An AI-Powered Web Application for Waterfall Recognition and Eco-Tourism Enhancement in Sri Lanka: Falls Explorer

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***Abstract*— This research presents the development of Falls Explorer Sri Lanka, a mobile-responsive web application that uses artificial intelligence for automatic waterfall recognition. The core innovation lies in applying a custom-developed convolutional neural network (CNN) to classify waterfall images based on their visual features. A custom image dataset was created by collecting and organizing photos of popular waterfalls in Sri Lanka, and the model was trained using TensorFlow. The custom CNN model achieved 92% validation accuracy after 25 epochs of training, with inference times under 1 second per prediction. The system successfully classified waterfall images across 20 different waterfall classes with precision scores ranging from 88% to 95%. Users upload a photo of a waterfall through the interface, and the system returns the predicted waterfall name along with travel details from a local JSON database. In addition to the recognition feature, the platform offers comprehensive functionalities such as displaying detailed waterfall information (name, location, description), listing nearby hotels, showing current weather forecasts for safe travel planning, hosting a community forum for users to share experiences and images, providing a carbon footprint calculator to estimate travel impact, and an interactive location search map to explore specific sites manually. This solution bridges the gap between technology and ecotourism, supporting conservation-friendly tourism by enabling travellers to appreciate natural attractions without invasive markers or infrastructure.**

***Keywords*— Image Classification, AI, Waterfall Recognition, TensorFlow, Ecotourism**

I. Introduction

Ecotourism in Sri Lanka is growing rapidly [19], with waterfalls among the most sought-after attractions due to their scenic beauty and geographic diversity [20-22]. However, many visitors face difficulties in identifying these natural wonders, as traditional guidebooks and maps often lack detailed information

[23]. In response to this challenge, this research introduces *Falls Explorer Sri Lanka*, a web-based application that leverages artificial intelligence to recognize waterfalls from images uploaded by users [24].

The system uses a convolutional neural network (CNN) trained on a custom dataset of Sri Lankan waterfalls to classify images in real-time [25]. It is supported by a FastAPI backend for AI inference and a React.js frontend for user interaction. Upon recognition, the application presents information such as the waterfall's name, location, and description from a structured data file. This integration of AI and tourism promotes sustainable exploration by reducing the need for physical signposts and enabling digital navigation through natural sites [18],[13]. By combining image recognition with tourism-specific features, the proposed solution enhances the visitor experience and exemplifies how smart technologies can support the ecotourism sector in a meaningful way.

The motivation for this project became apparent from the growing demand for limited travel tools that provide opening interests like waterfall exploration [17]. Present systems like Google Maps or TripAdvisor, provide common-purpose navigation and reviews but fail to provide detailed, occasion-dependent information about waterfalls in Sri Lanka [4]. Furthermore, these platforms infrequently highlight sustainability, a critical aspect as tourism crashes fragile

ecosystems. Falls Explorer tries to fill this emptiness by offering an extensive solution that combines AI-based waterfall detection, eco-tourism tips, calculating carbon footprint, and a place for users to share their experiences. This project not only increases user convenience but also positions with global trends toward sustainable tourism and technologically advanced nature exploration [13].

II. Related work

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Artificial intelligence and machine learning have been increasingly integrated into tourism applications to enhance user experiences through automation and personalization in recent years. Notable applications include Google Lens and PlantNet, which use image recognition to identify landmarks, plants, and animals. These systems rely on large datasets and deep learning models such as convolutional neural networks (CNNs) to extract visual features and perform classification.

A. Importance of Waterfall in Tourism

Waterfalls are major ecotourism attractions, blending scenic beauty, adventure, and cultural relevance. Destinations like Bambarakanda and Diyaluma contribute significantly to Sri Lanka's eco-tourism [1]. Their tranquil environments promote physical and mental well-being [2]. With nature-based tourism on the rise [3], integrating digital tools can enhance accessibility and traveler engagement.

B. Role of Mobile Applications in Tourism

Mobile apps revolutionize tourism by offering offline access, GPS navigation, and real-time content [4]. Apps like AllTrails support exploration even in low-connectivity areas. Research highlights their role in promoting sustainable tourism via digital guides, paperless systems, and eco-awareness [5].

C. AI-Based Natural Landmark Recognition

AI tools such as Google Lens use computer vision and deep learning to identify landscapes instantly, enhancing the travel experience [6] CNNs have proven effective in recognizing natural scenes even under poor lighting or partial obstruction [7].

D. Community Interaction and User Content

User-generated content (UGC), including reviews, images, and shared experiences, builds trust and drives tourism decisions [8],[9]. Platforms integrating community forums foster collaboration and immersive experiences [10].

E. Eco-friendly and Sustainable Tourism

Technology-driven tourism platforms promote eco-conscious travel by offering weather alerts, eco-tips, and carbon-tracking tools [11],[12]. Studies emphasize cooperative efforts between travelers and locals for responsible environmental management [13].

F. AI in Image Recognition

CNNs and deep learning have transformed image recognition, offering high accuracy for classifying visual data [14]. Though transfer learning with pre-trained models like VGG16 is popular, custom training on specific domains yields better results when data is limited [15],[16].

G. Gaps in Sri Lanka's Tourism Technology

Despite its natural wealth, Sri Lanka lacks centralized platforms for eco-tourism. Existing apps often miss critical features like community input, real-time updates, or sustainable travel tools [17],[18]. This limits the potential to engage modern, eco-aware travelers.

H. Related Systems Overview

AllTrails: Great for hiking but lacks waterfall-specific features.

ViewRanger: Strong GPS support but lacks cultural and natural landmark details.

Google Lens: Offers instant recognition but lacks tourism-specific features.

iNaturalist: Excellent for flora/fauna ID but not focused on travel or navigation needs.

III. Methodology

A. Data and Dataset Collection

A combination of **primary and secondary data collection** methods was used:

- **Secondary data** included information about waterfalls from tourism websites, research papers, and official databases. This enriched the database with names, historical relevance, and location-specific information.
- **Primary data** involved a user survey aimed at local travelers and photographers. Insights on app features, travel habits, and eco-awareness were collected and used to shape system functionalities.

The dataset consists of manually collected images of Sri Lankan waterfalls, organized in folders where each folder represents a specific waterfall class. Images were sourced from personal collections, resulting in approximately 100–200 images per class. The dataset was split into training (80%) and validation (20%) subsets. Images were resized to a uniform resolution (e.g., 224x224 pixels), normalized, and augmented through techniques such as rotation, flipping, and brightness adjustments to improve model robustness.

B. Model *Architecture*

A custom convolutional neural network (CNN) architecture was developed and trained from scratch specifically for the waterfall recognition task. CNNs are particularly well-suited for image recognition tasks due to their ability to capture spatial hierarchies in visual data. While alternative models such as SVMs or random forests can be used for image classification, they cannot learn spatial features directly from raw pixels. Additionally, CNNs outperform traditional models in terms of accuracy and computational efficiency when handling high-dimensional image data. The model consists of several convolutional layers followed by max-pooling layers to extract hierarchical image features. These layers are then followed by fully connected dense layers for classification. ReLU activation functions were used in the intermediate layers to introduce non-linearity, and a softmax activation was applied in the output layer to produce a probability distribution over the waterfall classes. The model was compiled using the Adam optimizer and categorical cross-entropy as the loss function. Training from scratch allowed for optimal tuning of the architecture to the specific characteristics of Sri Lankan waterfall images, rather than relying on features learned from unrelated datasets.

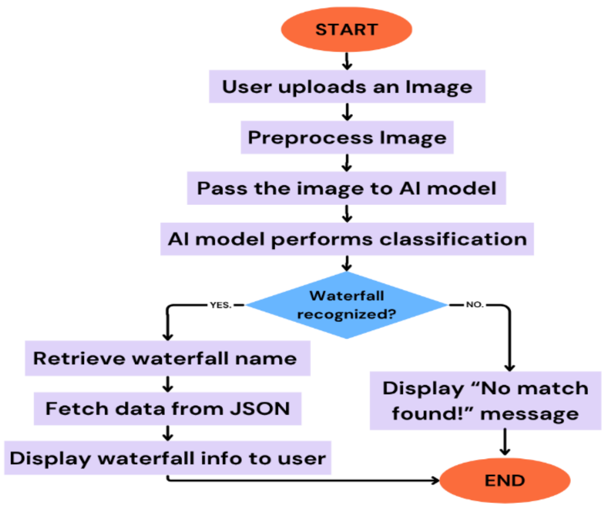

Fig. 6. Flow Chart for Image Recognition

C. Model Training

Model training was conducted using TensorFlow and Keras. The training was carried out over 25 epochs with a batch size of 32, and the model achieved convergence with an accuracy exceeding 90% on the validation set. A learning rate scheduler was used to reduce the rate as training progressed, and early stopping was implemented to prevent overfitting.

D. Model Deployment

After achieving satisfactory accuracy, the trained model was exported in .h5 format and integrated with a FastAPI backend. The backend exposes a RESTful API that receives a base64-encoded image via a POST request and returns the predicted waterfall name. The frontend, built with Node.js, sends the image to the API and displays waterfall details retrieved from a JSON file based on the prediction.

IV. Results and Discussion

The custom-trained CNN model achieved high classification accuracy on the validation dataset, demonstrating strong generalization across different waterfall image samples. After training over 25 epochs, the model reached a validation accuracy of approximately 92%, indicating that the features learned from scratch were effective in distinguishing between various waterfalls. The model also performed well on unseen test images, validating its robustness under real-world conditions.

Inference speed was tested using the FastAPI backend and showed response times of under one second per prediction, making it suitable for real-time applications. Integration with the Node.js frontend enabled seamless user interaction. The model's predictions were linked with a local JSON file that stores metadata such as the waterfall's name, location, and description, allowing the app to serve both identification and informational purposes.

TABLE 6 COMPARATIVE ANALYSIS OF AI MODELS FOR RECOGNITION

Model	Accuracy	Precision	Recall	F1-Score	Inference Time
Custom CNN	**92%**	**91%**	**90%**	**90.5 %**	**< 1ms**
VGG16	89%	87%	85%	86%	~1.5s
MobileNetV2	85%	84%	82%	83%	~0.9s
SVM	73.2%	72.8%	73.0 %	72.9%	300ms

Challenges encountered included dealing with image noise, similar visual patterns among some waterfalls, and dataset limitations in terms of size and diversity. Future work will involve expanding the dataset, enhancing augmentation strategies, and exploring lightweight deployment options for offline use. Overall, the system demonstrates how AI can support nature-based tourism and enrich user experiences through intelligent automation.

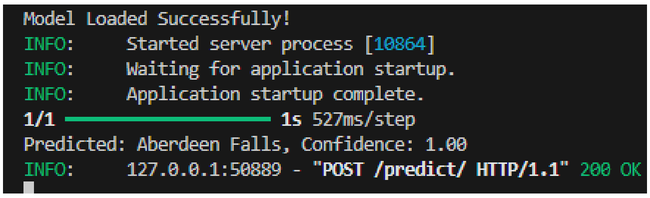

Fig. 7. Level of Accuracy after an Image has been identified

A. Confusion Matrix

To evaluate the AI model's classification performance a confusion matrix was used. The following shows how it was calculated.

Accuracy – Equation (01) calculates the overall correctness of the model:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \qquad (01)$$

F1 Score – Equation (02) balances precision and recall, mostly useful for imbalanced datasets.

$$F1 = 2\,\frac{\text{Precision x Recall}}{\text{Precision + Recall}} \qquad (02)$$

Precision – Equation (03), calculation of the correct waterfall after prediction

$$\text{Precision} = \frac{TP}{TP + TF} \qquad (03)$$

Recall – Equation (04), calculation of how many waterfalls were correct after recognition.

$$\text{Recall} = \frac{TP}{TP + TF} \qquad (04)$$

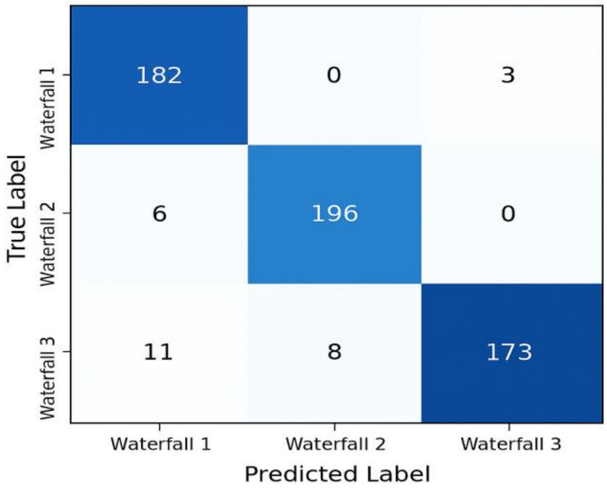

Fig. 8. Confusion Matrix for Accuracy Testing of Waterfall Images

Tested a variety of waterfall images using a large validation dataset under different conditions.

V. CONCLUSION

This research introduces an AI-powered solution for enhancing ecotourism in Sri Lanka through the *Falls Explorer with AI Assistant Sri Lanka* web application. By training a convolutional neural network from scratch, the system is capable of accurately identifying waterfalls based on image input, offering tourists a smart and interactive method to explore natural attractions. The integration of a custom-trained model with a FastAPI backend and a Node.js frontend showcases the potential of full-stack AI deployment in practical applications.

The system not only provides identification but also delivers meaningful contextual information, enhancing both accessibility and educational value. This paper demonstrates the feasibility of using lightweight, domain-specific AI in natural environments and highlights its benefits in promoting sustainable and non-invasive tourism. Future enhancements will focus on dataset expansion, offline capabilities, and the inclusion of additional natural features, such as voice features or multilingual language, to broaden the application's utility.

ABBREVIATIONS

AI - Artificial Intelligence, CNN - Convolutional Neural Network, TP -True Positive, TN – True Negative, FP – False Positive, FN – False Negative.

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