



AQUAVISION: AI POWERED FISH SPECIES DETECTION AND DISEASE ANALYSIS

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Abstract: Misclassification of fish species presents a critical challenge to aquaculture, impacting operational efficiency, biodiversity conservation, and sustainable fisheries management. Accurately identifying fish species is essential for preserving ecological balance and enhancing breeding programs. Similarly, delayed detection of fish diseases can lead to devastating consequences, including mass fish deaths, substantial financial losses, and heightened risks of disease outbreaks in aquaculture farms. Traditional methods for identifying fish species and diagnosing diseases largely depend on manual observation, which can be slow, prone to errors, and impractical for large-scale operations. To address these limitations, our system employs an advanced, automated approach to streamline fish species classification and early disease detection. By leveraging cutting-edge image processing and intelligent pattern recognition techniques, the system delivers fast and accurate results. Enhancements in image quality facilitate superior feature extraction, which improves classification and detection outcomes. This automation minimizes reliance on manual inspections, reducing the likelihood of human errors while enabling aquaculture farmers to monitor fish health more effectively. By integrating intelligent technology into aquaculture management, this solution aims to transform fish farming practices. It supports sustainability by promoting healthier aquatic ecosystems, reducing disease-related losses, and contributing to more efficient and eco-friendly fish farming operations.

Keywords: Artificial Intelligence (AI), Deep Learning, Aquaculture, Fish Species Classification, Fish Disease Detection, Convolutional Neural Network (CNN), Transfer Learning, Computer Vision, Image Processing, EfficientNet, MobileNetV2, Grad-CAM, Explainable AI (XAI), Fish Health Monitoring, Smart Aquaculture, Disease Analysis, Machine Learning, Image Classification, Aquaculture Management, Automated Detection, Flask Web Application, SQLite Database, Real-Time Monitoring, Fish Farming, Aquatic Disease Detection.

I. INTRODUCTION

The rapid advancement of artificial intelligence (AI) and its increasing adoption across various industries has significantly transformed the way complex problems are addressed. In recent years, agriculture and aquaculture have particularly benefited from AI-driven technologies, especially those based on deep learning and computer vision. These technologies are enabling automated systems to perform tasks that previously required extensive human expertise, thereby improving efficiency, accuracy, and scalability. In the aquaculture sector, the ability to accurately identify fish species and continuously monitor fish health plays a crucial role in achieving sustainable production, controlling disease outbreaks, and reducing financial losses.

Traditionally, fish species identification and disease diagnosis are performed manually by trained professionals through visual inspection and laboratory testing. While effective, these conventional methods are labor-intensive, time-consuming, and highly dependent on expert availability. Furthermore, as aquafarms expand in size and production volume, manual monitoring becomes increasingly impractical and prone to errors. Delayed detection of diseases can result in rapid spread of infection, leading to significant mortality rates and economic damage. Therefore, the need for an automated, reliable, and scalable monitoring solution has become a critical requirement in modern aquaculture practices.

1.1 Project Description

AquaVision: AI-Powered Fish Species Detection and Disease Analysis is an intelligent system developed using Artificial Intelligence, Deep Learning, and Computer Vision technologies. The project is designed to automatically identify fish species and detect fish diseases from uploaded fish images. The system uses deep learning models such as EfficientNet for species classification and MobileNetV2 for disease detection.

The system also uses Grad-CAM visualization to highlight the important regions of the image that influenced the prediction, making the system more transparent and reliable.

AquaVision includes features such as prediction history storage, PDF report generation, and a user-friendly interface. The project helps reduce manual effort, supports early disease detection, improves aquaculture management, and provides a scalable solution for smart fish farming environments.



The user uploads a fish image through a web application, and the system preprocesses the image using techniques like resizing, normalization, and noise removal. After preprocessing, the AI models analyze the image and generate

1.2 Motivation

The main motivation behind AquaVision is to solve the problems faced in aquaculture such as difficulty in identifying fish species, delayed disease detection, and dependence on manual inspection. Traditional methods require experts, consume more time, and may lead to errors, especially in large fish farms. Fish diseases can spread quickly and cause huge financial losses if they are not detected early. Existing systems usually focus only on fish species identification or disease detection separately. Therefore, AquaVision was developed to provide a smart AI-based solution that can perform both tasks together with high accuracy, reduced human effort, faster analysis, and better fish health management.

II. RELATED WORK

Reference	Year	Authors	Data Parameters	Methodology	Result	Limitation
Environmental Management through Machine Learning-based Fish Species Classification	2023	Various Researchers	Fish images, texture features, shape features	Image preprocessing, segmentation, SVM, CNN	Improved fish species classification accuracy	Performance depends on image quality
Classification of Freshwater Fish Diseases in Bangladesh	2023	Various Researchers	Fish disease images, augmented dataset	Deep learning, transfer learning, Grad-CAM	Reliable disease classification with high accuracy	Requires large computational resources
Advanced Techniques for the Intelligent Diagnosis of Fish Diseases	2022	Various Researchers	Fish disease images, infected regions	CNN models, feature extraction, image processing	Supports automated and real-time disease detection	Underwater image quality affects accuracy
Fish Species Classification using Optimized Deep Learning Model	2022	Various Researchers	Underwater fish images	Deep learning with optimization techniques	Better classification accuracy and stable performance	Needs larger datasets for better reliability
Fish Species Classification Using Firefly Algorithm and Neural Network	2021	Various Researchers	Marine fish images, visual features	Image enhancement, Firefly optimization, Neural Network	High accuracy even with blurred images	Increased computational cost
Fish Diseases Detection Using Convolutional Neural Network	2021	Various Researchers	RGB fish disease images	CNN-based disease classification	Early disease detection with good accuracy	Limited dataset affects generalization
Fish Disease Detection Using Image Based Machine Learning Technique	2020	Various Researchers	Salmon fish disease images	Image enhancement, feature extraction, SVM	Reliable disease detection performance	Real-time implementation is limited
Shape and Texture Based Classification of Fish Species	2019	Various Researchers	Fish shape and texture data	Shape alignment, texture analysis, dimensionality reduction	Improved classification using combined features	Manual annotation required



II. METHODOLOGY

The AquaVision system follows a structured methodology to perform fish species classification and disease detection using Artificial Intelligence and Deep Learning techniques.

[1] 1. Image Collection

Fish images containing different fish species and disease conditions are collected from datasets and online sources. The dataset includes both healthy and diseased fish images.

[2] 2. Image Preprocessing

The collected images are preprocessed to improve image quality and model performance. Preprocessing steps include:

- Image resizing
- Normalization
- Noise removal
- Data augmentation such as rotation, flipping, and zooming

These steps help the model handle different lighting conditions and fish orientations.

[3] 3. Feature Extraction

Important visual features such as shape, texture, color, and patterns are automatically extracted using deep learning models.

[4] 4. Fish Species Classification

EfficientNet CNN model is used to classify the uploaded fish image into its correct fish species category. The model is trained using transfer learning to improve accuracy and reduce training time.

[5] 5. Fish Disease Detection

MobileNetV2 deep learning model is used to identify diseases from fish images. The model detects visible symptoms such as white spots, lesions, fungal infections, and discoloration.

[6] 6. Prediction and Confidence Score

After analysis, the system generates:

- Fish species name
- Disease type
- Confidence score for prediction reliability

[7] 7. Explainable AI using Grad-CAM

Grad-CAM heatmaps are generated to highlight the important image regions used by the model during prediction. This improves transparency and user trust.

[8] 8. Database Storage

All prediction results, uploaded images, timestamps, and confidence scores are stored in an SQLite database for future reference.

[9] 9. PDF Report Generation

The system automatically generates downloadable PDF reports containing prediction details, disease information, and confidence values.

[10] 10. Result Display

Finally, the prediction results are displayed to the user through a Flask-based web interface in a simple and user-friendly format.

III. SYSTEM DESIGN

The AquaVision system follows a layered architecture that separates user interaction, application logic, and data/model management. This structured design improves scalability, maintainability, and ease of integration. The system is composed of three main layers: Presentation Layer, Application Layer, and Data and Model Layer.

1. Presentation Layer: The Presentation Layer provides the user interface through which users interact with the AquaVision system. It is designed to be intuitive and user-friendly, allowing aquaculture professionals and researchers to access system functionalities with minimal technical knowledge. Users can upload fish images, view species classification and disease detection results, analyze confidence scores, and download detailed PDF reports. This layer ensures smooth interaction and real-time visualization of outputs generated by the AI models.

2. Application Layer: The Application Layer acts as the core processing unit of the system. It manages the overall workflow by handling user requests received from the Presentation Layer and coordinating with the underlying AI models and data storage components. This layer performs image preprocessing, triggers deep learning model inference, generates explainable AI visualizations such as Grad-CAM heatmaps, and formats prediction results. It also controls report generation, database updates, and system-level validations, ensuring secure and efficient operation.



3. Data and Model Layer: The Data and Model Layer is responsible for storing datasets, managing trained deep learning models, and maintaining prediction records. It includes the trained CNN models for fish species classification and disease detection, along with the supporting preprocessing configurations. This layer also handles structured data storage using a lightweight database to maintain image metadata, prediction history, confidence values, and timestamps. By isolating data and model management, this layer enables easy model updates, retraining, and scalability as new species or disease data becomes available.

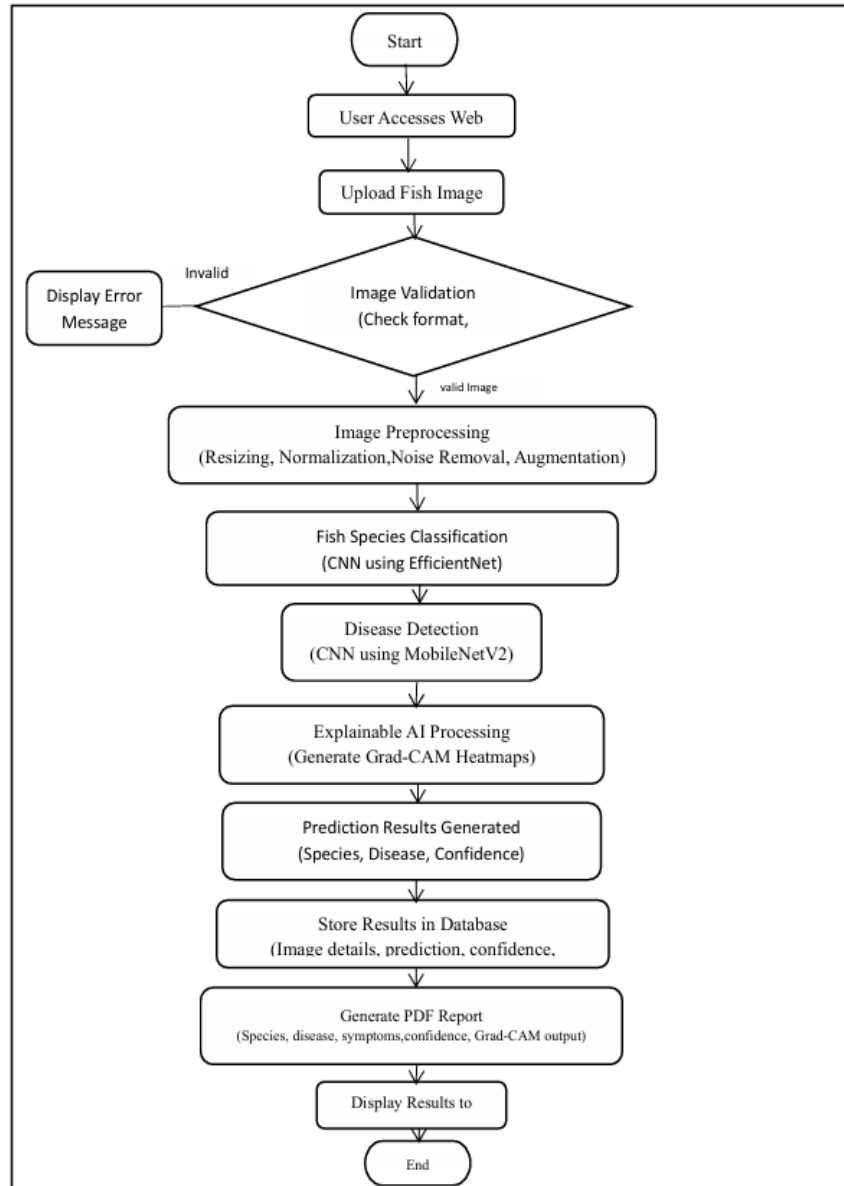


Figure 1 : System Flow Chart for Fish Species and Disease Detection Process.

Hardware Requirements:

Minimum Configuration:

- **Processor:** Intel Core i5 or equivalent
- **RAM:** 8 GB
- **Storage:** 250 GB HDD/SSD
- **GPU:** Optional (for image testing, not training)

• Recommended Configuration:

- **Processor:** Intel Core i7 / AMD Ryzen 7 or higher



- **RAM:** 16 GB or more
- **Storage:** 500 GB SSD
- **GPU:** NVIDIA CUDA-enabled GPU (RTX 3060 or higher) for training deep learning models.

Software Requirements:

•Python (v3.8 or above):

Used as the core programming language for implementing AI models, image processing, backend logic, and system integration due to its strong support for machine learning libraries.

•Flask Framework:

Acts as the backend web framework, enabling image upload, model inference, real-time result display, prediction history access, and PDF report downloads through RESTful services.

•TensorFlow & Keras:

Utilized for building, training, and fine-tuning deep learning models for fish species classification and disease detection, with support for GPU acceleration and transfer learning.

•Deep Learning Models:

- **EfficientNet:** Used for accurate and efficient fish species classification.
- **MobileNetV2:** Used for lightweight and fast detection of fish diseases based on visual symptoms.

•Frontend Technologies:

HTML, CSS, and JavaScript are used to create a responsive user interface for image upload, result visualization, confidence display, and report access.

•Database (SQLite):

Stores prediction records, timestamps, confidence scores, and user interaction history in a lightweight and structured format.

•Development Tools:

Jupyter Notebook for model experimentation and analysis, and VS Code / PyCharm for application development, debugging, and deployment integration.

Testing was conducted through multiple levels to ensure the reliability and performance of AquaVision. Unit testing verified individual functions such as image prediction, fish validation, and database operations. Integration testing confirmed seamless interaction between modules like the Flask web interface, machine learning models, and PDF generation system. System testing evaluated the complete application across devices, ensuring fast predictions, responsive design, offline functionality, and correct handling of invalid inputs. Finally, acceptance testing with real users—including fish farmers and students—validated the system's usability and practical value, leading to improvements in design and content, and confirming that the application meets its intended goals.

UNIT TESTING Unit testing involves verifying individual components of the system in isolation to ensure each function works correctly before integration. • Individual Components Tested – Each function like `predict_image ()`, `is_valid_fish_image ()`, and database operations were tested separately to ensure they work correctly in isolation. • Model Prediction Accuracy – The species and disease prediction functions were verified using sample images to confirm correct output class and confidence level. • Fish Validation Logic – The system was tested to reject non-fish images (e.g., cars, people) by checking if the model's confidence is below a threshold (e.g., < 0.4). • Error Handling & Robustness – Functions were tested with invalid inputs (corrupted files, no image) to ensure graceful error messages without crashing the app.

INTEGRATION TESTING Integration testing verifies how different modules of the AquaVision system work together, ensuring seamless interaction between the web interface, AI models, database, and PDF generator. • Ensured seamless communication between the Flask web interface, AI models, database, and PDF generator. Bangalore Institute of Technology Department Of MCA 2025-26 AquaVision: Ai Powered Fish Species Detection And Disease Analysis Page 48 • Validated the complete flow: image upload → prediction → result display → history save → PDF download. • Confirmed that only species or disease result is shown based on user selection, not both together. • Resolved issues with image paths in PDF reports by correctly passing the `'uploaded_image'` URL from frontend to backend.



SYSTEM TESTING System testing ensures the complete AquaVision application works reliably and efficiently in real-world conditions, validating functionality, performance, and user experience across different devices and scenarios. • Tested end-to-end workflow on multiple devices to verify responsiveness, fast prediction times, offline functionality, and correct handling of valid, invalid, and non-fish images. • Validated PDF generation, history storage, dark mode, and task-specific result display to ensure a smooth and intuitive user experience.

TEST CASES In software engineering, test cases define the specific inputs, execution conditions, testing procedures, and expected results that are used to verify that the software behaves correctly. For the AquaVision system, a comprehensive set of test cases has been created to ensure that all features species identification, disease detection, fish validation, PDF generation, and history tracking work as intended. Each test case is carefully designed to verify a specific function or pathway within the system, such as object detection (fish), classification (species/disease), and report generation. The test cases will include scenarios to validate the detection of fish in images using EfficientNetV2-S models, the correct classification of 24 species and 12 diseases, and the generation of downloadable PDF reports with accurate information. They will also cover edge cases such as handling images with no detectable fish, managing low-resolution images, and processing images under different lighting conditions.

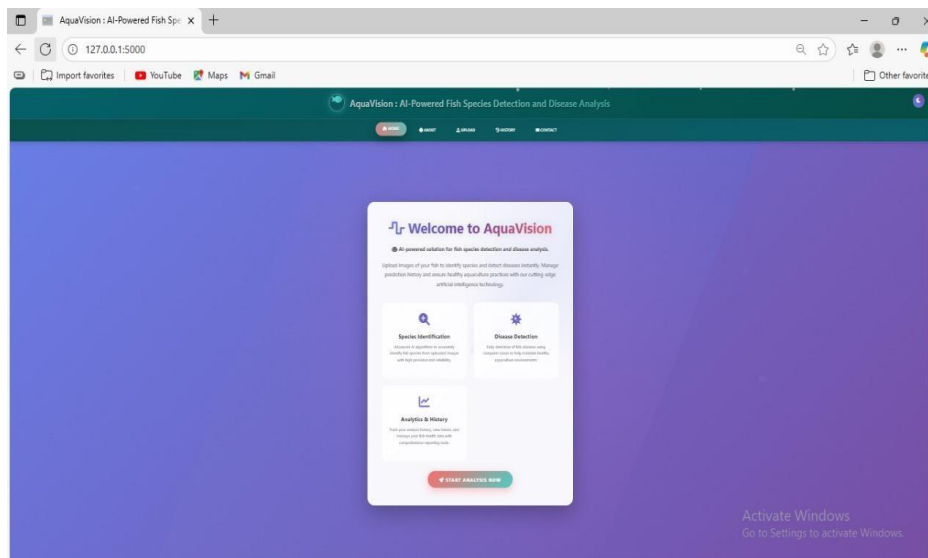


Figure 1: Welcome page of the website.

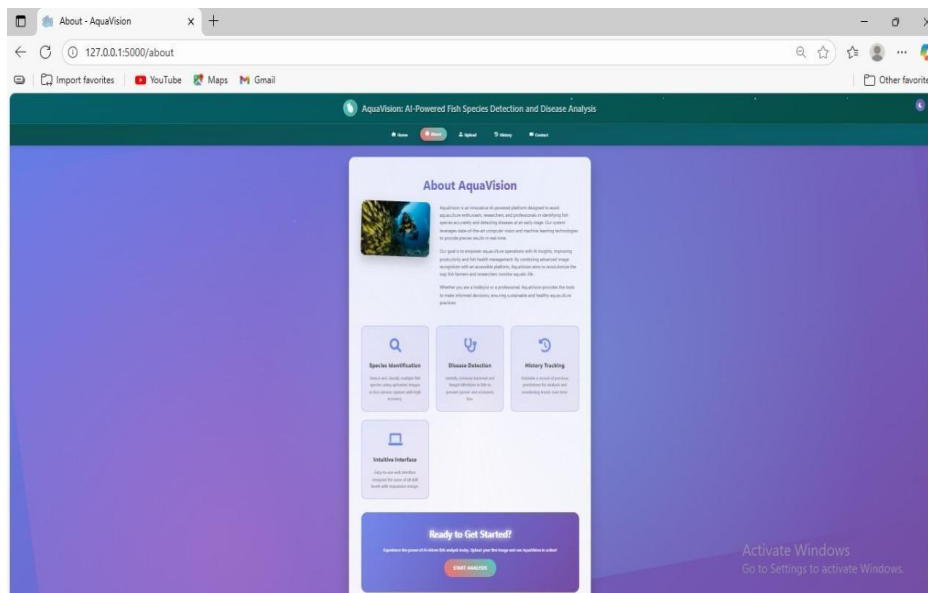


Figure 2: About page of the website.

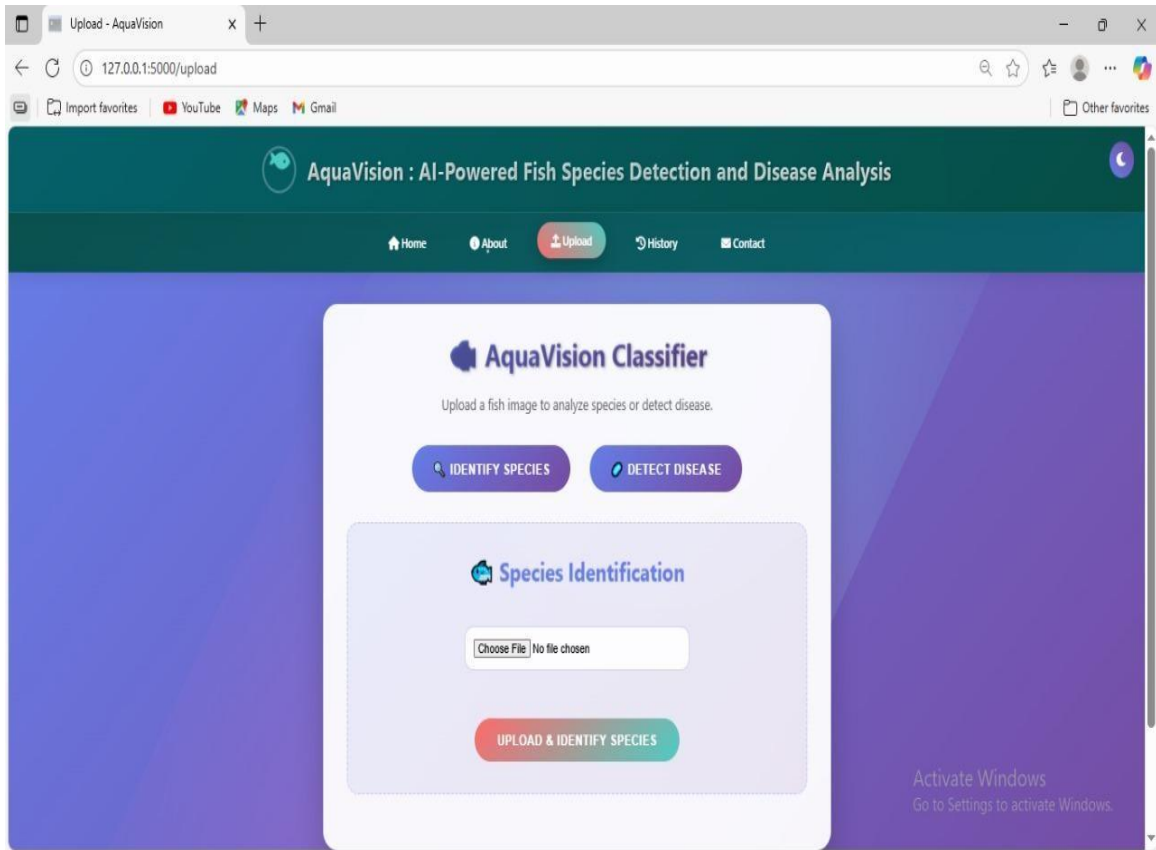


Figure 3: Upload image for species identification and disease detection.

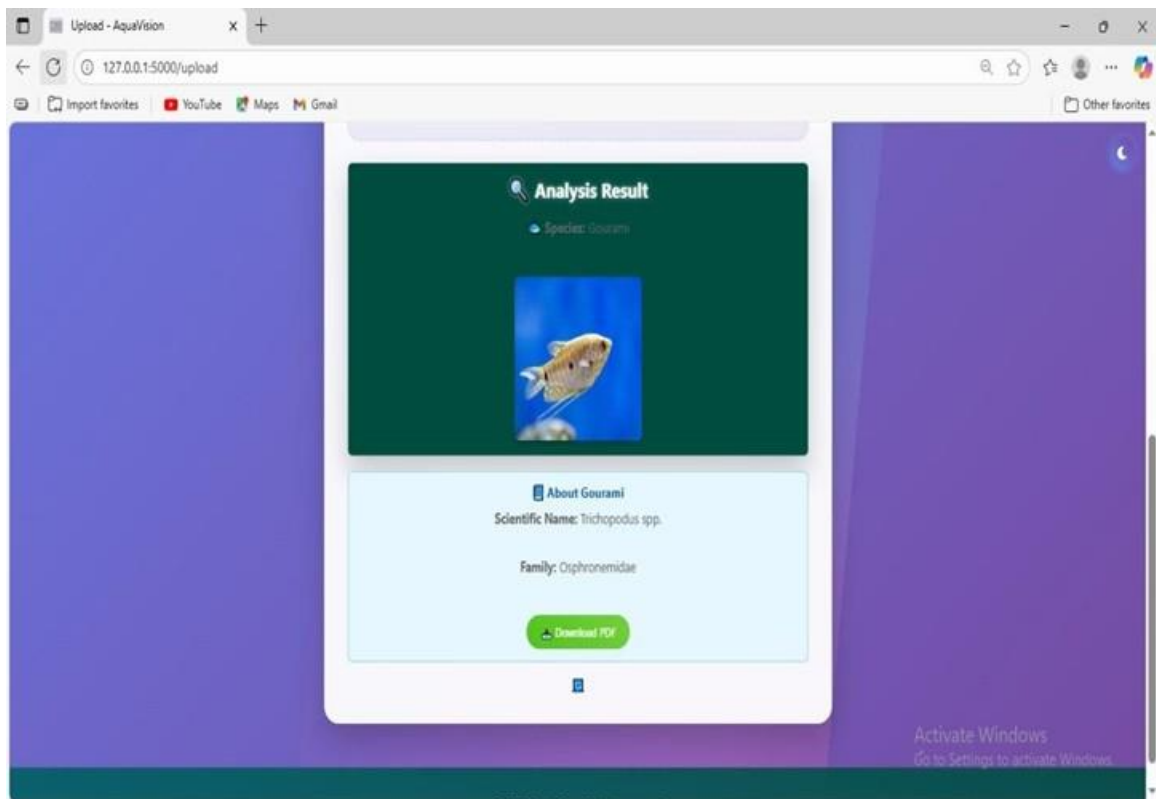


Figure 4: Result of the species identified by uploaded image.

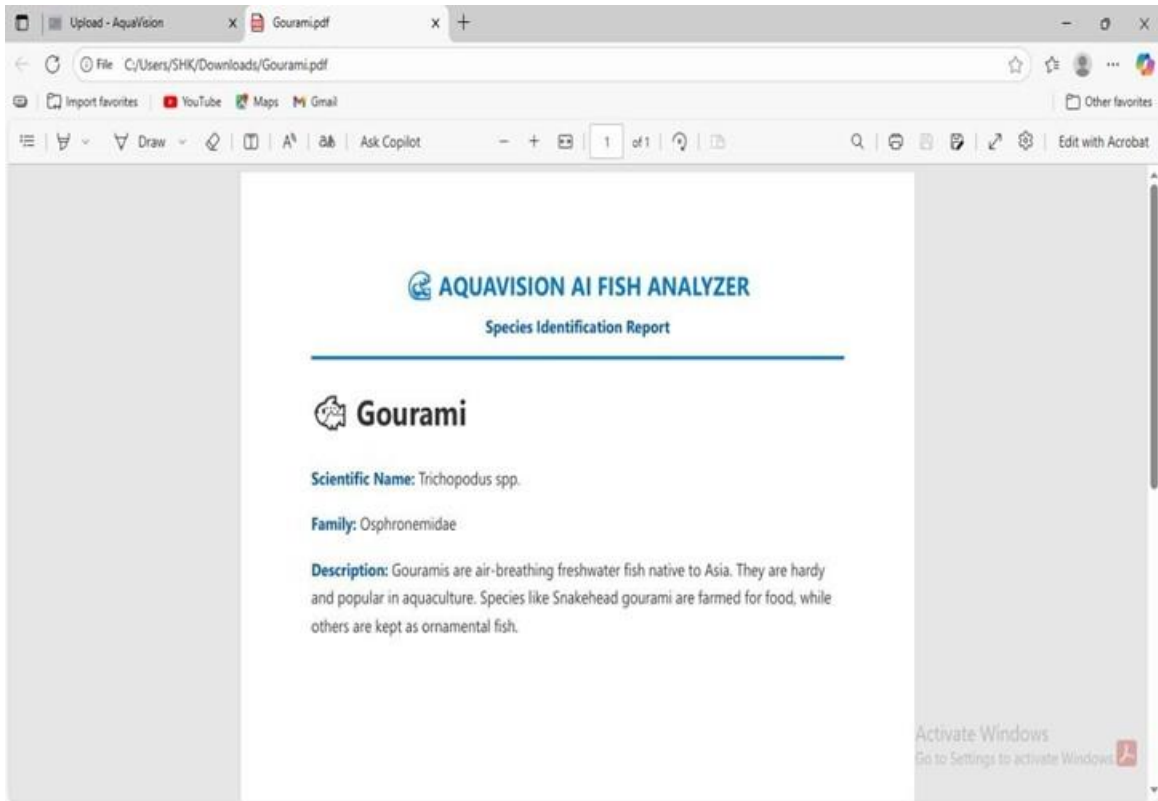


Figure 5: Report generated for the identified species.

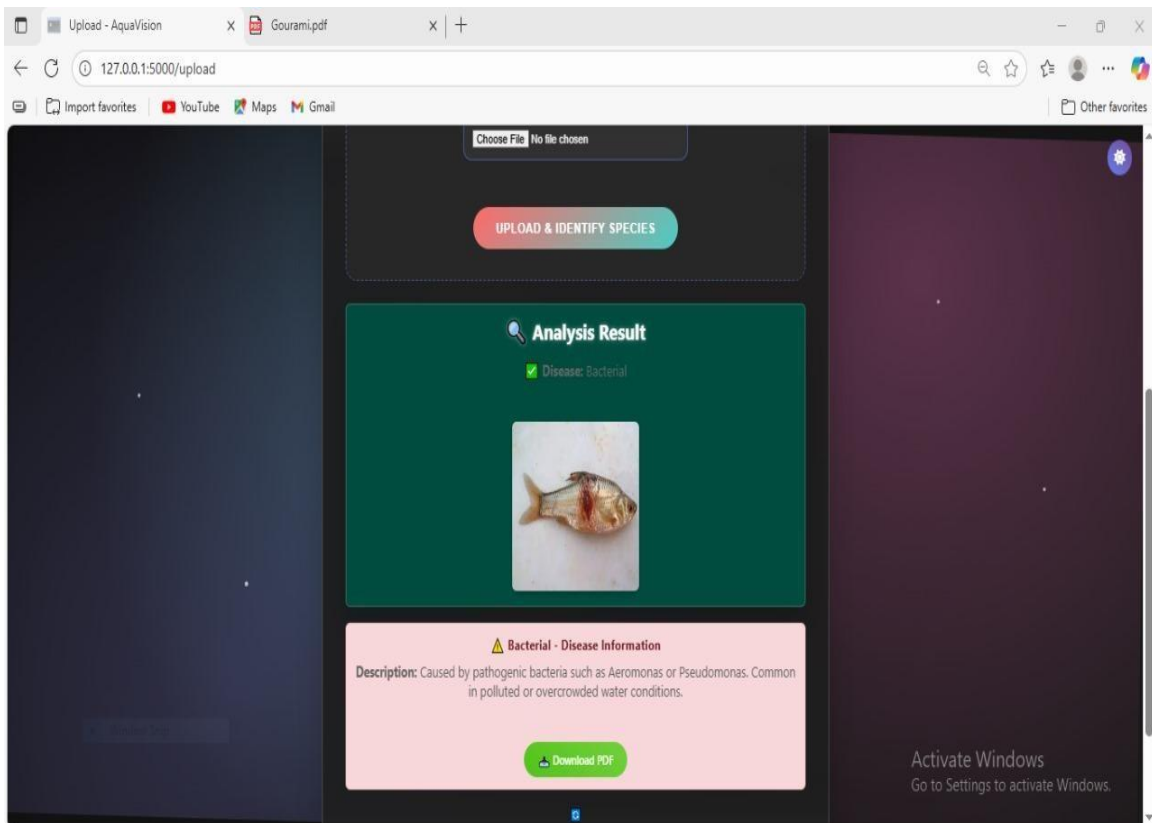


Figure 6: Result of the disease detected by uploaded image.



Figure 7: Report generated for the detected disease.

The screenshot shows a web browser window with the URL 127.0.0.1:5000/history. The page title is 'AquaVision : AI-Powered Fish Species Detection and Disease Analysis'. The navigation menu includes Home, About, Upload, History (active), and Contact. The main content area is titled 'Prediction History' and contains a search bar and a table of analysis results.

Timestamp	Image	Result
2025-11-05 07:58:13		Barb Bacterial
2025-11-05 07:53:00		Barb Bacterial
2025-11-05 07:52:24		Barb Bacterial
2025-11-05 07:50:36		Perch Fungal
2025-11-05 07:49:39		Perch Fungal
2025-11-05 07:47:06		Perch Fungal
2025-11-04 09:59:17		Carp

Figure 8: Prediction History.

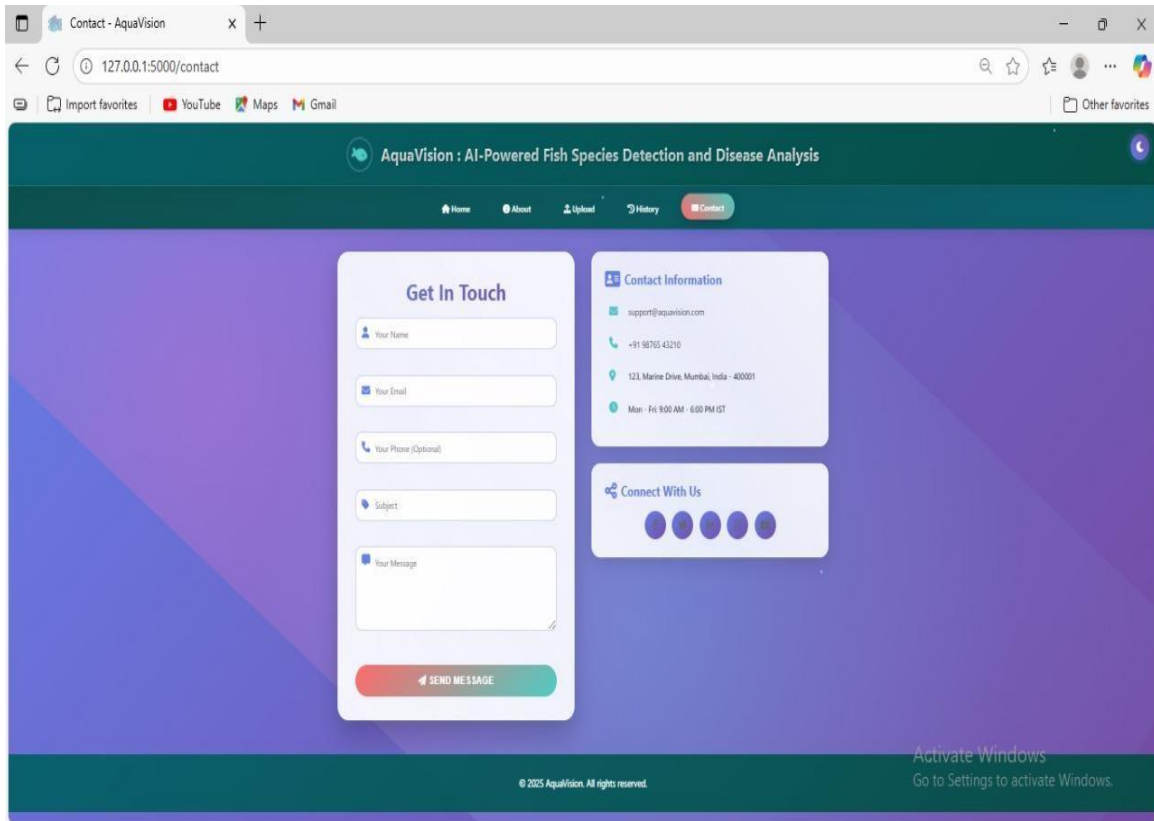


Figure 9: Contact page of the website.

V.RESULTS AND DISCUSSION

Test Case ID	Test Scenario	Test Steps	Expected Result	Actual Output	Status
TC01	Image Upload	Upload a valid fish image (.jpg / .png)	Image should upload successfully and move to preprocessing	The fish image is uploaded successfully and displayed on the interface.	Pass
TC02	Invalid Image Upload	Upload unsupported or corrupted file (.pdf / .txt / damaged image)	System should block upload and display an error message	The system blocks the invalid file and shows an error message.	Pass
TC03	Preprocessing & Model Prediction	Upload a valid fish image and process it	System should preprocess (resize, denoise) and predict species & disease	The image is preprocessed and the fish species and disease are predicted.	Pass
TC04	Database Storage	Upload image and complete prediction	Image and prediction result should be saved in SQLite database	The image and prediction results are saved in the SQLite database.	Pass



TC05	Report Download	Complete prediction and click download report	System should provide downloadable PDF/summary with confidence score	The system generates and downloads the PDF report with confidence score.	Pass
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VI. CONCLUSION

AquaVision successfully addresses a critical gap in modern aquaculture by integrating fish species classification and disease detection into a single, unified AI-powered system. Traditional methods rely heavily on manual inspection, which is time-consuming, subjective, and impractical for large-scale operations. In contrast, AquaVision leverages deep learning—specifically transfer learning with pre-trained architectures—and advanced image preprocessing techniques to deliver accurate, automated, and interpretable results from still fish images. The system's use of Grad-CAM enhances transparency by visually highlighting the regions of the image that influence predictions, thereby building trust among non-technical users such as fish farmers and field biologists.

The project demonstrates that combining species identification and disease diagnosis in one pipeline is not only feasible but also more efficient than maintaining separate systems. By applying data augmentation, noise reduction, and contrast enhancement, AquaVision achieves robust performance even under suboptimal imaging conditions such as variable lighting or partial occlusion. The Flask-based web interface ensures accessibility and ease of use, allowing users to upload images and receive immediate feedback on species identity and disease status. While the current implementation is limited to external, visually detectable diseases and static images, it establishes a strong foundation for intelligent, scalable, and sustainable aquaculture management. Overall, AquaVision represents a practical step toward smart farming by reducing human error, enabling early intervention, and supporting data-driven decision-making in real-world aquaculture environments.

VII. FUTURE WORK

Although AquaVision delivers promising results in its current form, several enhancements can significantly expand its capabilities and real-world applicability:

- **Adoption of EfficientNet Architecture:** Replace the initial ResNet50 backbone with EfficientNet-B3 (or EfficientNetV2-S) to improve accuracy and computational efficiency, especially for resource-constrained environments.
- **Real-Time Video Analysis:** Extend the system to process live video streams from underwater cameras, enabling continuous monitoring of fish behavior, movement patterns, and dynamic disease progression.
- **Mobile and Edge Deployment:** Optimize the trained model using quantization and TensorFlow Lite to deploy AquaVision on smartphones or Raspberry Pi devices, facilitating on-site diagnostics in remote or low-infrastructure aquafarms.
- **Integration of Multi-Modal Data:** Incorporate environmental sensors (e.g., pH, temperature, dissolved oxygen) and behavioral analytics to complement visual diagnosis, creating a holistic fish health assessment framework.
- **Expanded Dataset Coverage:** Continuously enrich the training dataset with more fish species (e.g., *Labeo rohita*, *Catla*, *Cyprinus carpio*) and additional disease categories (e.g., Columnaris, Dropsy, Gill Flukes) to improve generalization across diverse geographical and ecological contexts.
- **User Feedback Loop:** Implement a mechanism for users to report misclassifications or suggest corrections, enabling periodic model retraining and continuous learning in production.
- **Cloud-Based Scalability:** Develop a cloud-hosted version with user authentication, prediction history storage, and downloadable PDF reports for farm management and regulatory compliance.
- **Enhanced Explainability:** Refine Grad-CAM visualizations or integrate newer XAI techniques (e.g., Integrated Gradients) to provide even clearer, more reliable explanations for both species and disease predictions.

These future directions will transform AquaVision from a prototype into a production ready, industry-standard tool that supports the global transition toward intelligent, sustainable, and resilient aquaculture practices.



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