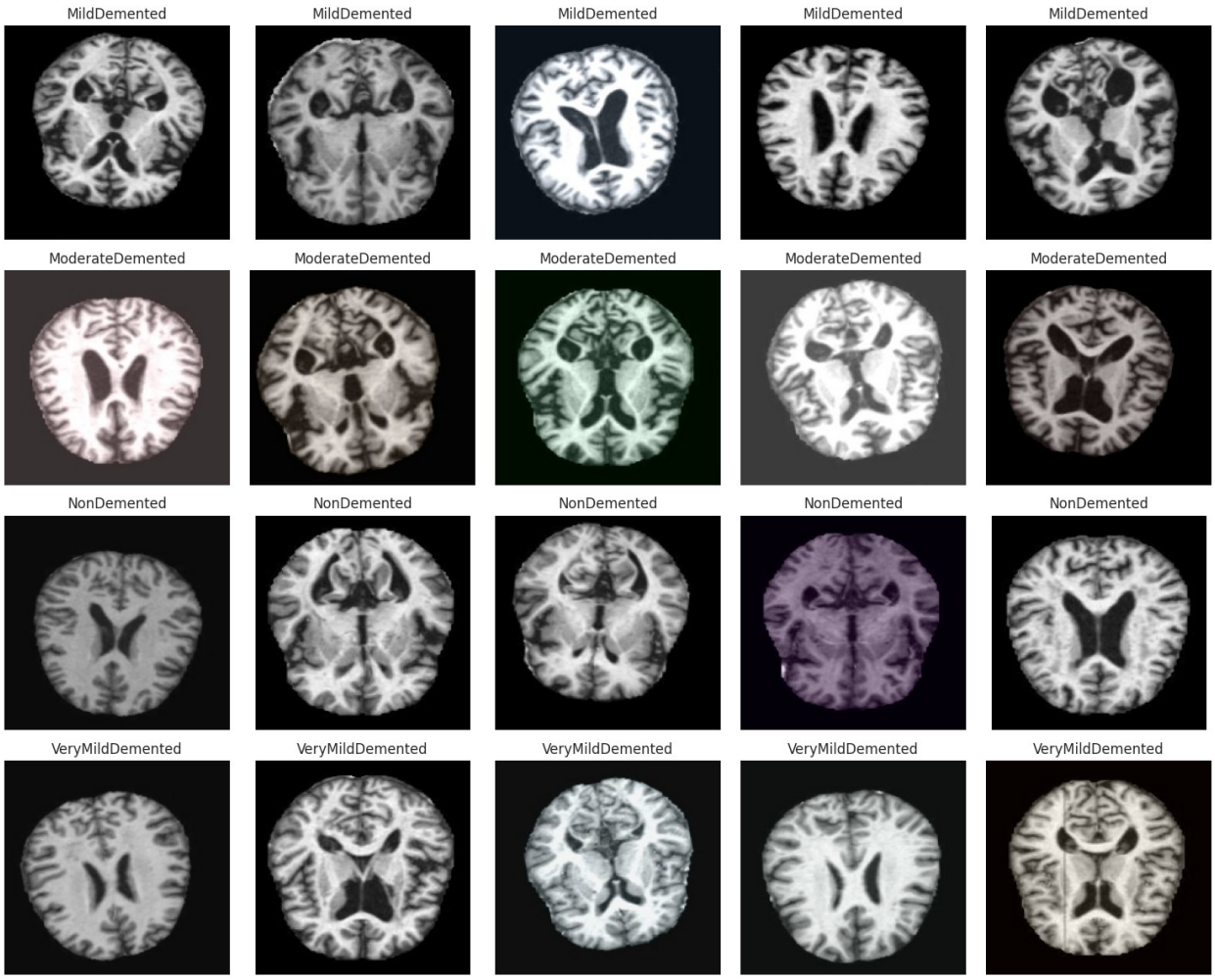
```
import seaborn as sns
import matplotlib.pyplot as plt

sns.set_style("whitegrid")

fig, ax = plt.subplots(figsize=(8, 6))
sns.countplot(data=df, x="label", palette="viridis", ax=ax)

ax.set_title("Distribution of Tumor Types", fontsize=14,
fontweight='bold')
ax.set_xlabel("Tumor Type", fontsize=12)
ax.set_ylabel("Count", fontsize=12)

for p in ax.patches:
    ax.annotate(f'{int(p.get_height())}',
                (p.get_x() + p.get_width() / 2., p.get_height()),
                ha='center', va='bottom', fontsize=11, color='black',
                xytext=(0, 5), textcoords='offset points')

plt.show()

label_counts = df["label"].value_counts()

fig, ax = plt.subplots(figsize=(8, 6))
colors = sns.color_palette("viridis", len(label_counts))

ax.pie(label_counts, labels=label_counts.index, autopct='%1.1f%%',
       startangle=140, colors=colors, textprops={'fontsize': 12,
'weight': 'bold'},
       wedgeprops={'edgecolor': 'black', 'linewidth': 1})

ax.set_title("Distribution of Tumor Types - Pie Chart", fontsize=14,
```

```
fontweight='bold')

plt.show()
```






```
import cv2

num_images = 5

plt.figure(figsize=(15, 12))

for i, category in enumerate(categories):
    category_images = df[df['label'] == category]
['image_path'].iloc[:num_images]

    for j, img_path in enumerate(category_images):

        img = cv2.imread(img_path)
        img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)

        plt.subplot(len(categories), num_images, i * num_images + j +
1)
        plt.imshow(img)
        plt.axis('off')
        plt.title(category)

plt.tight_layout()
plt.show()
```




```
from sklearn.preprocessing import LabelEncoder

label_encoder = LabelEncoder()

df['category_encoded'] = label_encoder.fit_transform(df['label'])

df = df[['image_path', 'category_encoded']]

from sklearn.utils import resample

max_count = df['category_encoded'].value_counts().max()

dfs = []
for category in df['category_encoded'].unique():
    class_subset = df[df['category_encoded'] == category]
    class_upsampled = resample(class_subset,
                               replace=True,
                               n_samples=max_count,
                               random_state=42)
    dfs.append(class_upsampled)
```

```
df_balanced = pd.concat(dfs).sample(frac=1,
random_state=42).reset_index(drop=True)

df_balanced['category_encoded'].value_counts()
```

```
category_encoded
2    9600
1    9600
0    9600
3    9600
Name: count, dtype: int64
```

```
df_resampled = df_balanced

df_resampled['category_encoded'] =
df_resampled['category_encoded'].astype(str)

import time
import shutil
import pathlib
import itertools
from PIL import Image

import cv2
import seaborn as sns
sns.set_style('darkgrid')
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix, classification_report

import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.models import Sequential
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten,
Dense, Activation, Dropout, BatchNormalization
from tensorflow.keras import regularizers

import warnings
warnings.filterwarnings("ignore")

print ('check')
```

```
2025-05-21 09:33:44.955597: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:477] Unable to
register cuFFT factory: Attempting to register factory for plugin
cuFFT when one has already been registered
WARNING: All log messages before absl::InitializeLog() is called are
written to STDERR
```

```
E0000 00:00:1747820025.531747      35 cuda_dnn.cc:8310] Unable to
register cuDNN factory: Attempting to register factory for plugin
cuDNN when one has already been registered
E0000 00:00:1747820025.667365      35 cuda_blas.cc:1418] Unable to
register cuBLAS factory: Attempting to register factory for plugin
cuBLAS when one has already been registered
```

```
check
```

```
train_df_new, temp_df_new = train_test_split(
    df_resampled,
    train_size=0.8,
    shuffle=True,
    random_state=42,
    stratify=df_resampled['category_encoded']
)

valid_df_new, test_df_new = train_test_split(
    temp_df_new,
    test_size=0.5,
    shuffle=True,
    random_state=42,
    stratify=temp_df_new['category_encoded']
)

from tensorflow.keras.preprocessing.image import ImageDataGenerator

batch_size = 16
img_size = (224, 224)
channels = 3
img_shape = (img_size[0], img_size[1], channels)

tr_gen = ImageDataGenerator(
    rescale=1./255
)

ts_gen = ImageDataGenerator(rescale=1./255)

train_gen_new = tr_gen.flow_from_dataframe(
    train_df_new,
    x_col='image_path',
    y_col='category_encoded',
    target_size=img_size,
    class_mode='sparse',
    color_mode='rgb',
    shuffle=True,
    batch_size=batch_size
)

valid_gen_new = ts_gen.flow_from_dataframe(
    valid_df_new,
```

```
    x_col='image_path',
    y_col='category_encoded',
    target_size=img_size,
    class_mode='sparse',
    color_mode='rgb',
    shuffle=True,
    batch_size=batch_size
)

test_gen_new = ts_gen.flow_from_dataframe(
    test_df_new,
    x_col='image_path',
    y_col='category_encoded',
    target_size=img_size,
    class_mode='sparse',
    color_mode='rgb',
    shuffle=False,
    batch_size=batch_size
)
```

```
Found 30720 validated image filenames belonging to 4 classes.
Found 3840 validated image filenames belonging to 4 classes.
Found 3840 validated image filenames belonging to 4 classes.
```

```
print("Num GPUs Available: ",
len(tf.config.list_physical_devices('GPU')))
```

```
Num GPUs Available:  2
```

```
gpus = tf.config.list_physical_devices('GPU')
if gpus:
    try:
        for gpu in gpus:
            tf.config.experimental.set_memory_growth(gpu, True)
        print("GPU is set for TensorFlow")
    except RuntimeError as e:
        print(e)
```

```
GPU is set for TensorFlow
```

```
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Dense,
Flatten, Input, Concatenate, Lambda, Add

img_size = (224, 224)
channels = 3
img_shape = (224, 224, 3)
num_classes = len(train_df_new['category_encoded'].unique())

def split_image(image):
    upper_half = image[:, :img_size[0]//2, :, :]
```

```
    lower_half = image[:, img_size[0]//2:, :, :]
    return upper_half, lower_half

def flip_lower_half(lower_half):
    return tf.image.flip_left_right(lower_half)

input_layer = Input(shape=img_shape)

upper_half, lower_half = Lambda(split_image)(input_layer)

lower_half_flipped = Lambda(flip_lower_half)(lower_half)

upper_conv1 = Conv2D(32, (3, 3), activation='relu', padding='same')
(upper_half)
upper_pool1 = MaxPooling2D((2, 2))(upper_conv1)
upper_conv2 = Conv2D(64, (3, 3), activation='relu', padding='same')
(upper_pool1)
upper_pool2 = MaxPooling2D((2, 2))(upper_conv2)
upper_conv3 = Conv2D(128, (3, 3), activation='relu', padding='same')
(upper_pool2)
upper_pool3 = MaxPooling2D((2, 2))(upper_conv3)

lower_conv1 = Conv2D(32, (3, 3), activation='relu', padding='same')
(lower_half_flipped)
lower_pool1 = MaxPooling2D((2, 2))(lower_conv1)
lower_conv2 = Conv2D(64, (3, 3), activation='relu', padding='same')
(lower_pool1)
lower_pool2 = MaxPooling2D((2, 2))(lower_conv2)
lower_conv3 = Conv2D(128, (3, 3), activation='relu', padding='same')
(lower_pool2)
lower_pool3 = MaxPooling2D((2, 2))(lower_conv3)

upper_flat = Flatten()(upper_pool3)
lower_flat = Flatten()(lower_pool3)

weight_upper = 0.5
weight_lower = 0.5
weighted_upper = Dense(512, activation='relu')(upper_flat)
weighted_lower = Dense(512, activation='relu')(lower_flat)
combined = Add()([weighted_upper * weight_upper, weighted_lower *
weight_lower])

fc1 = Dense(256, activation='relu')(combined)
fc2 = Dense(128, activation='relu')(fc1)
output = Dense(num_classes, activation='softmax')(fc2)

model = Model(inputs=input_layer, outputs=output)

model.compile(optimizer='adam',
loss='sparse_categorical_crossentropy', metrics=['accuracy'])
```

```
model.summary()
```

```
I0000 00:00:1747820419.841119      35 gpu_device.cc:2022] Created
device /job:localhost/replica:0/task:0/device:GPU:0 with 13942 MB
memory:  -> device: 0, name: Tesla T4, pci bus id: 0000:00:04.0,
compute capability: 7.5
I0000 00:00:1747820419.841810      35 gpu_device.cc:2022] Created
device /job:localhost/replica:0/task:0/device:GPU:1 with 13942 MB
memory:  -> device: 1, name: Tesla T4, pci bus id: 0000:00:05.0,
compute capability: 7.5
```

```
Model: "functional"
```

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━┓
┃ Layer (type)                    ┃ Output Shape           ┃       Param # ┃
┃ Connected to                    ┃                        ┃               ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━┩
│ input_layer (InputLayer)        │ (None, 224, 224, 3)    │             0 │
│ -                               │                        │               │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ lambda (Lambda)                 │ [(None, 112, 224, 3),  │             0 │
│ input_layer[0][0]               │                        │               │
│                                 │ (None, 112, 224, 3)]   │               │
│                                 │                        │               │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ lambda_1 (Lambda)               │ (None, 112, 224, 3)    │             0 │
│ lambda[0][1]                    │                        │               │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ conv2d (Conv2D)                 │ (None, 112, 224, 32)   │           896 │
│ lambda[0][0]                    │                        │               │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ conv2d_3 (Conv2D)               │ (None, 112, 224, 32)   │           896 │
│ lambda_1[0][0]                  │                        │               │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ max_pooling2d                   │ (None, 56, 112, 32)    │             0 │
│ conv2d[0][0]                    │                        │               │
│ (MaxPooling2D)                  │                        │               │
│                                 │                        │               │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ max_pooling2d_3                 │ (None, 56, 112, 32)    │             0 │
│ conv2d_3[0][0]                  │                        │               │
```

```
(MaxPooling2D)                  |                           |
                                |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
conv2d_1 (Conv2D)               | (None, 56, 112, 64)       |          18,496
max_pooling2d[0][0]             |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
conv2d_4 (Conv2D)               | (None, 56, 112, 64)       |          18,496
max_pooling2d_3[0][0]           |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
max_pooling2d_1                 | (None, 28, 56, 64)        |               0
conv2d_1[0][0]                  |                           |
(MaxPooling2D)                  |                           |
                                |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
max_pooling2d_4                 | (None, 28, 56, 64)        |               0
conv2d_4[0][0]                  |                           |
(MaxPooling2D)                  |                           |
                                |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
conv2d_2 (Conv2D)               | (None, 28, 56, 128)       |          73,856
max_pooling2d_1[0][0]           |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
conv2d_5 (Conv2D)               | (None, 28, 56, 128)       |          73,856
max_pooling2d_4[0][0]           |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
max_pooling2d_2                 | (None, 14, 28, 128)       |               0
conv2d_2[0][0]                  |                           |
(MaxPooling2D)                  |                           |
                                |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
max_pooling2d_5                 | (None, 14, 28, 128)       |               0
conv2d_5[0][0]                  |                           |
(MaxPooling2D)                  |                           |
                                |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
flatten (Flatten)               | (None, 50176)             |               0
max_pooling2d_2[0][0]           |                           |
--------------------------------+---------------------------+-----------------
--------------------------------+
flatten_1 (Flatten)             | (None, 50176)             |               0
```

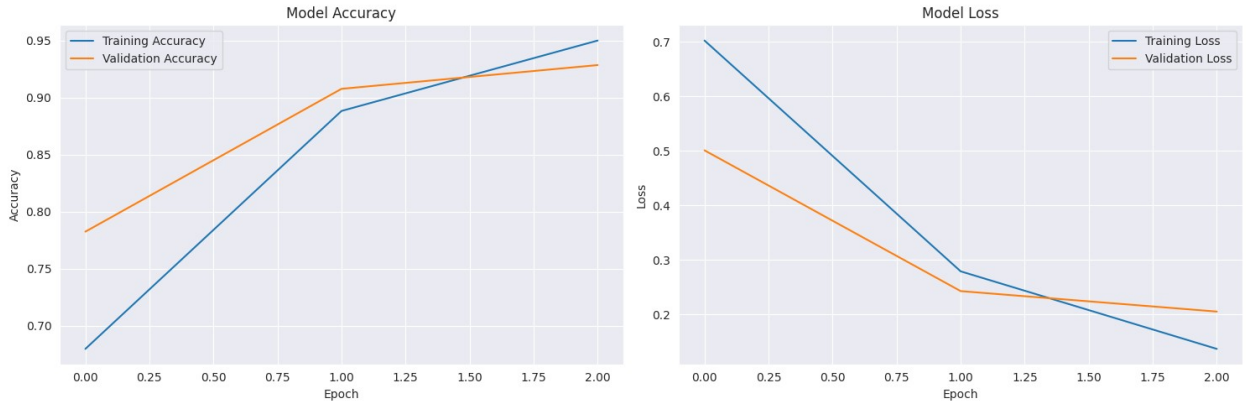
```
│ max_pooling2d_5[0][0]      │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ dense (Dense)              │ (None, 512)             │   25,690,624 │
│ flatten[0][0]              │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ dense_1 (Dense)            │ (None, 512)             │   25,690,624 │
│ flatten_1[0][0]            │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ multiply (Multiply)        │ (None, 512)             │            0 │
│ dense[0][0]                │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ multiply_1 (Multiply)      │ (None, 512)             │            0 │
│ dense_1[0][0]              │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ add (Add)                  │ (None, 512)             │            0 │
│ multiply[0][0],            │
│                            │                         │
│ multiply_1[0][0]           │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ dense_2 (Dense)            │ (None, 256)             │      131,328 │
│ add[0][0]                  │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ dense_3 (Dense)            │ (None, 128)             │       32,896 │
│ dense_2[0][0]              │
├────────────────────────────┼─────────────────────────┼──────────────┤
│ dense_4 (Dense)            │ (None, 4)               │          516 │
│ dense_3[0][0]              │
└────────────────────────────┴─────────────────────────┴──────────────┘

 Total params: 51,732,484 (197.34 MB)

 Trainable params: 51,732,484 (197.34 MB)

 Non-trainable params: 0 (0.00 B)
```

```
history = model.fit(
    train_gen_new,
    validation_data=valid_gen_new,
    epochs=3,
    batch_size=batch_size
)
```

```
Epoch 1/3

WARNING: All log messages before absl::InitializeLog() is called are
written to STDERR
I0000 00:00:1747820454.337545     137 service.cc:148] XLA service
0x7e1038005cb0 initialized for platform CUDA (this does not guarantee
that XLA will be used). Devices:
I0000 00:00:1747820454.339158     137 service.cc:156]   StreamExecutor
device (0): Tesla T4, Compute Capability 7.5
I0000 00:00:1747820454.339178     137 service.cc:156]   StreamExecutor
device (1): Tesla T4, Compute Capability 7.5
I0000 00:00:1747820455.028033     137 cuda_dnn.cc:529] Loaded cuDNN
version 90300

   1/1920 ━━━━━━━━━━━━━━━━━━━━ 5:43:46 11s/step - accuracy: 0.1875 -
loss: 1.3904

I0000 00:00:1747820460.297014     137 device_compiler.h:188] Compiled
cluster using XLA!  This line is logged at most once for the lifetime
of the process.

1920/1920 ━━━━━━━━━━━━━━━━━━━━ 316s 159ms/step - accuracy: 0.5609 -
loss: 0.9288 - val_accuracy: 0.7826 - val_loss: 0.5007
Epoch 2/3
1920/1920 ━━━━━━━━━━━━━━━━━━━━ 81s 42ms/step - accuracy: 0.8730 -
loss: 0.3117 - val_accuracy: 0.9078 - val_loss: 0.2424
Epoch 3/3
1920/1920 ━━━━━━━━━━━━━━━━━━━━ 81s 42ms/step - accuracy: 0.9491 -
loss: 0.1355 - val_accuracy: 0.9286 - val_loss: 0.2049
```

```python
def plot_training_history(history):

    fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(15, 5))

    ax1.plot(history.history['accuracy'], label='Training Accuracy')
    ax1.plot(history.history['val_accuracy'], label='Validation
Accuracy')
    ax1.set_title('Model Accuracy')
    ax1.set_xlabel('Epoch')
    ax1.set_ylabel('Accuracy')
    ax1.legend()
    ax1.grid(True)

    ax2.plot(history.history['loss'], label='Training Loss')
    ax2.plot(history.history['val_loss'], label='Validation Loss')
    ax2.set_title('Model Loss')
    ax2.set_xlabel('Epoch')
    ax2.set_ylabel('Loss')
    ax2.legend()
    ax2.grid(True)
```

```
    plt.tight_layout()
    plt.show()

plot_training_history(history)
```



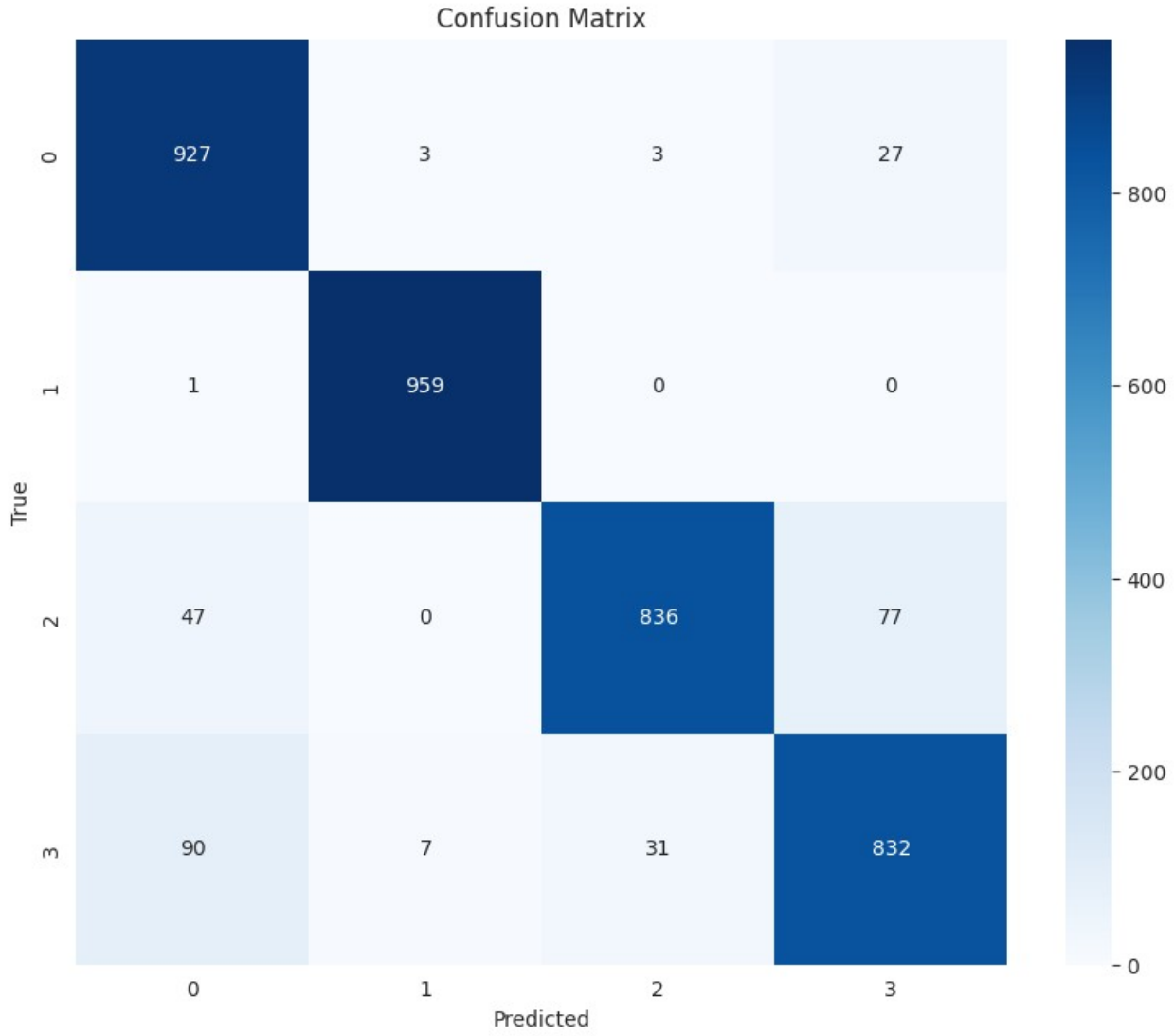

```
test_loss, test_accuracy = model.evaluate(test_gen_new)
print(f"Test Accuracy: {test_accuracy:.4f}, Test Loss:
{test_loss:.4f}")
```

```
240/240 ━━━━━━━━━━━━━━━━━━━━ 19s 81ms/step - accuracy: 0.9226 - loss:
0.2155
Test Accuracy: 0.9255, Test Loss: 0.2091
```

```
from sklearn.metrics import confusion_matrix, classification_report

test_gen_new.reset()
y_pred = model.predict(test_gen_new)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true = test_gen_new.classes
```

```
240/240 ━━━━━━━━━━━━━━━━━━━━ 11s 41ms/step
```

```
class_names = list(test_gen_new.class_indices.keys())

cm = confusion_matrix(y_true, y_pred_classes)

plt.figure(figsize=(10, 8))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues',
xticklabels=class_names, yticklabels=class_names)
plt.title('Confusion Matrix')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.show()
```




```
print("\nClassification Report:")
print(classification_report(y_true, y_pred_classes,
target_names=class_names))


Classification Report:
              precision    recall  f1-score   support

           0       0.87      0.97      0.92       960
           1       0.99      1.00      0.99       960
           2       0.96      0.87      0.91       960
           3       0.89      0.87      0.88       960

    accuracy                           0.93      3840
   macro avg       0.93      0.93      0.93      3840
weighted avg       0.93      0.93      0.93      3840
```