Project Title:

Enchanted Wings: Marvels of Butterfly Species

Team Name:

None

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Phase-1: Brainstorming & Ideation

Objective:

The objective of this code is to build, train, evaluate, and save a Convolutional Neural Network (CNN) model for classifying butterfly images using the Leeds Butterfly Dataset.

Purpose:
To build a deep learning model using CNNs that can automatically classify butterfly images, simplifying the identification process in ecological and biological research.

Impact:

- Assists in biodiversity monitoring and conservation
- Reduces manual effort in species identification

Key Points:

1.Problem Statement:

Manual butterfly identification is slow and labor-intensive. This project solves that by using a deep learning model to automatically classify butterfly images, making the process faster and more efficient.

2.Proposed Solution:

Use a CNN-based deep learning model to automatically classify butterfly images by learning visual patterns, improving speed and accuracy over manual methods.

3. Target Users:

Biologists and Ecologists – for faster species identification and biodiversity studies

Researchers – in computer vision and environmental science

Educators and Students – for learning and teaching image classification

4. Expected Outcome:

An accurate and efficient CNN model that can automatically identify butterflies in images, reducing manual effort and supporting ecological research.

Phase-2: Requirement Analysis

Objective:

Technical Requirements:

- **Hardware:**
  - GPU-enabled system (recommended) for faster model training
  - Sufficient storage for dataset and model files
- **Software:**
  - Python environment with libraries: TensorFlow, NumPy, OpenCV, Matplotlib, scikit-learn
  - Access to the butterfly image dataset
- **Data:**
  - Labeled butterfly images in supported formats (JPEG, PNG)
- **Model:**
  - CNN architecture for image classification
  - Image preprocessing and augmentation tools

Functional Requirements:

- Load and preprocess images (resize, normalize)
- Split data into training and testing sets
- Train a CNN model with data augmentation
- Visualize prediction results

Key Points:

1. Technical Requirements:

- **Programming Language:** Python
- **Frameworks/Libraries:**
    - TensorFlow / Keras (for building and training CNN)
    - NumPy (for numerical operations)
    - OpenCV (for image processing)
    - scikit-learn (for data splitting and evaluation)
    - Matplotlib (for visualization)
- **Tools:**
    - Jupyter Notebook or any Python IDE
    - GPU support (optional but recommended for faster training)
- **Dataset:**
    - Leeds Butterfly Dataset (image files)

2.Functional Requirements

- Load and preprocess butterfly images (resize, normalize)
- Handle different image formats (JPEG, PNG)
- Split dataset into training and testing sets
- Implement data augmentation for training
- Build and train a CNN model for binary classification

3.Constraints & Challenges

- **Limited Dataset Size:** Small or imbalanced data can reduce model accuracy and generalization.
- **Single-Class Labels:** Current code uses only one label (butterfly), limiting multi-class classification.
- **Image Quality Variations:** Differences in lighting, angle, and resolution may affect performance.
- **Computational Resources:** Training CNNs can be slow without GPU acceleration.

Phase-3: Project Design

Objective:

Architecture:

- **Input:** Load and preprocess images (resize, normalize)
- **Data Prep:** Split dataset, apply augmentation
- **Model:** CNN with Conv2D, MaxPooling, Dense, Dropout layers

User Flow:

- User uploads butterfly images
- System preprocesses and splits data
- User initiates model training

Key Points:

1. System Architecture Diagram:

Start

↓

Load Dataset Images

↓

Preprocess Images

↓

Split Data: Train / Test

↓

Data Augmentation (Train set only)

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Train CNN Model

↓

Evaluate Model on Test set

↓

Predict on New Images

↓

Display Results & Save Model

↓

End

2. User Flow:

1. **User provides dataset**
    - Uploads butterfly images to the specified folder.
2. **System preprocesses images**
    - Resizes, normalizes, and checks formats.
3. **System splits data**
    - Divides images into training and testing sets.
4. **User starts training**
    - Runs the training script with CNN and data augmentation.
5. **System trains and validates model**
    - Displays training progress and accuracy.
6. **User tests model**
    - Selects a sample image or lets the system choose randomly.

7. **System makes prediction**
    - Displays the predicted result with confidence.
8. **User saves model**
    - Trained model is saved for future use or deployment.

3. UI/UX Considerations:

Since the current project runs in a **code/script environment** (like Google Colab), the UI/UX is minimal and mostly code-driven. However, if you plan to turn it into a user-facing app or interface, here's a simple layout idea:

```
-------------------------------------------------
| 🦋 Butterfly Image Classifier              |
-------------------------------------------------
| [Upload Image] [Upload Dataset Folder]      |
-------------------------------------------------
| [Preprocess Images] [Train Model]           |
-------------------------------------------------
| Training Progress: [██████████-----] 70%       |
| Accuracy: 92.5%                            |
-------------------------------------------------
| [Choose Test Image] [Predict]              |
| Prediction: Butterfly (Confidence: 0.93)    |
| [Display Image Here]                       |
-------------------------------------------------
| [Save Model] [Download Model]               |
-------------------------------------------------
```

Phase-4: Project Planning (Agile Methodologies)

Objective:

Agile Task Breakdown :

Sprint 1: Setup & Data Preparation

- Install libraries (TensorFlow, OpenCV, etc.)
- Load and preprocess images
- Resize, normalize, and filter image formats

Sprint 2: Model Building

- Define and compile CNN architecture
- Set loss function and optimizer

Sprint 3: Training

- Apply data augmentation
- Train model and validate performance

Sprint 4: Evaluation & Prediction

- Predict on test images
- Display predictions with confidence

Sprint 5: Finalization

- Save trained model
- Document workflow and results

Key Points:

1.Sprint Planning (Task Assignment by Role)

Here's a simple breakdown of tasks assigned to different team members in a small project team using Agile methodology:

Developer 1: Data & Preprocessing

- Set up environment and install dependencies
- Load and validate image dataset
- Resize, normalize, and convert images

- Handle invalid/missing images

Developer 2: Model Architecture

- Design CNN layers
- Compile the model with appropriate loss and optimizer
- Display model summary for review

Developer 3: Training & Augmentation

- Implement ImageDataGenerator
- Train the model on training data
- Monitor training/validation accuracy and loss

Developer 4: Evaluation & Deployment

- Evaluate the model on test data
- Implement prediction and result display logic
- Save trained model (.h5 format)

Project Lead / Documentation

- Define objective, problem statement, and requirements
- Create user flow, architecture, and task breakdown
- Maintain progress tracking and sprint reviews

2.Task Allocation :

Developer 1 – Data Handling

- Install required libraries
- Load and preprocess images (resize, normalize)
- Handle image format validation and errors

Developer 2 – Model Development

- Build the CNN architecture
- Compile and summarize the model
- Integrate with input data shape

Developer 3 – Training & Augmentation

- Apply data augmentation (ImageDataGenerator)
- Train the CNN model
- Monitor training progress and log metrics

Developer 4 – Evaluation & Prediction

- Evaluate model on test set
- Predict using test images
- Display results with matplotlib
- Save trained model (.h5 file)

Project Manager / Team Lead

- Define objectives, problem statement, and scope
- Coordinate team and assign sprint tasks
- Document technical/functional requirements and user flow
- Ensure timely delivery and reporting

Timeline & Milestones (1-Week):

Day 1 – Project Setup & Data Loading

- Set up development environment (Python, libraries)
- Load and preprocess image dataset
- Resize and normalize images

Day 2 – Model Design

- Define CNN architecture
- Compile and review model structure

Day 3 – Data Augmentation & Training

- Apply image augmentation
- Train model on training data

Day 4 – Evaluation & Prediction

- Evaluate model on test data
- Perform predictions on sample images
- Display results with labels and confidence

Day 5 – Save Model & Documentation

- Save the trained model (.h5 format)
- Document project purpose, flow, and results

Day 6 – Review & Testing

- Internal testing and review
- Fix issues or bugs
- Finalize reports and prepare demo (if needed)

Phase-5: Project Development

Objective:

```
import os
import cv2
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense,
Dropout
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from google.colab import drive

drive.mount('/content/drive')

dataset_path = '/content/drive/MyDrive/Colab
Notebooks/leedsbutterfly_dataset_v1.1/leedsbutterfly/images'
img_size = 128
data, labels = [], []
valid_extensions = ['.jpg', '.jpeg', '.png']

if not os.path.isdir(dataset_path):
    print(f"Error: dataset_path '{dataset_path}' is not a directory.")
```

```
else:
    for img_name in os.listdir(dataset_path):
        if any(img_name.lower().endswith(ext) for ext in
valid_extensions):
            img_path = os.path.join(dataset_path, img_name)
            try:
                img = cv2.imread(img_path)
                if img is not None:
                    img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
                    img = cv2.resize(img, (img_size, img_size))
                    data.append(img)
                    labels.append(1)
                else:
                    print(f"Failed to load image: {img_path}")
            except Exception as e:
                print(f"Error processing image {img_path}: {e}")

print(f"Total images attempted: {len(os.listdir(dataset_path))}")
print(f"Successfully loaded images: {len(data)}")

if len(data) == 0:
    print("No images were loaded. Please check your dataset.")
else:
    X = np.array(data, dtype='float32') / 255.0
    y = np.array(labels)

    X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.2, random_state=42)

    model = Sequential([
        Conv2D(32, (3,3), activation='relu', input_shape=(img_size,
img_size, 3)),
        MaxPooling2D(2, 2),
        Conv2D(64, (3,3), activation='relu'),
        MaxPooling2D(2, 2),
        Flatten(),
        Dense(128, activation='relu'),
        Dropout(0.5),
        Dense(1, activation='sigmoid')
    ])

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

```
datagen = ImageDataGenerator(rotation_range=20, zoom_range=0.15,
                             width_shift_range=0.2,
height_shift_range=0.2,
                             horizontal_flip=True)

datagen.fit(X_train)

history = model.fit(datagen.flow(X_train, y_train, batch_size=32),
                    validation_data=(X_test, y_test),
                    epochs=10)

loss, accuracy = model.evaluate(X_test, y_test)
print(f"Test Accuracy: {accuracy * 100:.2f}%")

index = np.random.randint(0, len(X_test))
img = X_test[index]
prediction = model.predict(np.expand_dims(img, axis=0))[0][0]
predicted_class = "Butterfly" if prediction > 0.5 else "Not Butterfly"

plt.imshow(img)
plt.title(f"Predicted: {predicted_class} ({prediction:.2f})")
plt.axis('off')
plt.show()

model.save("/content/butterfly_classifier_model.h5")
print("Model saved as butterfly_classifier_model.h5")
```

Key Points:

1.Technology Stack Used:

Programming Language:

- **Python** – Core language for scripting, data processing, and model development

Libraries & Frameworks

- **TensorFlow / Keras** – For building, training, and evaluating the CNN model
- **NumPy** – For handling numerical operations and arrays
- **OpenCV** – For image loading, resizing, and basic preprocessing
- **Matplotlib** – For visualizing predictions and training performance
- **scikit-learn** – For data splitting and evaluation metrics

Tools & Platforms

- **Google Colab / Jupyter Notebook** – For interactive development and GPU acceleration
- **Google Drive (optional)** – For dataset storage and model saving

2.Development Process:

1. **Setup:** Installed libraries and configured environment (e.g., Colab)
2. **Data Prep:** Loaded, resized, and normalized butterfly images
3. **Split Data:** Divided into training and testing sets
4. **Model Design:** Built CNN using TensorFlow/Keras
5. **Augmentation:** Applied data augmentation to improve training
6. **Training:** Trained model and monitored accuracy
7. **Evaluation:** Tested model on unseen data
8. **Prediction:** Predicted and displayed results for sample images
9. **Model Save:** Saved the trained model for future use

3.Challenges & Fixes :

1. Image Loading Errors

- **Challenge:** Some images failed to load or were unreadable.
- **Fix:** Added a check for None images and skipped invalid files.

2. Single-Class Labeling

- **Challenge:** Dataset only labeled all images as butterflies (no class variety).
- **Fix:** Used binary classification for now; future versions can add multi-class support.

3. Overfitting Risk

- **Challenge:** Model performed too well on training but risked overfitting.
- **Fix:** Used data augmentation and Dropout layers to improve generalization.

4. Training Speed

- **Challenge:** Training was slow on CPU.
- **Fix:** Used Google Colab with GPU to speed up training.

Phase-6: Functional & Performance Testing

Objective: Checklist

1. Dataset Structure

- Folder: /leedsbutterfly/images/

images/

butterfly/

not_butterfly/

- Images must be valid (.jpg, .png, etc.)

2. Data Loading

- Uses ImageDataGenerator.flow_from_directory
- Output should show:

pgsql

Found XXX images belonging to 2 classes.

3. Model Training

- CNN with 2 Conv layers, MaxPooling, Dropout.
- Trains for 10 epochs.
- Shows training & validation accuracy.

4. Model Evaluation

- Prints:

yaml

Validation Accuracy: XX.XX%

5 Prediction

- Displays a random validation image.
- Shows prediction and actual label.

6. Model Saving

- Saves model as:

bash

/content/butterfly_classifier_model.h5

Success

- Both classes detected
- Model trains & evaluates without error
- Accuracy > 50%
- Image with prediction displays
- .h5 file is created

Key Points:

1.Test Cases Executed:

Test Case	Expected Outcome	Result
1. **Dataset directory exists and is accessible**	Path is valid and no error raised	Passed
2. **Correct folder structure with 2 classes**	`flow_from_directory` detects 2 classes	Passed
3. **Image preprocessing and loading**	All images resized and normalized without errors	Passed
4. **Model compiles successfully**	`model.summary()` shows correct architecture	Passed
5. **Training runs without interruption**	Model trains for 10 epochs with valid data	Passed
6. **Validation accuracy computed**	Validation accuracy printed after training	Passed
7. **Random image prediction and display**	Random validation image shown with predicted class	Passed
8. **Model file saved successfully**	`butterfly_classifier_model.h5` is created	Passed

2. Bug Fixes & Improvements:

- Fixed the issue where **all images were labeled as class 1** by implementing folder-based labeling to correctly assign labels for butterfly and non-butterfly images.
- Replaced manual image loading with **ImageDataGenerator.flow_from_directory()** to simplify data loading and automatically handle training-validation splits.
- Added **data augmentation** (rotation, zoom, flips, shifts) to improve model generalization.
- Ensured proper **model input shape** and adjusted the output layer for binary classification with sigmoid activation and binary cross-entropy loss.

3.Final Validation:

- **DatasetLoading:**
  Successfully loads images from a structured directory with correct labeling for butterfly vs. non-butterfly classes.
- **Preprocessing&Augmentation:**
  Images are resized, normalized, and augmented appropriately to improve model robustness.
- **ModelArchitecture:**
  The CNN is built with suitable layers for binary image classification and compiles without errors.
- **Training&Validation:**
  The model trains for 10 epochs, showing reasonable accuracy improvement and achieves validation accuracy above baseline (≥50%).

4.Deployment:

- Model saved as: /content/butterfly_classifier_model.h5
- Can be deployed using:
  - TensorFlow Serving, Flask, or FastAPI
  - Cloud platforms like Google Cloud, AWS SageMaker, or Heroku
- *(Add Nemo or other hosting links if used)*
- Next steps: Export model, create API, connect frontend
