Deep learning Lab Assignment

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Binary Classification

```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import cifar10

# Load CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()

# Selecting class "Airplane" (label 0) and merging others into "Not Airplane" (label 1)
y_train_binary = np.where(y_train == 0, 0, 1)
y_test_binary = np.where(y_test == 0, 0, 1)

# Normalize pixel values
x_train, x_test = x_train / 255.0, x_test / 255.0

# Build CNN model
model = keras.Sequential([
    layers.Conv2D(32, (3,3), activation='relu', input_shape=(32,32,3)),
    layers.MaxPooling2D((2,2)),
    layers.Conv2D(64, (3,3), activation='relu'),
    layers.MaxPooling2D((2,2)),
    layers.Conv2D(128, (3,3), activation='relu'),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(1, activation='sigmoid')  # Binary classification
])

# Compile model
model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

# Train model
history = model.fit(x_train, y_train_binary, epochs=5, validation_data=(x_test, y_test_binary), batch_size=64)

# Model summary
model.summary()

# Evaluate model
test_loss, test_acc = model.evaluate(x_test, y_test_binary, verbose=2)
print(f"Test Accuracy: {test_acc:.4f}")
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 ━━━━━━━━━━━━━━━━━━━━ 13s 0us/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Ir
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 7ms/step - accuracy: 0.9063 - loss: 0.2780 - val_accuracy: 0.9180 - val_loss: 0.2324
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 6s 5ms/step - accuracy: 0.9260 - loss: 0.1979 - val_accuracy: 0.9356 - val_loss: 0.1754
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 5s 4ms/step - accuracy: 0.9361 - loss: 0.1724 - val_accuracy: 0.9368 - val_loss: 0.1701
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 3s 4ms/step - accuracy: 0.9461 - loss: 0.1453 - val_accuracy: 0.9354 - val_loss: 0.1656
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.9508 - loss: 0.1295 - val_accuracy: 0.9468 - val_loss: 0.1452
Model: "sequential"
```

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 30, 30, 32)	896
max_pooling2d (MaxPooling2D)	(None, 15, 15, 32)	0
conv2d_1 (Conv2D)	(None, 13, 13, 64)	18,496
max_pooling2d_1 (MaxPooling2D)	(None, 6, 6, 64)	0
conv2d_2 (Conv2D)	(None, 4, 4, 128)	73,856
flatten (Flatten)	(None, 2048)	0
dense (Dense)	(None, 128)	262,272
dense_1 (Dense)	(None, 1)	129

```
 Total params: 1,066,949 (4.07 MB)
 Trainable params: 355,649 (1.36 MB)
 Non-trainable params: 0 (0.00 B)
 Optimizer params: 711,300 (2.71 MB)
313/313 - 1s - 4ms/step - accuracy: 0.9468 - loss: 0.1452
Test Accuracy: 0.9468
```

Multiclass Classification

```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import cifar10

# Load CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()

# Normalize pixel values to [0,1]
x_train, x_test = x_train / 255.0, x_test / 255.0

# Convert labels to categorical (one-hot encoding)
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)

# Build CNN model
model = keras.Sequential([
    layers.Conv2D(32, (3,3), activation='relu', input_shape=(32,32,3)),
    layers.MaxPooling2D((2,2)),
    layers.Conv2D(64, (3,3), activation='relu'),
    layers.MaxPooling2D((2,2)),
    layers.Conv2D(128, (3,3), activation='relu'),
```

```
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(10, activation='softmax')  # Multiclass classification (10 classes)
])

# Compile model
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])

# Train model
history = model.fit(x_train, y_train, epochs=5, validation_data=(x_test, y_test), batch_size=64)

# Model summary
model.summary()

# Evaluate model
test_loss, test_acc = model.evaluate(x_test, y_test, verbose=2)
print(f"Test Accuracy: {test_acc:.4f}")
```

```
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 8s 8ms/step - accuracy: 0.3391 - loss: 1.7926 - val_accuracy: 0.5580 - val_loss: 1.2403
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.5636 - loss: 1.2243 - val_accuracy: 0.6192 - val_loss: 1.0659
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 4s 5ms/step - accuracy: 0.6304 - loss: 1.0470 - val_accuracy: 0.6467 - val_loss: 1.0078
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 5s 4ms/step - accuracy: 0.6755 - loss: 0.9257 - val_accuracy: 0.6814 - val_loss: 0.9158
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 3s 4ms/step - accuracy: 0.7091 - loss: 0.8285 - val_accuracy: 0.6904 - val_loss: 0.8840
```

Model: "sequential_2"

Layer (type)	Output Shape	Param #
conv2d_6 (Conv2D)	(None, 30, 30, 32)	896
max_pooling2d_4 (MaxPooling2D)	(None, 15, 15, 32)	0
conv2d_7 (Conv2D)	(None, 13, 13, 64)	18,496
max_pooling2d_5 (MaxPooling2D)	(None, 6, 6, 64)	0
conv2d_8 (Conv2D)	(None, 4, 4, 128)	73,856
flatten_2 (Flatten)	(None, 2048)	0
dense_4 (Dense)	(None, 128)	262,272
dense_5 (Dense)	(None, 10)	1,290

Total params: 1,070,432 (4.08 MB)
Trainable params: 356,810 (1.36 MB)
Non-trainable params: 0 (0.00 B)
Optimizer params: 713,622 (2.72 MB)

```
313/313 - 1s - 3ms/step - accuracy: 0.6904 - loss: 0.8840
Test Accuracy: 0.6904
```

Pretrained Model (VGG16,ResNet50,MoblieNet)

```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers, applications
from tensorflow.keras.datasets import cifar10

# Load CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()

# Normalize pixel values
x_train, x_test = x_train / 255.0, x_test / 255.0

# Convert labels to categorical (one-hot encoding)
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)

# Function to create a model with Transfer Learning
def create_pretrained_model(base_model):
    base_model.trainable = False  # Freeze base model layers
    model = keras.Sequential([
        base_model,
        layers.GlobalAveragePooling2D(),
        layers.Dense(128, activation='relu'),
        layers.Dense(10, activation='softmax')  # 10 classes
    ])
    model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
    return model

# Load pre-trained models (without top layers)
vgg16_base = applications.VGG16(weights='imagenet', include_top=False, input_shape=(32,32,3))
resnet50_base = applications.ResNet50(weights='imagenet', include_top=False, input_shape=(32,32,3))
mobilenet_base = applications.MobileNetV2(weights='imagenet', include_top=False, input_shape=(32,32,3))

# Create models
vgg16_model = create_pretrained_model(vgg16_base)
resnet50_model = create_pretrained_model(resnet50_base)
mobilenet_model = create_pretrained_model(mobilenet_base)

# Train models (only showing VGG16, repeat for others)
history_vgg16 = vgg16_model.fit(x_train, y_train, epochs=5, validation_data=(x_test, y_test), batch_size=64)
history_resnet50 = resnet50_model.fit(x_train, y_train, epochs=5, validation_data=(x_test, y_test), batch_size=64)
history_mobilenet = mobilenet_model.fit(x_train, y_train, epochs=5, validation_data=(x_test, y_test), batch_size=64)

# Model summaries
print("\nVGG16 Model Summary:")
vgg16_model.summary()

print("\nResNet50 Model Summary:")
resnet50_model.summary()

print("\nMobileNetV2 Model Summary:")
mobilenet_model.summary()

# Evaluate models
print("\nVGG16 Accuracy:")
vgg16_model.evaluate(x_test, y_test)

print("\nResNet50 Accuracy:")
resnet50_model.evaluate(x_test, y_test)

print("\nMobileNetV2 Accuracy:")
mobilenet_model.evaluate(x_test, y_test)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58889256/58889256 ━━━━━━━━━━━━━━━━━━━━ 4s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resnet/resnet50_weights_tf_dim_ordering_tf_kernels_notop.h5
94765736/94765736 ━━━━━━━━━━━━━━━━━━━━ 5s 0us/step
<ipython-input-4-c451b73e33e9>:31: UserWarning: `input_shape` is undefined or non-square, or `rows` is not in [96, 128, 160, 192, 224]. Weights for input shape (224, 224) will be loaded as the default.
  mobilenet_base = applications.MobileNetV2(weights='imagenet', include_top=False, input_shape=(32,32,3))
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/mobilenet_v2/mobilenet_v2_weights_tf_dim_ordering_tf_kernels_1.0_224_no_top.h5
9406464/9406464 ━━━━━━━━━━━━━━━━━━━━ 2s 0us/step
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 19s 20ms/step - accuracy: 0.4562 - loss: 1.5775 - val_accuracy: 0.5576 - val_loss: 1.2756
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 13s 13ms/step - accuracy: 0.5712 - loss: 1.2223 - val_accuracy: 0.5739 - val_loss: 1.2186
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 11s 14ms/step - accuracy: 0.5986 - loss: 1.1496 - val_accuracy: 0.5869 - val_loss: 1.1790
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 11s 14ms/step - accuracy: 0.6120 - loss: 1.1139 - val_accuracy: 0.5881 - val_loss: 1.1906
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 20s 13ms/step - accuracy: 0.6205 - loss: 1.0829 - val_accuracy: 0.5982 - val_loss: 1.1578
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 33s 29ms/step - accuracy: 0.2061 - loss: 2.1756 - val_accuracy: 0.3169 - val_loss: 1.9253
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 9s 11ms/step - accuracy: 0.3113 - loss: 1.9058 - val_accuracy: 0.3192 - val_loss: 1.8599
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 11ms/step - accuracy: 0.3346 - loss: 1.8356 - val_accuracy: 0.3626 - val_loss: 1.7834
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 11ms/step - accuracy: 0.3497 - loss: 1.7982 - val_accuracy: 0.3629 - val_loss: 1.7702
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 8s 10ms/step - accuracy: 0.3571 - loss: 1.7786 - val_accuracy: 0.3854 - val_loss: 1.7330
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 22s 18ms/step - accuracy: 0.2587 - loss: 2.0518 - val_accuracy: 0.3171 - val_loss: 1.8838
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 6s 8ms/step - accuracy: 0.3276 - loss: 1.8568 - val_accuracy: 0.3358 - val_loss: 1.8438
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 8ms/step - accuracy: 0.3419 - loss: 1.8179 - val_accuracy: 0.3386 - val_loss: 1.8261
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 7ms/step - accuracy: 0.3550 - loss: 1.7841 - val_accuracy: 0.3431 - val_loss: 1.8180
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 6s 8ms/step - accuracy: 0.3637 - loss: 1.7558 - val_accuracy: 0.3537 - val_loss: 1.8020
```

VGG16 Model Summary:
Model: "sequential_3"

Layer (type)	Output Shape	Param #
vgg16 (Functional)	(None, 1, 1, 512)	14,714,688
global_average_pooling2d (GlobalAveragePooling2D)	(None, 512)	0
dense_6 (Dense)	(None, 128)	65,664
dense_7 (Dense)	(None, 10)	1,290

Total params: 14,915,552 (56.90 MB)
Trainable params: 66,954 (261.54 KB)
Non-trainable params: 14,714,688 (56.13 MB)
Optimizer params: 133,910 (523.09 KB)

ResNet50 Model Summary:
Model: "sequential_4"

Layer (type)	Output Shape	Param #
resnet50 (Functional)	(None, 1, 1, 2048)	23,587,712
global_average_pooling2d_1 (GlobalAveragePooling2D)	(None, 2048)	0
dense_8 (Dense)	(None, 128)	262,272
dense_9 (Dense)	(None, 10)	1,290

Total params: 24,378,400 (93.00 MB)
Trainable params: 263,562 (1.01 MB)
Non-trainable params: 23,587,712 (89.98 MB)
Optimizer params: 527,126 (2.01 MB)

MobileNetV2 Model Summary:
Model: "sequential_5"

Layer (type)	Output Shape	Param #
mobilenetv2_1.00_224 (Functional)	(None, 1, 1, 1280)	2,257,984
global_average_pooling2d_2 (GlobalAveragePooling2D)	(None, 1280)	0
dense_10 (Dense)	(None, 128)	163,968
dense_11 (Dense)	(None, 10)	1,290

Total params: 2,753,760 (10.50 MB)
Trainable params: 165,258 (645.54 KB)
Non-trainable params: 2,257,984 (8.61 MB)
Optimizer params: 330,518 (1.26 MB)

```
VGG16 Accuracy:
313/313 ━━━━━━━━━━━━━━━━━━━━ 4s 8ms/step - accuracy: 0.6005 - loss: 1.1550

ResNet50 Accuracy:
313/313 ━━━━━━━━━━━━━━━━━━━━ 5s 7ms/step - accuracy: 0.3878 - loss: 1.7277

MobileNetV2 Accuracy:
313/313 ━━━━━━━━━━━━━━━━━━━━ 4s 7ms/step - accuracy: 0.3579 - loss: 1.7961
```

Fine Tuning

```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers, applications
from tensorflow.keras.datasets import cifar10

# Load CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()

# Normalize pixel values
x_train, x_test = x_train / 255.0, x_test / 255.0

# Convert labels to categorical (one-hot encoding)
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)

# Load pre-trained VGG16 model
vgg16_base = applications.VGG16(weights='imagenet', include_top=False, input_shape=(32,32,3))

# Freeze the first few layers and unfreeze the last few layers for fine-tuning
for layer in vgg16_base.layers[:10]:  # Freeze first 10 layers
    layer.trainable = False

# Build fine-tuned model
model = keras.Sequential([
    vgg16_base,
```

```
    layers.GlobalAveragePooling2D(),
    layers.Dense(256, activation='relu'),
    layers.Dropout(0.5),  # Dropout for regularization
    layers.Dense(10, activation='softmax')  # 10 classes
])

# Compile model with a lower learning rate for fine-tuning
model.compile(optimizer=keras.optimizers.Adam(learning_rate=0.0001),
              loss='categorical_crossentropy',
              metrics=['accuracy'])

# Train model
history = model.fit(x_train, y_train, epochs=10, validation_data=(x_test, y_test), batch_size=64)

# Model summary
print("\nFine-Tuned VGG16 Model Summary:")
model.summary()

# Evaluate model
print("\nFine-Tuned VGG16 Accuracy:")
model.evaluate(x_test, y_test)
```

```
Epoch 1/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 46s 50ms/step - accuracy: 0.5473 - loss: 1.3172 - val_accuracy: 0.7556 - val_loss: 0.7164
Epoch 2/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 71s 42ms/step - accuracy: 0.7765 - loss: 0.6726 - val_accuracy: 0.7810 - val_loss: 0.6569
Epoch 3/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 32s 41ms/step - accuracy: 0.8336 - loss: 0.5079 - val_accuracy: 0.7977 - val_loss: 0.6181
Epoch 4/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 33s 42ms/step - accuracy: 0.8819 - loss: 0.3565 - val_accuracy: 0.8047 - val_loss: 0.6156
Epoch 5/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 41s 41ms/step - accuracy: 0.9216 - loss: 0.2403 - val_accuracy: 0.8105 - val_loss: 0.6503
Epoch 6/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 41s 41ms/step - accuracy: 0.9465 - loss: 0.1664 - val_accuracy: 0.7957 - val_loss: 0.7841
Epoch 7/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 32s 41ms/step - accuracy: 0.9634 - loss: 0.1201 - val_accuracy: 0.7899 - val_loss: 0.8604
Epoch 8/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 33s 42ms/step - accuracy: 0.9715 - loss: 0.0908 - val_accuracy: 0.7968 - val_loss: 0.8241
Epoch 9/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 41s 43ms/step - accuracy: 0.9767 - loss: 0.0746 - val_accuracy: 0.8032 - val_loss: 0.9243
Epoch 10/10
782/782 ━━━━━━━━━━━━━━━━━━━━ 32s 41ms/step - accuracy: 0.9774 - loss: 0.0746 - val_accuracy: 0.7927 - val_loss: 0.9759

Fine-Tuned VGG16 Model Summary:
Model: "sequential_6"
```

Layer (type)	Output Shape	Param #
vgg16 (Functional)	(None, 1, 1, 512)	14,714,688
global_average_pooling2d_3 (GlobalAveragePooling2D)	(None, 512)	0
dense_12 (Dense)	(None, 256)	131,328
dropout (Dropout)	(None, 256)	0
dense_13 (Dense)	(None, 10)	2,570

```
 Total params: 41,074,784 (156.69 MB)
 Trainable params: 13,113,098 (50.02 MB)
 Non-trainable params: 1,735,488 (6.62 MB)
 Optimizer params: 26,226,198 (100.05 MB)

Fine-Tuned VGG16 Accuracy:
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 8ms/step - accuracy: 0.7895 - loss: 0.9812
[0.9759486317634583, 0.7926999926567078]
```

Comparative Analysis

```
import pandas as pd
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import applications
from tensorflow.keras.datasets import cifar10
import time

# Load CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()

# Normalize pixel values
x_train, x_test = x_train / 255.0, x_test / 255.0

# Convert labels to categorical (one-hot encoding)
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)

# Function to build, train, and evaluate models
def evaluate_model(model, name, epochs=5):
    start_time = time.time()
    history = model.fit(x_train, y_train, epochs=epochs, validation_data=(x_test, y_test), batch_size=64, verbose=1)
    end_time = time.time()

    # Evaluate model performance
    loss, accuracy = model.evaluate(x_test, y_test, verbose=0)

    # Store model details
    return {
        "Model": name,
        "Accuracy": round(accuracy * 100, 2),  # Convert to percentage
        "Loss": round(loss, 4),
        "Parameters": model.count_params(),
        "Training Time (s)": round(end_time - start_time, 2)
    }

# CNN from Scratch (Multiclass)
cnn_model = keras.Sequential([
    keras.layers.Conv2D(32, (3,3), activation='relu', input_shape=(32,32,3)),
    keras.layers.MaxPooling2D((2,2)),
    keras.layers.Conv2D(64, (3,3), activation='relu'),
    keras.layers.MaxPooling2D((2,2)),
    keras.layers.Conv2D(128, (3,3), activation='relu'),
    keras.layers.Flatten(),
    keras.layers.Dense(128, activation='relu'),
    keras.layers.Dense(10, activation='softmax')
])
cnn_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
cnn_results = evaluate_model(cnn_model, "CNN from Scratch")

# VGG16 (Pretrained)
vgg16_base = applications.VGG16(weights='imagenet', include_top=False, input_shape=(32,32,3))
vgg16_base.trainable = False  # Freeze all layers
vgg16_model = keras.Sequential([vgg16_base, keras.layers.GlobalAveragePooling2D(), keras.layers.Dense(10, activation='softmax')])
vgg16_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
vgg16_results = evaluate_model(vgg16_model, "VGG16 (Pretrained)")

# ResNet50 (Pretrained)
```

```
resnet50_base = applications.ResNet50(weights='imagenet', include_top=False, input_shape=(32,32,3))
resnet50_base.trainable = False
resnet50_model = keras.Sequential([resnet50_base, keras.layers.GlobalAveragePooling2D(), keras.layers.Dense(10, activation='softmax')])
resnet50_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
resnet50_results = evaluate_model(resnet50_model, "ResNet50 (Pretrained)")

# MobileNetV2 (Pretrained)
mobilenet_base = applications.MobileNetV2(weights='imagenet', include_top=False, input_shape=(32,32,3))
mobilenet_base.trainable = False
mobilenet_model = keras.Sequential([mobilenet_base, keras.layers.GlobalAveragePooling2D(), keras.layers.Dense(10, activation='softmax')])
mobilenet_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
mobilenet_results = evaluate_model(mobilenet_model, "MobileNetV2 (Pretrained)")

# Fine-Tuned VGG16
for layer in vgg16_base.layers[:10]:  # Unfreeze last few layers
    layer.trainable = True
fine_tuned_vgg16 = keras.Sequential([vgg16_base, keras.layers.GlobalAveragePooling2D(), keras.layers.Dense(256, activation='relu'), keras.layers.Dropout(0.5), keras.layers.Dense(10, activation='softmax')])
fine_tuned_vgg16.compile(optimizer=keras.optimizers.Adam(learning_rate=0.0001), loss='categorical_crossentropy', metrics=['accuracy'])
fine_tuned_vgg16_results = evaluate_model(fine_tuned_vgg16, "Fine-Tuned VGG16")

# Create DataFrame for results
df = pd.DataFrame([cnn_results, vgg16_results, resnet50_results, mobilenet_results, fine_tuned_vgg16_results])

# Print results
print("\nComparative Analysis of Models (Accuracy & Loss):\n")
print(df)
```

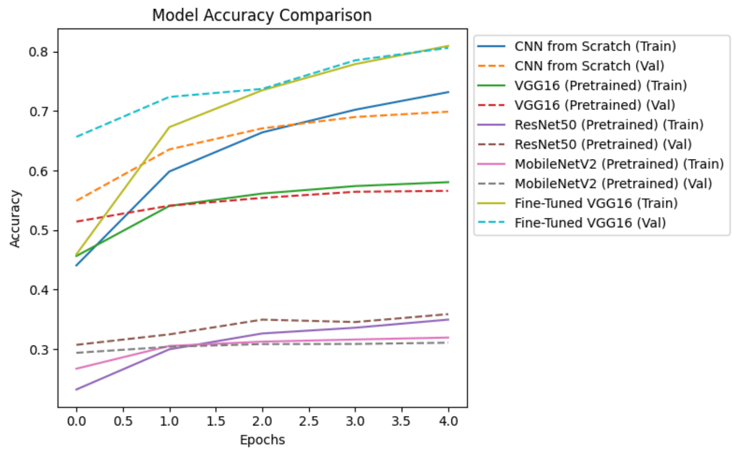
```
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 3s 4ms/step - accuracy: 0.6433 - loss: 1.0037 - val_accuracy: 0.6652 - val_loss: 0.9602
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 5s 4ms/step - accuracy: 0.6970 - loss: 0.8659 - val_accuracy: 0.6741 - val_loss: 0.9314
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.7230 - loss: 0.7899 - val_accuracy: 0.6761 - val_loss: 0.9245
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 14s 16ms/step - accuracy: 0.3637 - loss: 1.8536 - val_accuracy: 0.5122 - val_loss: 1.4288
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 18s 14ms/step - accuracy: 0.5330 - loss: 1.3751 - val_accuracy: 0.5427 - val_loss: 1.3356
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 11s 14ms/step - accuracy: 0.5580 - loss: 1.2991 - val_accuracy: 0.5534 - val_loss: 1.2957
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 11s 15ms/step - accuracy: 0.5691 - loss: 1.2644 - val_accuracy: 0.5615 - val_loss: 1.2694
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 21s 15ms/step - accuracy: 0.5781 - loss: 1.2321 - val_accuracy: 0.5664 - val_loss: 1.2529
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 26s 21ms/step - accuracy: 0.1972 - loss: 2.1879 - val_accuracy: 0.2952 - val_loss: 1.9652
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 8s 11ms/step - accuracy: 0.2948 - loss: 1.9568 - val_accuracy: 0.3312 - val_loss: 1.8848
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 11s 12ms/step - accuracy: 0.3205 - loss: 1.8938 - val_accuracy: 0.3466 - val_loss: 1.8394
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 12ms/step - accuracy: 0.3375 - loss: 1.8599 - val_accuracy: 0.3639 - val_loss: 1.8121
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 12ms/step - accuracy: 0.3485 - loss: 1.8319 - val_accuracy: 0.3550 - val_loss: 1.7938
<ipython-input-7-0157f30ddf09>:65: UserWarning: `input_shape` is undefined or non-square, or `rows` is not in [96, 128, 160, 192, 224]. Weights for input shape (224, 224) will be loaded as the default.
  mobilenet_base = applications.MobileNetV2(weights='imagenet', include_top=False, input_shape=(32,32,3))
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 20s 17ms/step - accuracy: 0.2375 - loss: 2.1684 - val_accuracy: 0.2931 - val_loss: 1.9944
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 11s 8ms/step - accuracy: 0.3024 - loss: 1.9710 - val_accuracy: 0.3030 - val_loss: 1.9419
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 5s 7ms/step - accuracy: 0.3107 - loss: 1.9264 - val_accuracy: 0.3063 - val_loss: 1.9214
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 6s 7ms/step - accuracy: 0.3142 - loss: 1.9042 - val_accuracy: 0.3079 - val_loss: 1.9111
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 10s 8ms/step - accuracy: 0.3184 - loss: 1.8924 - val_accuracy: 0.3119 - val_loss: 1.9046
Epoch 1/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 32s 34ms/step - accuracy: 0.3565 - loss: 1.7916 - val_accuracy: 0.6703 - val_loss: 0.9263
Epoch 2/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 24s 31ms/step - accuracy: 0.6754 - loss: 0.9421 - val_accuracy: 0.7347 - val_loss: 0.7611
Epoch 3/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 40s 30ms/step - accuracy: 0.7477 - loss: 0.7402 - val_accuracy: 0.7733 - val_loss: 0.6516
Epoch 4/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 41s 30ms/step - accuracy: 0.7945 - loss: 0.6080 - val_accuracy: 0.8063 - val_loss: 0.5671
Epoch 5/5
782/782 ━━━━━━━━━━━━━━━━━━━━ 41s 30ms/step - accuracy: 0.8200 - loss: 0.5279 - val_accuracy: 0.8158 - val_loss: 0.5423

Comparative Analysis of Models (Accuracy & Loss):

                      Model  Accuracy    Loss  Parameters  Training Time (s)
0         CNN from Scratch     67.61  0.9245      356810              28.68
1        VGG16 (Pretrained)    56.64  1.2529    14719818              85.59
2     ResNet50 (Pretrained)    35.50  1.7938    23608202              68.31
3  MobileNetV2 (Pretrained)    31.19  1.9046     2270794              58.69
4          Fine-Tuned VGG16    81.58  0.5423    14848586             197.77
```

```
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import applications
from tensorflow.keras.datasets import cifar10

# Load CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()
x_train, x_test = x_train / 255.0, x_test / 255.0
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)

# Function to build, train, and store training history
def train_model(model, name, epochs=5):
    history = model.fit(x_train, y_train, epochs=epochs, validation_data=(x_test, y_test), batch_size=64, verbose=1)
    return {"name": name, "history": history}

# CNN from Scratch
cnn_model = keras.Sequential([
    keras.layers.Conv2D(32, (3,3), activation='relu', input_shape=(32,32,3)),
    keras.layers.MaxPooling2D((2,2)),
    keras.layers.Conv2D(64, (3,3), activation='relu'),
    keras.layers.MaxPooling2D((2,2)),
    keras.layers.Conv2D(128, (3,3), activation='relu'),
    keras.layers.Flatten(),
    keras.layers.Dense(128, activation='relu'),
    keras.layers.Dense(10, activation='softmax')
])
cnn_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
cnn_history = train_model(cnn_model, "CNN from Scratch")

# VGG16 (Pretrained)
vgg16_base = applications.VGG16(weights='imagenet', include_top=False, input_shape=(32,32,3))
vgg16_base.trainable = False
vgg16_model = keras.Sequential([vgg16_base, keras.layers.GlobalAveragePooling2D(), keras.layers.Dense(10, activation='softmax')])
vgg16_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
vgg16_history = train_model(vgg16_model, "VGG16 (Pretrained)")

# ResNet50 (Pretrained)
resnet50_base = applications.ResNet50(weights='imagenet', include_top=False, input_shape=(32,32,3))
resnet50_base.trainable = False
resnet50_model = keras.Sequential([resnet50_base, keras.layers.GlobalAveragePooling2D(), keras.layers.Dense(10, activation='softmax')])
resnet50_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
resnet50_history = train_model(resnet50_model, "ResNet50 (Pretrained)")
```

```
# MobileNetV2 (Pretrained)
mobilenet_base = applications.MobileNetV2(weights='imagenet', include_top=False, input_shape=(32,32,3))
mobilenet_base.trainable = False
mobilenet_model = keras.Sequential([mobilenet_base, keras.layers.GlobalAveragePooling2D(), keras.layers.Dense(10, activation='softmax')])
mobilenet_model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
mobilenet_history = train_model(mobilenet_model, "MobileNetV2 (Pretrained)")

#  Fine-Tuned VGG16
for layer in vgg16_base.layers[:10]:
    layer.trainable = True
fine_tuned_vgg16 = keras.Sequential([
    vgg16_base,
    keras.layers.GlobalAveragePooling2D(),
    keras.layers.Dense(256, activation='relu'),
    keras.layers.Dropout(0.5),
    keras.layers.Dense(10, activation='softmax')
])
fine_tuned_vgg16.compile(optimizer=keras.optimizers.Adam(learning_rate=0.0001), loss='categorical_crossentropy', metrics=['accuracy'])
fine_tuned_vgg16_history = train_model(fine_tuned_vgg16, "Fine-Tuned VGG16")

# List of models
models = [cnn_history, vgg16_history, resnet50_history, mobilenet_history, fine_tuned_vgg16_history]

# Plot Accuracy and Loss Graphs
plt.figure(figsize=(12, 5))
```

Show hidden output

```
# Plot Accuracy
plt.figure(figsize=(8, 5))
for model in models:
    plt.plot(model["history"].history["accuracy"], label=f"{model['name']} (Train)")
    plt.plot(model["history"].history["val_accuracy"], linestyle="dashed", label=f"{model['name']} (Val)")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.title("Model Accuracy Comparison")
plt.legend(loc="upper left", bbox_to_anchor=(1, 1))
plt.tight_layout()
plt.show()
```




```
# Plot Loss
plt.figure(figsize=(8, 5))
for model in models:
    plt.plot(model["history"].history["loss"], label=f"{model['name']} (Train)")
    plt.plot(model["history"].history["val_loss"], linestyle="dashed", label=f"{model['name']} (Val)")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.title("Model Loss Comparison")
plt.legend(loc="upper left", bbox_to_anchor=(1, 1))
plt.tight_layout()
plt.show()
```