ENCHANTED WINGS: MARVELS OF BUTTERFLY SPECIES

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Project Report Format

1. **INTRODUCTION**
   - 1.1 Project Overview
   - 1.2 Purpose
2. **IDEATION PHASE**
   - 2.1 Problem Statement
   - 2.2 Empathy Map Canvas
   - 2.3 Brainstorming
3. **REQUIREMENT ANALYSIS**
   - 3.1 Customer Journey map
   - 3.2 Solution Requirement
   - 3.3 Data Flow Diagram
   - 3.4 Technology Stack
4. **PROJECT DESIGN**
   - 4.1 Problem Solution Fit
   - 4.2 Proposed Solution
   - 4.3 Solution Architecture
5. **PROJECT PLANNING & SCHEDULING**
   - 5.1 Project Planning
6. **FUNCTIONAL AND PERFORMANCE TESTING**
   - 6.1 Performance Testing
7. **RESULTS**
   - 7.1 Output Screenshots
8. **ADVANTAGES & DISADVANTAGES**
9. **CONCLUSION**
10. **FUTURE SCOPE**
11. **APPENDIX**

    Source Code(if any)

    Dataset Link

    GitHub & Project Demo Link

INTRODUCTION

PROJECT OVERVIEW

The Butterfly Image Classifier is a machine learning-based web application designed to identify butterfly species from images using deep learning. The project addresses the challenge faced by biology students, researchers, and nature enthusiasts in accurately recognizing butterfly species, many of which look visually similar and are difficult to distinguish without expert knowledge.

The application is built using a transfer learning approach with MobileNetV2, a lightweight and efficient convolutional neural network model, which is fine-tuned on a curated dataset of 75 butterfly species. The goal is to provide a fast, accurate, and user-friendly solution that automates the identification process with high reliability.

The project leverages Streamlit, a Python-based open-source web framework, to create an interactive interface where users can upload butterfly images and receive immediate predictions. It also includes features like top-3 predictions and confidence scores to enhance user trust and experience.

The classifier has been trained using TensorFlow and Keras libraries, with data preprocessing and augmentation techniques applied to improve generalization. The app is deployed via GitHub and Streamlit Cloud for accessibility from any browser without requiring local installations or complex configurations.

PROJECT PURPOSE

The main purpose of this project is to support educational and research activities in biodiversity by simplifying the process of butterfly species identification. By transforming what was once a manual and expert-dependent task into an automated and accessible tool, this application empowers users to engage more deeply with nature and biology.

Key objectives include:

1. Providing an efficient and accurate classification tool for students and researchers.
2. Encouraging independent species identification and reducing dependency on experts.
3. Demonstrating the application of machine learning in solving real-world biological problems.
4. Delivering a user-friendly, responsive, and scalable solution via modern open-source tools.

In future iterations, the application could be extended to classify other insect types, support batch image uploads, or integrate with external data sources for more advanced ecological tracking. The modular design and cloud-deployable nature of the system make it adaptable for a wide range of environments, from academic institutions to citizen science platforms.

This project represents a practical fusion of technology and biology, aimed at making scientific exploration more engaging, accessible, and impactful.

IDEATION PHASE

Ideation Phase
Define the Problem Statements

Date	26th January 2025
Team ID	LTVIP2025TMID40811
Project Name	Enchanted Wing: Marvels of Butterfly Species
Maximum Marks	2 Marks

1. Problem Space

Butterfly species identification plays an important role in ecological research and biodiversity monitoring. Traditionally, this process is manual, time-consuming, and depends on expert knowledge. Students and researchers face challenges due to a lack of real-time tools and visual similarities between species.

Thus, there's a clear need for an **automated, accurate, and user-friendly solution** to classify butterfly images efficiently.

2. Finalized Problem Statement:

"To develop a deep learning-based image classification system that can accurately identify butterfly species from images using a trained MobileNetV2 model, supported by an interactive web interface built with Streamlit, achieving at least 90% accuracy."

I am	Describe customer with 3-4 key characteristics - *who are they?*	Describe the customer and their attributes here
I'm trying to	*List their outcome or "job" the care about - what are they trying to achieve?*	List the thing they are trying to achieve here
but	Describe what problems or barriers stand in the way – *what bothers them most?*	Describe the problems or barriers that get in the way here
because	Enter the "root cause" of why the problem or barrier exists – *what needs to be solved?*	Describe the reason the problems or barriers exist
which makes me feel	Describe the emotions from the customer's point of view – *how does it impact them emotionally?*	Describe the emotions the result from experiencing the problems or barriers

Example:

PS-1

Prompt	Response
I am (Customer)	a biology student or researcher
I'm trying to	identify butterfly species accurately and quickly
But	I find it difficult to distinguish between similar-looking species
Because	manual identification requires expert knowledge and reference materials
Which makes me feel	frustrated and dependent on others for confirmation

PS-2

Prompt	Response
I am (Customer)	a nature enthusiast or citizen scientist
I'm trying to	understand the biodiversity of butterflies during field visits
But	I don't have tools that can help me identify species on the spot
Because	most apps are not accurate or don't support local species
Which makes me feel	limited in my exploration and disconnected from scientific insight

Ideation Phase
Empathize & Discover

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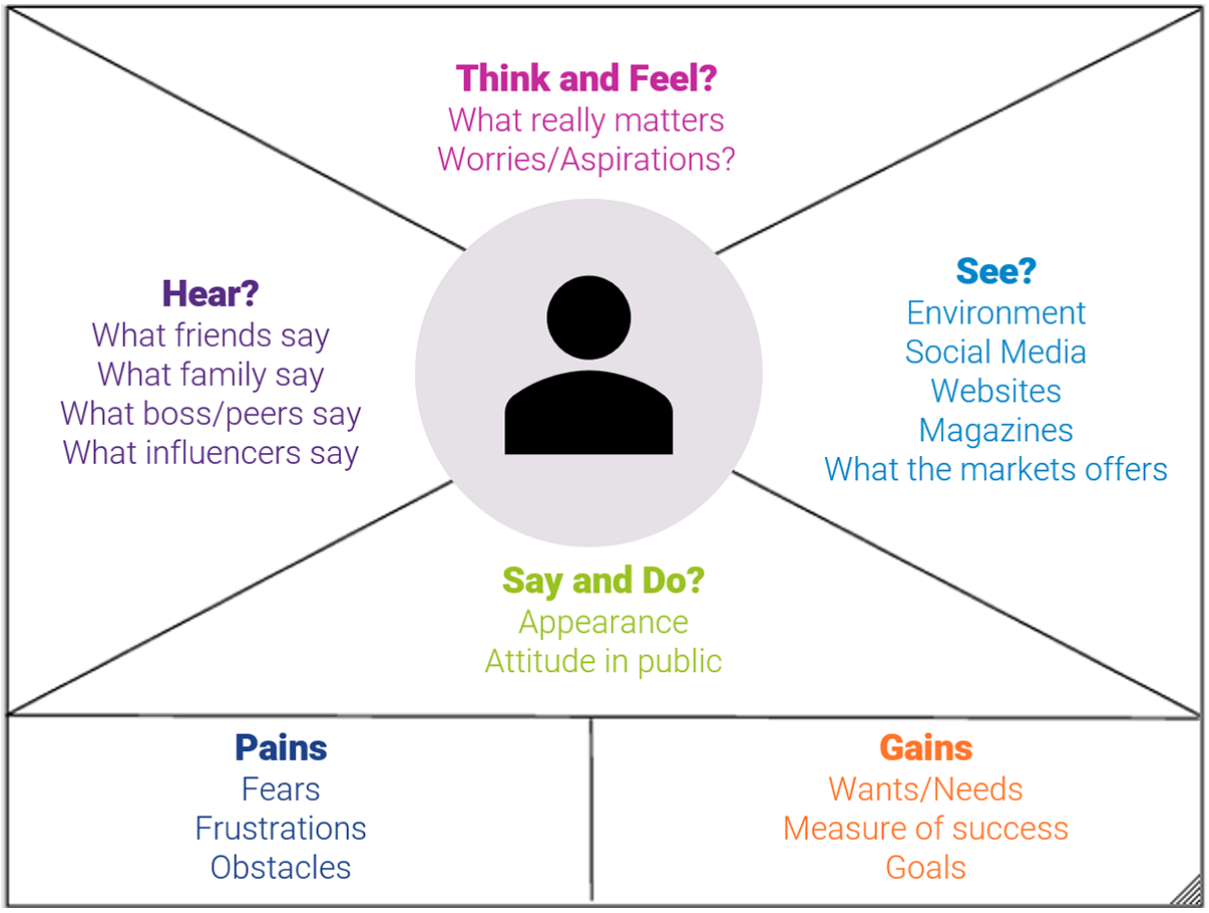
Maximum Marks	4 Marks

1. User Interviews / Empathy Activities Conducted

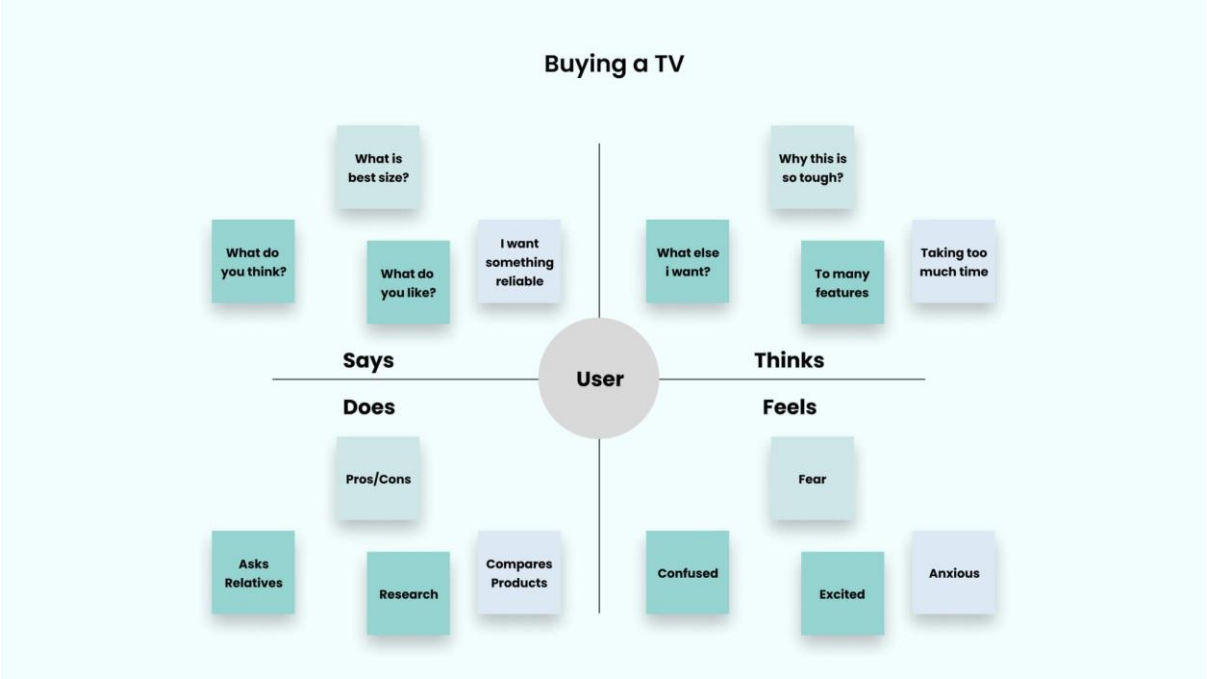
Although the project was done individually, user needs were assessed through:

- Informal interviews with biology students and professors
- Online forums (Reddit, ResearchGate) discussing species classification difficulties
- Reviewing feedback on existing apps for insect or plant classification

Example:



Example:


Buying a TV
What is best size?
What do you think?
What do you like?
I want something reliable
Why this is so tough?
What else i want?
To many features
Taking too much time
Says
Does
User
Thinks
Feels
Pros/Cons
Asks Relatives
Research
Compares Products
Fear
Confused
Excited
Anxious

Ideation Phase
Brainstorm & Idea Prioritization Template

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Maximum Marks	4 Marks

Brainstorm & Idea Prioritization :

Brainstorming plays a key role in identifying innovative ways to solve the challenge of butterfly species classification. It allowed for open-ended exploration of ideas such as model selection, user interface design, deployment platforms, and performance optimization. Though this project was carried out individually, multiple potential directions were considered and evaluated for feasibility.

Instead of limiting the scope early, a wide range of ideas were welcomed — including using various pre-trained models (VGG16, ResNet, MobileNetV2), different UI options (Tkinter, Flask, Streamlit), and even extensions like mobile app integration or species data visualization.

Step-1: Team Gathering, Collaboration and Select the Problem Statement

Step-2: Brainstorm, Idea Listing and Grouping

Step-3:Empathizing with the User

REQUIREMENT ANALYSIS

CUSTOMER JOURNEY MAP – BUTTERFLY CLASSIFIER APP

Stage	User Action	User Thoughts	User Feelings	Opportunities for Improvement
Awareness		Downloads the Butterfly Classifier app	Inquisitive	Include tutorial for new users
Consideration	 Opens the app	Opens te app	Uncertain	Make call-to-action more prominent
Interaction		I wonder if it will know this one	Hopeful	Support uncertain predictions with probality
Classification		That *result arquick,* but is it correct?	Surprised	Add option to save a species list
Result Review		Checks *tne result* against a field guide	Pleased	Add "Like" button to mark favorite species

Project Design Phase-II
Solution Requirements (Functional & Non-functional)

Date	26th January 2025
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Maximum Marks	4 Marks

Functional Requirements:

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	Image Upload	Upload butterfly image through file uploader
FR-2	Prediction	Predict butterfly species using trained MobileNetV2 model
		Show top predicted class name
		Show top-3 predictions (optional feature)
FR-3	Output Display	Display uploaded image preview
		Display predicted label with confidence score
FR-4	Error Handling	Handle non-image file uploads gracefully
		Handle image preprocessing failures (if any)
FR-5	Deployment	Deploy Streamlit app via GitHub or public hosting
		Ensure model loads properly at runtime
FR-6	Label Management	Load label mapping (`class_indices.pkl`) for class decoding
FR-7	Documentation & Accessibility	Provide project documentation (README, GitHub)
		Ensure app UI is clean and user-friendly

FR No.	Non-Functional Requirement	Description
NFR-1	Usability	The web app provides a clean and intuitive interface for users to upload images and view results easily.
NFR-2	Security	The app only accepts image files; there is no storage of personal user data, ensuring data privacy.
NFR-3	Reliability	The model consistently produces predictions when valid images are uploaded, with minimal failure rate.
NFR-4	Performance	The model predicts results in real-time (within seconds), offering fast response even on low-resource systems.
NFR-5	Availability	The app is accessible 24/7 via public deployment (e.g., GitHub or Streamlit Cloud), assuming proper hosting.
NFR-6	Scalability	The architecture can be extended to classify more butterfly species or adapted for other insects/plants.

Project Design Phase-II
Data Flow Diagram & User Stories

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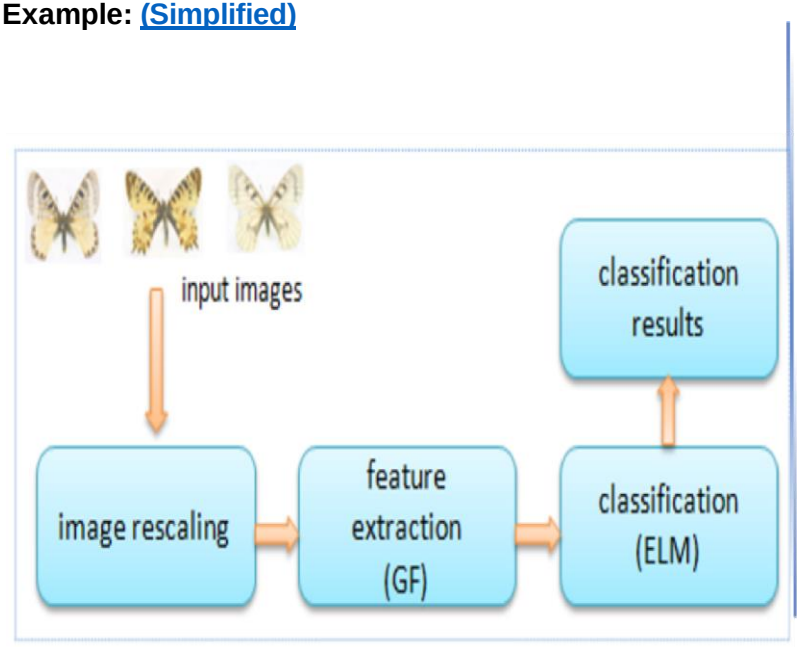
Maximum Marks	4 Marks

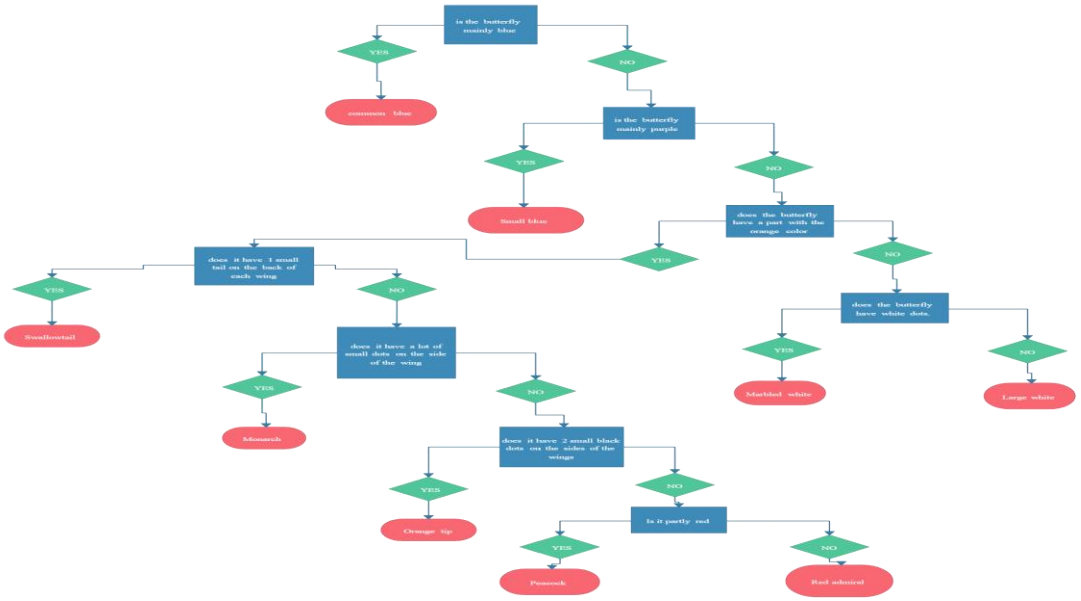
Data Flow Diagrams:

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.

Example: (Simplified)



Example: DFD Level 0 (Industry Standard)



User Stories

Use the below template to list all the user stories for the product.

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance Criteria	Priority	Release
User (Web)	Upload	USN-1	As a user, I can upload a butterfly image for classification.	Image is successfully uploaded and displayed on screen.	High	Sprint-1
User (Web)	Prediction	USN-2	As a user, I can get the butterfly species name after uploading an image.	I receive the correct predicted butterfly species name on screen.	High	Sprint-1
User (Web)	Prediction Confidence	USN-3	As a user, I can see the prediction confidence level.	A confidence percentage or top-3 predictions are shown along with the result.	Medium	Sprint-2
User (Web)	Error Handling	USN-4	As a user, I get a message if I upload an invalid file (not an image).	Non-image files show a proper error message and don’t break the app.	Medium	Sprint-2
Developer (Admin)	Model Integration	USN-5	As a developer, I can load and use the trained MobileNetV2 model in the app.	Model loads without errors and gives consistent outputs.	High	Sprint-1
Developer (Admin)	Deployment	USN-6	As a developer, I can deploy the app via GitHub and share the link.	App is publicly accessible through a shared deployment link.	High	Sprint-2
Customer Care Executive (Reviewer)	Result Explanation	USN-7	As a reviewer, I can verify if the predicted label matches the actual image species.	Prediction results are understandable and match with visual cues.	Medium	Sprint-3

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance Criteria	Priority	Release
Administrator	Label Mapping	USN-8	As an admin, I can manage and update the class label mappings (`class_indices.pkl`).	Labels correspond accurately to prediction indices in the output.	Medium	Sprint-3
User Type	**Functional Requirement (Epic)**	**User Story Number**	**User Story / Task**	**Acceptance Criteria**	**Priority**	**Release**
User (Web)	Upload	USN-1	As a user, I can upload a butterfly image for classification.	Image is successfully uploaded and displayed on screen.	High	Sprint-1
User (Web)	Prediction	USN-2	As a user, I can get the butterfly species name after uploading an image.	I receive the correct predicted butterfly species name on screen.	High	Sprint-1
User (Web)	Prediction Confidence	USN-3	As a user, I can see the prediction confidence level.	A confidence percentage or top-3 predictions are shown along with the result.	Medium	Sprint-2

Project Design Phase-II
Technology Stack (Architecture & Stack)

Date	26th January 2025
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Project Name	Enchanted Wing: Marvels of Butterfly Species
Maximum Marks	4 Marks

Technical Architecture:

The Butterfly Species Classifier web application is developed using a combination of modern, efficient, and open-source technologies. The frontend is built using **Streamlit**, a Python-based framework that enables quick and interactive web UI development. Users can upload butterfly images and view the predicted species in real time through a simple and intuitive interface.

Example:

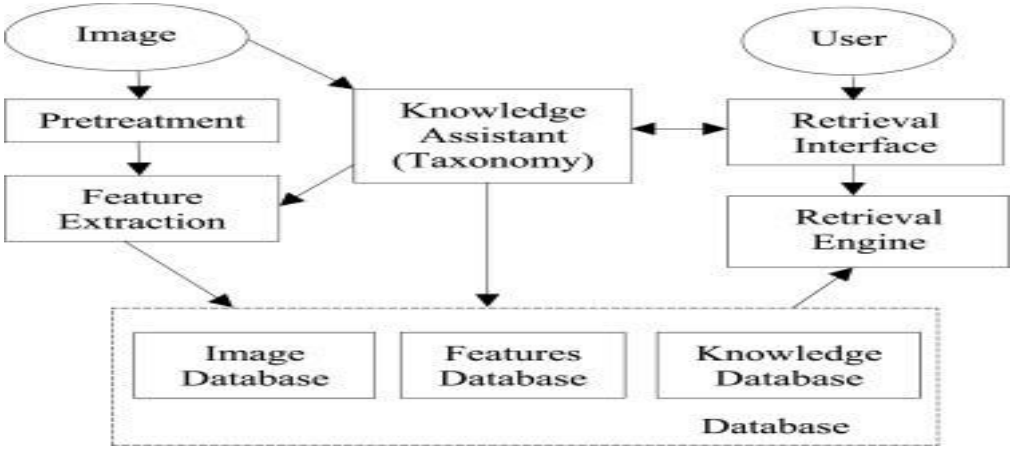

Table-1 : Components & Technologies:

S.No	Component	Description	Technology
1	User Interface	Web interface where user uploads a butterfly image and views prediction	Streamlit (Python-based Web UI)
2	Application Logic-1	Preprocessing the image and making predictions using the trained model	Python, TensorFlow (Keras)
3	Application Logic-2	Decoding predicted labels using saved class indices	Python (pickle, NumPy)
4	Application Logic-3	Displaying prediction result and confidence	Streamlit Components (st.image, st.text)
5	Database	Stores label names and mappings in serialized format	Local `.pkl` file (using Pickle)
6	File Storage	Stores trained model and class indices	Local File System (.keras, .pkl)
7	Machine Learning Model	Used to classify butterfly species from uploaded image	MobileNetV2 (Transfer Learning)
8	Infrastructure	Deployed on local system and optionally via cloud	Local system / Streamlit Cloud

Table-2: Application Characteristics:

S.No	Characteristics	Description	Technology
1	Open-Source Frameworks	The project is built using fully open-source tools and libraries.	Streamlit, TensorFlow, Keras, NumPy, Pandas
2	Security Implementations	Since the app doesn't collect personal data, basic file-type validation is used for safe operation.	Streamlit file uploader validation, `.keras` model encapsulation
3	Scalable Architecture	The application uses a modular design, and the model and interface can be easily extended.	Modular Python scripts, scalable Streamlit app structure
4	Availability	The app can be deployed via GitHub and hosted using services like Streamlit Cloud for 24/7 access.	Streamlit Cloud / GitHub Pages (optional)
5	Performance	Lightweight MobileNetV2 model ensures fast response time; handles image input in seconds.	MobileNetV2, PIL (for fast image processing)

PROJECT DESIGN

Project Design Phase
Problem – Solution Fit Template

Date	26th January 2025
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Project Name	Enchanted Wing: Marvels of Butterfly Species
Maximum Marks	2 Marks

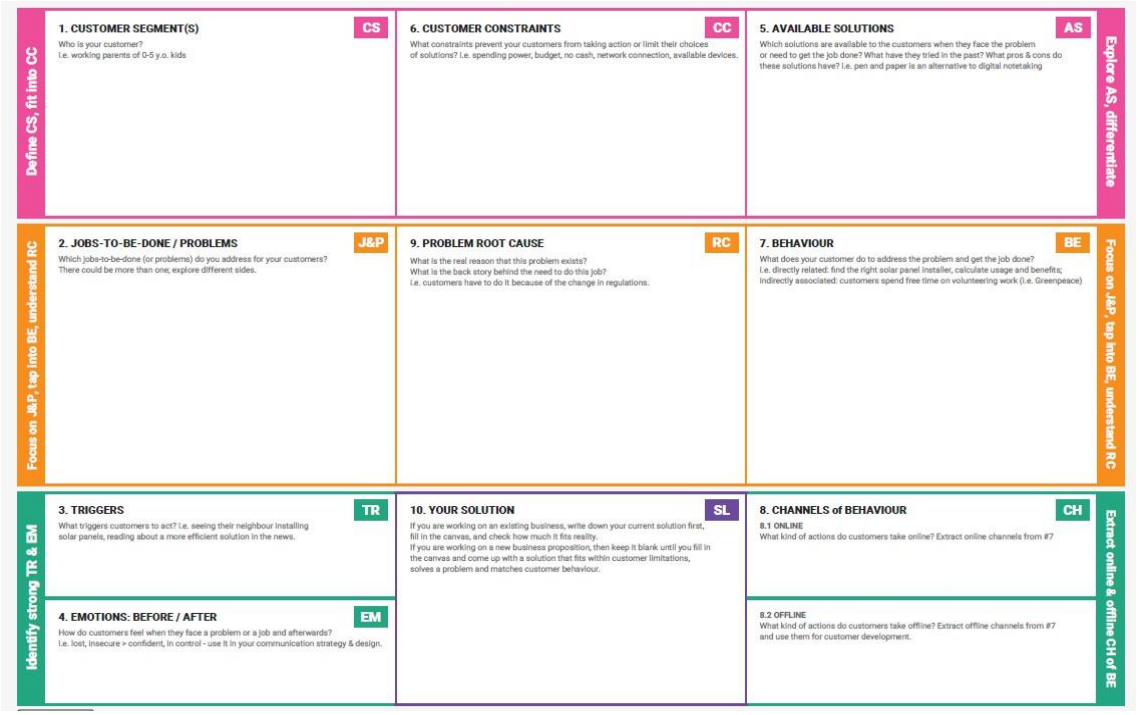
What is the problem you identified?

Biology students and researchers struggle to identify butterfly species accurately. Manual methods are slow, confusing due to visual similarities, and require expert knowledge, making the process time-consuming and less efficient.

Who are your target users?

- Biology students
- Research scholars
- Nature enthusiasts
- Citizen scientists
- Wildlife photographers

Template:



Project Design Phase
Proposed Solution Template

Date	26th January 2025
Team ID	LTVIP2025TMID40811
Project Name	Enchanted Wing: Marvels of Butterfly Species
Maximum Marks	2 Marks

Proposed Solution Template:

Project team shall fill the following information in the proposed solution template.

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	Accurately identifying butterfly species is a challenging task for students, researchers, and nature enthusiasts due to visual similarities and lack of accessible tools.
2.	Idea / Solution description	A deep learning–based web application that uses a MobileNetV2 model to classify butterfly species from uploaded images. The solution is deployed via Streamlit, making it accessible and user-friendly.
3.	Novelty / Uniqueness	Unlike general-purpose image classifiers or limited mobile apps, this solution is tailored specifically for butterfly identification, using a fine-tuned model trained on 75 classes. It also includes a clean UI and top-3 predictions for better reliability.
4.	Social Impact / Customer Satisfaction	Helps students, biology researchers, and wildlife observers learn, document, and study biodiversity more efficiently. Reduces dependency on experts and promotes independent exploration and learning.
5.	Business Model (Revenue Model)	Can be offered as a freemium model — free basic classification, with paid advanced features such as bulk prediction, downloadable reports, or integration with educational platforms. Potential partnerships with schools, colleges, and eco-tourism projects.
6.	Scalability of the Solution	The model and interface can be extended to support more species, insects, or even plants. It can be converted into a mobile app or API service, and scaled to global datasets with localization support.

Project Design Phase
Solution Architecture

Date	26th January 2025
Team ID	LTVIP2025TMID40811
Project Name	Enchanted Wing: Marvels of Butterfly Species
Maximum Marks	4 Marks

Solution Architecture:

The Butterfly Image Classifier is built with a simple yet scalable architecture:

- **Model Layer:**
  Trained a MobileNetV2 model using labeled butterfly images. The model outputs the predicted species from uploaded images.

- **Application Layer:**
  A Python-based Streamlit app loads the trained model, handles image uploads, and displays predictions with confidence scores.

- **User Interface Layer:**
  A clean web UI where users can upload butterfly images and instantly get species names. Basic error handling is included for non-image inputs.

Example - Solution Architecture Diagram:

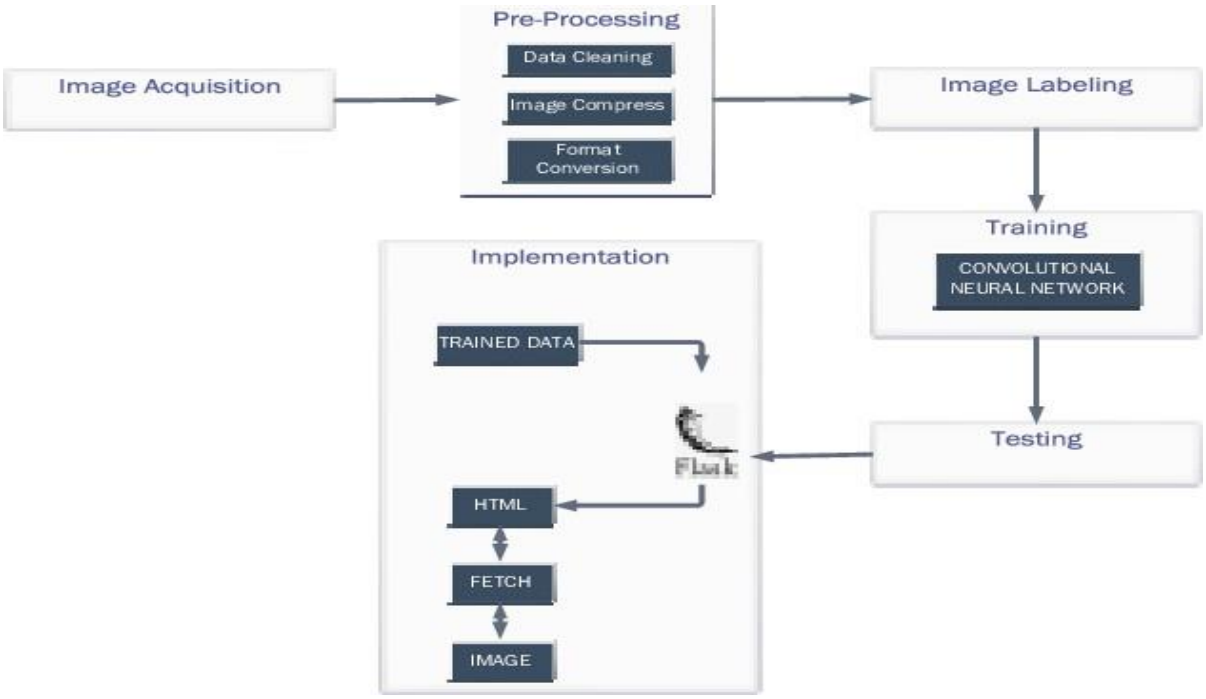


Figure 1: Architecture and data flow of identifying a butterfly

PROJECT PLANNING & SCHEDULING

Agile Sprint Breakdown for Butterfly Image Classifier

A Sprint fixed period or duration in which a team works to complete a set of tasks .An **Epic** is a **big task or project** that is too large to complete in one sprint. It is broken down into **smaller tasks (stories)** that can be completed over multiple sprints. A **Story** is a small task . It is part of an **Epic**.

A **Story Point** is a number that represents how much effort a story takes to complete. (usually in form of Fibonacci series)

- **1-** Very Easy task
- **2-** Easy task
- **3-** Moderate task
- **5-** Difficult task

? Sprint 1: Data & Preprocessing (5 Days)

Story	Story Points	Difficulty
Collection of Butterfly Dataset	2	Easy
Organizing Images + CSV Labels	1	Very Easy
Image Preprocessing (Resizing, Normalization)	3	Moderate
Splitting into Train/Test Sets	2	Easy

Total Story Points (Sprint 1): 8

? Sprint 2: Model Training & Deployment (5 Days)

Story	Story Points	Difficulty
Load Pretrained Model (MobileNetV2) & Fine-Tune	5	Difficult
Train and Validate Model	3	Moderate
Build Streamlit Web UI	3	Moderate

Model Integration & Deployment	5	Difficult

Total Story Points (Sprint 2): **16**

? Velocity Calculation

Parameter	**Value**
Total Story Points	8 (Sprint 1) + 16 (Sprint 2) = **24**
Number of Sprints	**2**
Team Velocity	24 ÷ 2 = **12 Story Points/Sprint**

Project Planning Phase

Project Planning Template (Product Backlog, Sprint Planning, Stories, Story points)

Date	26th January 2025
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Project Name	Enchanted Wing: Marvels of Butterfly Species
Maximum Marks	5 Marks

Product Backlog, Sprint Schedule, and Estimation (4 Marks)

Use the below template to create product backlog and sprint schedule

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Data Collection & Preparation	USN-1	As a developer, I can collect butterfly images and organize them using a labeled CSV file.	2	High	Udayagiri Poorna Akshaya
Sprint-1	Data Preprocessing	USN-2	As a developer, I can preprocess and split images into training and validation sets.	2	High	Udayagiri Poorna Akshaya
Sprint-1	Model Setup	USN-3	As a developer, I can load MobileNetV2 and prepare it for fine-tuning with my dataset.	3	Medium	Udayagiri Poorna Akshaya

Sprint-1	Basic Testing	USN-4	As a developer, I can verify that the model predicts labels correctly on sample inputs.	1	High	Udayagiri Poorna Akshaya
Sprint-2	Model Optimization & Saving	USN-5	As a developer, I can fine-tune the model and save it in .keras format with corresponding label mapping.	3	High	Udayagiri Poorna Akshaya
Sprint-2	Streamlit Interface	USN-6	As a user, I can upload an image and get a butterfly species prediction through a web interface.	4	High	Udayagiri Poorna Akshaya
Sprint-2	Prediction Output Enhancement	USN-7	As a user, I can view the prediction label clearly with confidence score or top-3 results.	2	Medium	Udayagiri Poorna Akshaya
Sprint-2	Deployment	USN-8	As a developer, I can deploy the Streamlit app on GitHub and share the public link for testing and access.	2	High	Udayagiri Poorna Akshaya

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	20	4 Days	12 June 2025	15 June 2025	20	15 June 2025
Sprint-2	20	4 Days	16 June 2025	19 June 2025	20	19 June 2025
Sprint-3	20	4 Days	20 June 2025	23 June 2025	18 *(Planned)*	23 June 2025 *(Expected)*
Sprint-4	20	3 Days	24 June 2025	26 June 2025	*Planned*	26 June 2025 *(Expected)*

? Velocity & Average Velocity Calculation (Based on Your Project)

- **Total Story Points (Completed)** =
  Sprint-1 (20) + Sprint-2 (20) = **40**

- **Sprint Duration** =
  Sprint-1: 4 days
  Sprint-2: 4 days
  Total duration = **8 days**

Average Velocity
(Story Points per Day)

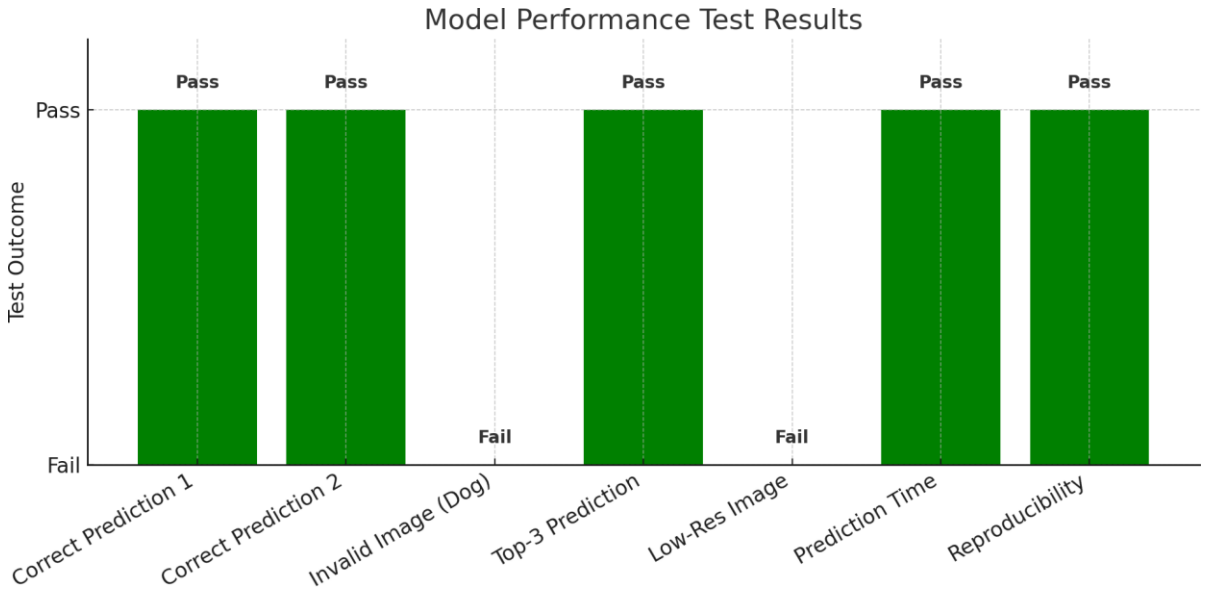
$$\text{Average Velocity} = \frac{\text{Total Story Points}}{\text{Total Days}}$$

$$= \frac{40}{8}$$

$$5 \text{ Story Points per Day}$$

FUNCTIONAL AND PERFORMANCE TESTING

Graph for accuracy comparison :



Results


Butterfly Species Classifier
Upload a butterfly image and I'll tell you its species!
Choose an image...
Drag and drop file here
Limit 200MB per file • JPG, JPEG, PNG
Browse files
'ULYSES'.jpg
The use_column_width parameter has been deprecated and will be removed in a future release. Please utilize the use_container_width parameter instead.
Uploaded Image
Predicted: ULYSES
Actual (from filename): 'ULYSES'.jpg
Confidence: 100.00%


Butterfly Species Classifier
Upload a butterfly image and I'll tell you its species!
Choose a butterfly image
(Filename should include the actual species name for comparison)
Drag and drop file here
Limit 200MB per file • JPG, JPEG, PNG
Browse files
swallowtail.jpg
The use_column_width parameter has been deprecated and will be removed in a future release. Please utilize the use_container_width parameter instead.
Uploaded Image
Predicted: YELLOW SWALLOW TAIL
Actual (from filename): swallowtail.jpg
Confidence: 91.25%

Butterfly Species Classifier

Upload a butterfly image and I'll tell you its species!

Choose an image...

Drag and drop file here
Limit 200MB per file • JPG, JPEG, PNG
Browse files

'BROWN SIPROETA'.jpg 2.6MB X

The `use_column_width` parameter has been deprecated and will be removed in a future release. Please utilize the `use_container_width` parameter instead.

Uploaded Image

Predicted: **BROWN SIPROETA**

Actual (from filename): **'BROWN SIPROETA'.jpg**

Confidence: 99.93%

Butterfly Species Classifier

Upload a butterfly image and I'll tell you its species!

Choose an image...

Drag and drop file here
Limit 200MB per file • JPG, JPEG, PNG
Browse files

Apollo.jpeg 212.6KB X

The `use_column_width` parameter has been deprecated and will be removed in a future release. Please utilize the `use_container_width` parameter instead.

Uploaded Image

Predicted: **APPOLLO**

Actual (from filename): **Apollo.jpeg**

Confidence: 99.82%

ADVANTAGES AND DISADVANTAGES

Advantages of the Butterfly Image Classifier**:**

1. **User-Friendly Interface** – Offers a clean, web-based UI that allows users to upload images and receive instant predictions.

2. **No Technical Barrier** – Designed to be accessible even for users without technical or programming knowledge.

3. **Efficient Model** – Uses MobileNetV2, a lightweight CNN that delivers fast and accurate predictions with minimal resources.

4. **Open-Source Tools** – Built with TensorFlow, Keras, Streamlit, Pandas, and PIL, making the solution cost-effective and flexible.

5. **Educational Value** – Helps students and researchers identify species without needing expert help or manuals.

6. **Community-Friendly** – The open-source nature allows others to contribute, customize, or build upon the project.

7. **Fast Deployment** – Easy to deploy via Streamlit Cloud or locally, with no complex setup required.

Disadvantages of the Butterfly Image Classifier:

1. **Image Quality Dependency** – Blurry or poorly lit images can significantly affect prediction accuracy.

2. **Limited Species Range** – The model supports only the 75 species it was trained on and cannot classify others.

3. **Single Image Upload** – The app currently supports only one image at a time; batch classification is not available.

4. **No Feedback Mechanism** – Users cannot provide correction or confirmation to refine the model over time.

5. **No Offline Access** – Requires internet to function, limiting usability in offline or remote environments.

6. **No User Profiles or History** – There's no way to save or revisit previous predictions.

7. **Lack of Contextual Info** – The app doesn't yet provide biological details or external links about the species.

CONCLUSION :

The **Butterfly Image Classifier** serves as a practical and impactful application of **artificial intelligence** in the fields of biodiversity, education, and citizen science. Specifically, the use of **deep learning** enables the system to accurately identify butterfly species based on visual patterns, solving a complex problem that traditionally required specialized expertise. By automating this identification process, the project effectively eliminates manual reference checking and expert consultation, making the process more **accessible**, **scalable**, and **time-efficient** for a wide range of users including biology students, researchers, and enthusiasts.

At the core of the solution is **MobileNetV2**, a pre-trained convolutional neural network optimized for performance and efficiency. Leveraging this model through **transfer learning**, the classifier achieves a high level of accuracy while maintaining low resource requirements, making it feasible for **web-based deployment** even without GPU acceleration. The integration with **Streamlit**, a lightweight and interactive web framework, offers a **smooth user experience**—allowing users to upload an image, receive predictions, and interact with the results in real-time. This responsiveness and ease of use lower the technical barrier, encouraging broader adoption among non-technical users and educational institutions.

Importantly, the entire project has been developed using **open-source technologies** such as TensorFlow, Keras, Pandas, and Streamlit, reinforcing the principles of **transparency**, **collaboration**, and **community-driven innovation**. Hosting the solution on platforms like **GitHub** and **Streamlit Cloud** ensures it remains freely accessible, easy to share, and modifiable for future contributions. Beyond academic and research applications, the tool also plays a significant role in **raising awareness about biodiversity**, encouraging more people to engage with nature and conservation efforts. In conclusion, the Butterfly Image Classifier stands as a compelling example of how AI can be thoughtfully applied to address real-world challenges while fostering learning and ecological curiosity.

FUTURE SCOPE :

There is significant potential to expand and improve the Butterfly Image Classifier in future iterations. One of the most impactful enhancements would be to increase the number of butterfly species supported by training on a larger, more diverse dataset. This would improve the model's generalization and make it applicable to a broader range of users across different geographic regions.

Additionally, the project could evolve to include the classification of other insects or wildlife, extending its reach beyond butterflies. A mobile application or offline mode would also be valuable, especially for researchers or students working in field conditions where internet access is limited or unavailable.

To enhance learning, the app could be integrated with external APIs (such as Wikipedia or biodiversity databases) to provide more information about each species, including habitat, behaviour, and conservation status. Adding a user feedback system would enable model improvement through real-world data validation. Finally, features like batch image processing, automated reporting, and multi-language support would make the tool even more powerful and inclusive for use in classrooms, research labs, and global citizen science initiatives.

APPENDIX:

□ **Source Code**

The complete source code for the Butterfly Image Classifier, including the trained MobileNetV2 model, image preprocessing logic, and the Streamlit-based frontend, is available on GitHub.

🔗 GitHub Repository:
https://github.com/chimataraghuram/Enchanted-Wings-Marvels-of-butterfly-species.git