```
import time
start_time = time.time()
```

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

```
Num GPUs Available: 1
```

```
# Install necessary packages
!pip install kagglehub -q
!pip install imutils -q
!pip install tensorflow -q
```

```
import os
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
import kagglehub
from imutils import paths

from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications import InceptionV3
from tensorflow.keras.layers import MaxPooling2D, Dropout, Flatten, Dense, Input
from tensorflow.keras.models import Model
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.applications.inception_v3 import preprocess_input
from tensorflow.keras.preprocessing.image import img_to_array, load_img
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.callbacks import EarlyStopping

from sklearn.preprocessing import LabelBinarizer
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report, confusion_matrix,accuracy_score
```

```
# Download Datasets and Get Paths
print("Downloading datasets...")
# Path for the training dataset
damage_dataset_path = kagglehub.dataset_download("anujms/car-damage-detection")
print(f"Damage dataset downloaded to: {damage_dataset_path}")

# Path for an example prediction image
coco_dataset_path = kagglehub.dataset_download("lplenka/coco-car-damage-detection-dataset")
print(f"COCO dataset downloaded to: {coco_dataset_path}")
```

```
Downloading datasets...
Damage dataset downloaded to: /kaggle/input/car-damage-detection
COCO dataset downloaded to: /kaggle/input/coco-car-damage-detection-dataset
```

```
# Configuration
INIT_LR = 1e-4
HEAD_EPOCHS = 20
FINE_TUNE_EPOCHS = 80
TOTAL_EPOCHS = HEAD_EPOCHS + FINE_TUNE_EPOCHS
BS = 64
CATEGORIES = ["00-damage", "01-whole"]

# Correctly Define Directories using the downloaded path
DIRECTORY_TRAIN = os.path.join(damage_dataset_path, "data1a", "training")
DIRECTORY_VAL = os.path.join(damage_dataset_path, "data1a", "validation")

# Load Data
print("Loading images...")
data = []
labels = []

# Function to load images from a directory
def load_images_from_dir(directory):
    for category in CATEGORIES:
        path = os.path.join(directory, category)
        if not os.path.exists(path):
            print(f"Directory not found: {path}. Skipping.")
            continue
        for img_file in os.listdir(path):
```

```
            img_path = os.path.join(path, img_file)
            image = load_img(img_path, target_size=(224, 224))
            image = img_to_array(image)
            image = preprocess_input(image)
            data.append(image)
            labels.append(category)

# Load training and validation images
load_images_from_dir(DIRECTORY_TRAIN)
load_images_from_dir(DIRECTORY_VAL)


# Preprocess Labels and Data
print("Preprocessing data...")
lb = LabelBinarizer()
labels = lb.fit_transform(labels)
labels = to_categorical(labels)

data = np.array(data, dtype="float32")
labels = np.array(labels)

# Split Data
(trainX, testX, trainY, testY) = train_test_split(data, labels,
                                                test_size=0.20, stratify=labels, random_state=42)

print(f"Training samples: {len(trainX)}, Testing samples: {len(testX)}")

# Data Augmentation
aug = ImageDataGenerator(
    rotation_range=20,
    zoom_range=0.15,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.15,
    horizontal_flip=True,
    fill_mode="nearest"
)
```

```
Loading images...
Preprocessing data...
Training samples: 1840, Testing samples: 460
```

```
# Build Model
print("Initializing InceptionV3 model...")
baseModel = InceptionV3(weights="imagenet", include_top=False,
                       input_tensor=Input(shape=(224, 224, 3)))

# Construct the head of the model
headModel = baseModel.output
headModel = MaxPooling2D(pool_size=(2, 2))(headModel)
headModel = Flatten(name="flatten")(headModel)
headModel = Dense(256, activation="relu")(headModel)
headModel = Dropout(0.5)(headModel)
headModel = Dense(2, activation="softmax")(headModel)

# Place the head FC model on top of the base model(Inceptionv3)
model = Model(inputs=baseModel.input, outputs=headModel)

# Freeze all layers in the base model
for layer in baseModel.layers:
    layer.trainable = False

# Callbacks
early_stopping = EarlyStopping(
    monitor='val_accuracy',
    patience=10, # Stop if val_accuracy doesn't improve for 10 epochs
    verbose=1,
    restore_best_weights=True
)
```

```
Initializing InceptionV3 model...
```

```
# Phase 1: Train the Head
print("Compiling and training head layers...")
opt = Adam(learning_rate=INIT_LR)
model.compile(loss="binary_crossentropy", optimizer=opt, metrics=["accuracy"])
```

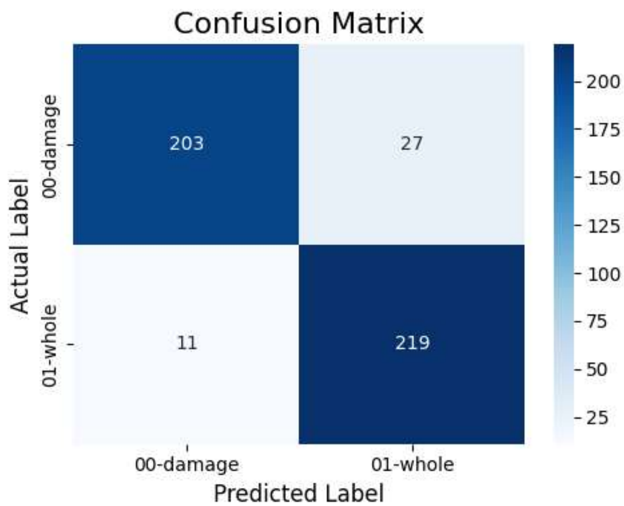
```
H1 = model.fit(
    aug.flow(trainX, trainY, batch_size=BS),
    validation_data=(testX, testY),
    epochs=HEAD_EPOCHS,
    callbacks=[early_stopping]
)

# Phase 2: Fine-Tuning
print("\nUnfreezing top layers for fine-tuning...")

# Unfreeze the top layers of the model
for layer in baseModel.layers[-50:]:
    layer.trainable = True

# Re-compile the model for fine-tuning with a lower learning rate
opt = Adam(learning_rate=INIT_LR / 10) # Use a 10x smaller learning rate
model.compile(loss="binary_crossentropy", optimizer=opt, metrics=["accuracy"])

print(" Starting fine-tuning phase...")
# We check if the first training phase completed all epochs or stopped early
initial_epoch = H1.epoch[-1] + 1
if initial_epoch < HEAD_EPOCHS:
    print(f"Early stopping occurred. Starting fine-tuning from epoch {initial_epoch}.")

H2 = model.fit(
    aug.flow(trainX, trainY, batch_size=BS),
    validation_data=(testX, testY),
    epochs=TOTAL_EPOCHS,
    initial_epoch=initial_epoch, # Continue from where we left off
    callbacks=[early_stopping]
)
```

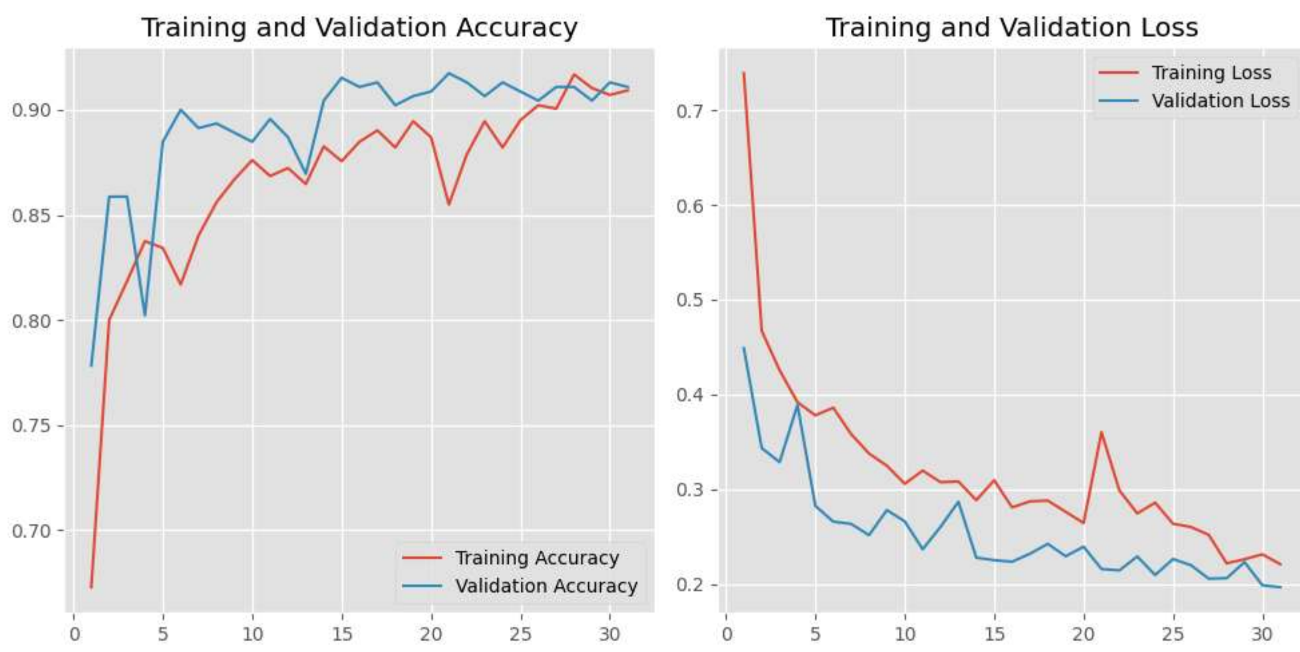
```
Epoch 6/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 23s 769ms/step - accuracy: 0.8109 - loss: 0.4042 - val_accuracy: 0.9000 - val_loss: 0.2660
Epoch 7/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 746ms/step - accuracy: 0.8513 - loss: 0.3432 - val_accuracy: 0.8913 - val_loss: 0.2637
Epoch 8/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 761ms/step - accuracy: 0.8588 - loss: 0.3432 - val_accuracy: 0.8935 - val_loss: 0.2518
Epoch 9/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 21s 736ms/step - accuracy: 0.8526 - loss: 0.3532 - val_accuracy: 0.8891 - val_loss: 0.2782
Epoch 10/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 41s 751ms/step - accuracy: 0.8679 - loss: 0.3227 - val_accuracy: 0.8848 - val_loss: 0.2663
Epoch 11/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 766ms/step - accuracy: 0.8705 - loss: 0.3073 - val_accuracy: 0.8957 - val_loss: 0.2369
Epoch 12/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 21s 734ms/step - accuracy: 0.8702 - loss: 0.3106 - val_accuracy: 0.8870 - val_loss: 0.2605
Epoch 13/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 42s 761ms/step - accuracy: 0.8584 - loss: 0.3006 - val_accuracy: 0.8696 - val_loss: 0.2870
Epoch 14/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 771ms/step - accuracy: 0.8907 - loss: 0.2807 - val_accuracy: 0.9043 - val_loss: 0.2280
Epoch 15/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 21s 712ms/step - accuracy: 0.8864 - loss: 0.2867 - val_accuracy: 0.9152 - val_loss: 0.2254
Epoch 16/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 21s 727ms/step - accuracy: 0.8876 - loss: 0.2769 - val_accuracy: 0.9109 - val_loss: 0.2238
Epoch 17/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 743ms/step - accuracy: 0.8927 - loss: 0.2844 - val_accuracy: 0.9130 - val_loss: 0.2322
Epoch 18/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 753ms/step - accuracy: 0.8924 - loss: 0.2698 - val_accuracy: 0.9022 - val_loss: 0.2426
Epoch 19/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 21s 720ms/step - accuracy: 0.8975 - loss: 0.2757 - val_accuracy: 0.9065 - val_loss: 0.2295
Epoch 20/20
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 763ms/step - accuracy: 0.8778 - loss: 0.2892 - val_accuracy: 0.9087 - val_loss: 0.2396
Restoring model weights from the end of the best epoch: 15.
```

```
29/29 ━━━━━━━━━━━━━━━━━━━━ 21s 742ms/step - accuracy: 0.9229 - loss: 0.2166 - val_accuracy: 0.9109 - val_loss: 0.2064
Epoch 29/100
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 750ms/step - accuracy: 0.9127 - loss: 0.2219 - val_accuracy: 0.9043 - val_loss: 0.2233
Epoch 30/100
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 773ms/step - accuracy: 0.9006 - loss: 0.2298 - val_accuracy: 0.9130 - val_loss: 0.1989
Epoch 31/100
29/29 ━━━━━━━━━━━━━━━━━━━━ 22s 755ms/step - accuracy: 0.9085 - loss: 0.2199 - val_accuracy: 0.9109 - val_loss: 0.1969
Epoch 31: early stopping
Restoring model weights from the end of the best epoch: 21.
```

```
# Evaluate Network
predictions = model.predict(testX, batch_size=BS)
y_pred = np.argmax(predictions, axis=1)
y_true = np.argmax(testY, axis=1)

# Calculate and Print Accuracy
accuracy = accuracy_score(y_true, y_pred)
print(f"\nOverall Accuracy: {accuracy * 100:.2f}%")
print("-" * 60) # Separator line

# Classification Report
print("Classification Report:")
print(classification_report(y_true, y_pred, target_names=lb.classes_))
print("-" * 60) # Separator line

# Plot Confusion Matrix as a Heatmap
cm = confusion_matrix(y_true, y_pred)
plt.figure(figsize=(5, 4))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues',
            xticklabels=lb.classes_, yticklabels=lb.classes_)
plt.title('Confusion Matrix', fontsize=16)
plt.ylabel('Actual Label', fontsize=12)
plt.xlabel('Predicted Label', fontsize=12)
plt.tight_layout()
plt.show()


# Plot Training History
history_dict = H1.history
if 'H2' in locals():
    for key in H1.history.keys():
        history_dict[key].extend(H2.history[key])

acc = history_dict['accuracy']
val_acc = history_dict['val_accuracy']
loss = history_dict['loss']
val_loss = history_dict['val_loss']
epochs_range = range(1, len(acc) + 1)

plt.style.use("ggplot")
plt.figure(figsize=(10, 5))

plt.subplot(1, 2, 1)
plt.plot(epochs_range, acc, label="Training Accuracy")
plt.plot(epochs_range, val_acc, label="Validation Accuracy")
plt.legend(loc="lower right")
plt.title("Training and Validation Accuracy")

plt.subplot(1, 2, 2)
plt.plot(epochs_range, loss, label="Training Loss")
plt.plot(epochs_range, val_loss, label="Validation Loss")
plt.legend(loc="upper right")
plt.title("Training and Validation Loss")

plt.tight_layout()
plt.show()


# Save the Model
model.save('car_damage_classifier.h5')
print("\nModel saved as car_damage_classifier.h5")
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/models/functional.py:237: UserWarning: The structure of `inputs` doesn't match the exp
Expected: ['keras_tensor']
Received: inputs=Tensor(shape=(64, 224, 224, 3))
  warnings.warn(msg)
8/8 ━━━━━━━━━━━━━━━━━━━━ 13s 983ms/step

Overall Accuracy: 91.74%
------------------------------------------------------------
Classification Report:
              precision    recall  f1-score   support

   00-damage       0.95      0.88      0.91       230
    01-whole       0.89      0.95      0.92       230

    accuracy                           0.92       460
   macro avg       0.92      0.92      0.92       460
weighted avg       0.92      0.92      0.92       460

------------------------------------------------------------
```






```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is consi

Model saved as car_damage_classifier.h5
```

```
# Prediction Function
def predict_damage(image_path):
    # Load and preprocess the image
    image = load_img(image_path, target_size=(224, 224))
    image_arr = img_to_array(image)
    image_arr = np.expand_dims(image_arr, axis=0)
```

```
        image_arr = preprocess_input(image_arr)

        # Make prediction
        prediction = model.predict(image_arr)
        class_index = np.argmax(prediction)
        label = lb.classes_[class_index]
        confidence = prediction[0][class_index] * 100

        # Display the image and result
        plt.imshow(image)
        plt.title(f"Prediction: {label} ({confidence:.2f}%)")
        plt.axis('off')
        plt.show()

        return label, confidence

    # Use the prediction function
    example_image_path = os.path.join(coco_dataset_path, "img", "1.jpg")
    if os.path.exists(example_image_path):
        predict_damage(example_image_path)
    else:
        print(f"Example image not found at: {example_image_path}")
```

1/1 ━━━━━━━━━━━━━━━━━━━━ 5s 5s/step

Prediction: 00-damage (99.08%)

```
predict_damage(os.path.join(coco_dataset_path, "train", "4.jpg"))
```

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 61ms/step

Prediction: 00-damage (97.23%)

(np.str_('00-damage'), np.float32(97.22979))

```
predict_damage(os.path.join(coco_dataset_path, "test", "28.jpg"))
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 48ms/step
```

Prediction: 01-whole (87.50%)

```
(np.str_('01-whole'), np.float32(87.50397))
```

```
predict_damage(os.path.join(coco_dataset_path, "img", "69.jpg"))
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 45ms/step
```

Prediction: 01-whole (99.99%)

```
(np.str_('01-whole'), np.float32(99.994194))
```

```
predict_damage(os.path.join(coco_dataset_path, "train", "37.jpg"))
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 48ms/step
```

Prediction: 01-whole (98.85%)