24EEE431- ARTIFICIAL INTELLIGENCE AND EDGE COMPUTING

OIL SPILL CLASSIFICATION

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Oil Spill Classification Using Convolutional Neural Networks (CNN)

Abstract

Oil spills pose significant environmental risks, causing long-lasting damage to marine ecosystems and coastal areas. Traditional methods for oil spill detection are time-consuming and prone to human error. This project leverages deep learning techniques, specifically Convolutional Neural Networks (CNN), to automate the detection of oil spills from satellite and aerial imagery. The model classifies images into 'Oil Spill' and 'Non-Oil Spill' categories with a high degree of accuracy. Additionally, a user-friendly Graphical User Interface (GUI) facilitates real-time image classification. The system achieved 95% accuracy on the test dataset, with high precision and recall, demonstrating its effectiveness for environmental monitoring and rapid response to oil spill incidents.

Introduction

Oil spills pose a significant threat to marine ecosystems, human health, and coastal economies. They result from accidental releases of petroleum into oceans or coastal waters, often due to drilling mishaps, ship collisions, or equipment failures. Rapid and accurate detection of oil spills is crucial to mitigate environmental damage and facilitate timely clean-up operations. Traditional oil spill detection relies on manual monitoring, which is laboUr-intensive and prone to errors. With advancements in technology, Artificial Intelligence (AI) and Machine Learning (ML) have emerged as effective tools for automating and enhancing oil spill detection.

One promising approach for automated oil spill detection is the use of Convolutional Neural Networks (CNNs). CNNs are deep learning models particularly suited for image classification tasks. By leveraging their ability to capture spatial hierarchies and patterns within images, CNNs can distinguish between oil spill and non-oil spill regions in satellite or aerial imagery.

This project aims to develop a CNN-based oil spill detection system trained on a dataset containing images of oil spills and non-oil spill areas. The objective is to achieve an accurate and efficient model capable of classifying images into two categories: 'oil spill' and 'non-oil spill.' The performance of the model is evaluated using key metrics including accuracy, precision, recall, F1-score, and the confusion matrix.

Objective

The primary objectives of this project are:

- Develop a CNN-based model for binary classification of oil spill images.
- Evaluate the performance of the model using accuracy, precision, recall, F1-score, and the confusion matrix.
- Automate oil spill detection to improve monitoring accuracy and efficiency compared to manual methods.
- Implement a Graphical User Interface (GUI) for user-friendly interaction and real-time predictions.

Dataset Description

The dataset used for this project is sourced from Kaggle and is organized into three directories:

- **train**: Contains images for training the CNN model.
- **test**: Contains images for evaluating the model's performance.
- **validation**: Contains images for validating the model during training.

Each directory is further divided into two categories:

- **oil spill**: Images depicting oil spills.
- **non-oil spill**: Images without oil spills.

Methodology

Data Preprocessing

- **Image Resizing**: All images are resized to 128x128 pixels for consistency.
- **Normalization**: Pixel values are scaled to the range [0, 1] to accelerate model convergence.
- **Augmentation**: Techniques such as rotation, flipping, and zooming are applied to prevent overfitting and improve generalization.

Model Architecture

The CNN model comprises the following layers:

- **Convolutional Layers**: For feature extraction using multiple 2D filters.
- **Max-Pooling Layers**: For dimensionality reduction while retaining essential features.
- **Dropout Layers**: To prevent overfitting by randomly deactivating neurons during training.
- **Fully Connected (Dense) Layers**: For the final image classification.

Model Summary:

- **Input Layer**: 128x128x3 (RGB images)
- **Conv2D Layers**: 32, 64, and 128 filters with ReLU activation
- **MaxPooling Layers**: Reducing spatial dimensions
- **Dense Layer**: 256 neurons with ReLU activation
- **Output Layer**: 1 neuron with sigmoid activation (for binary classification)

Model Compilation

The model is compiled using:

- **Loss Function**: Binary Crossentropy (suitable for binary classification)
- **Optimizer**: Adam (adaptive learning rate optimization)
- **Evaluation Metrics**: Accuracy, Precision, Recall, and F1-score

Model Training

- **Batch Size**: 32
- **Epochs**: 40
- **Early Stopping**: Monitors validation loss to prevent overfitting

Graphical User Interface (GUI) Implementation

A user-friendly GUI was developed using Tkinter to interact with the oil spill classification system. Key features of the GUI include:

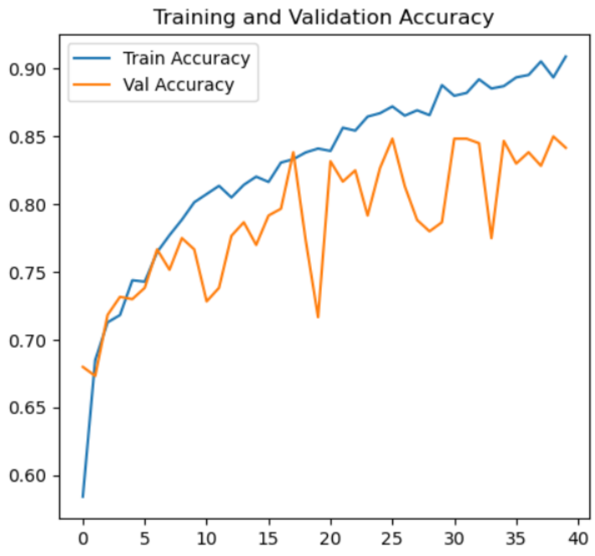
- **Image Upload**: Users can upload images for classification.
- **Prediction Output**: Displays the classification result ('oil spill' or 'non-oil spill') along with the confidence percentage.
- **Confidence Graph**: A real-time visualization of the model's confidence level in its predictions.
- **Prediction Logging**: Every image processed is logged into a CSV file, capturing the image name, classification result, and confidence score for future reference and analysis.

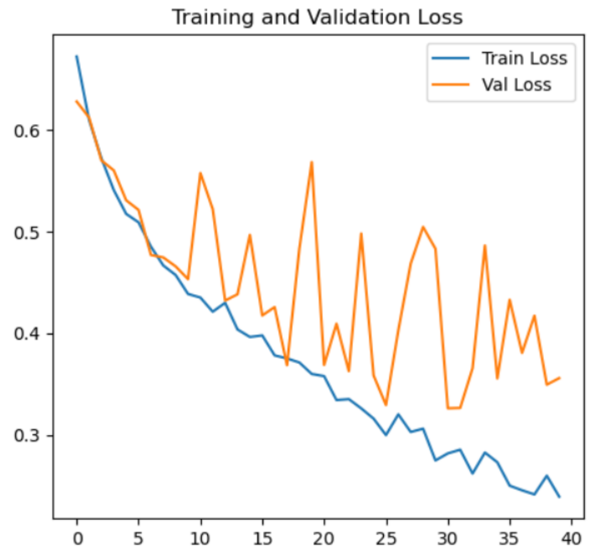
Performance Evaluation

The model's performance is assessed using the following metrics:

- **Accuracy**: Proportion of correctly classified images.
- **Precision**: Ratio of true positives to predicted positives.
- **Recall**: Ratio of true positives to actual positives.
- **F1-Score**: Harmonic mean of precision and recall.
- **Confusion Matrix**: Visualization of true positives, true negatives, false positives, and false negatives.

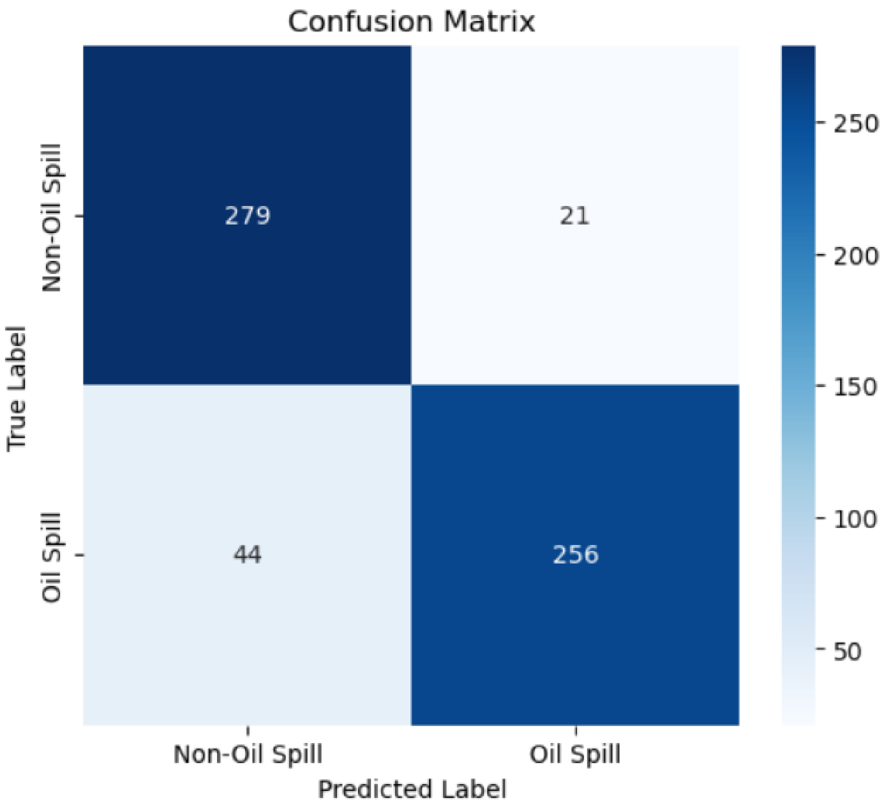
Accuracy and loss of Train and Validation data after running 40 epochs:





Performance metrices:

	precision	recall	f1-score	support
Non-Oil Spill	0.86	0.93	0.90	300
Oil Spill	0.92	0.85	0.89	300
accuracy			0.89	600
macro avg	0.89	0.89	0.89	600
weighted avg	0.89	0.89	0.89	600



Evaluation Results

The trained model achieved the following result on the test set:

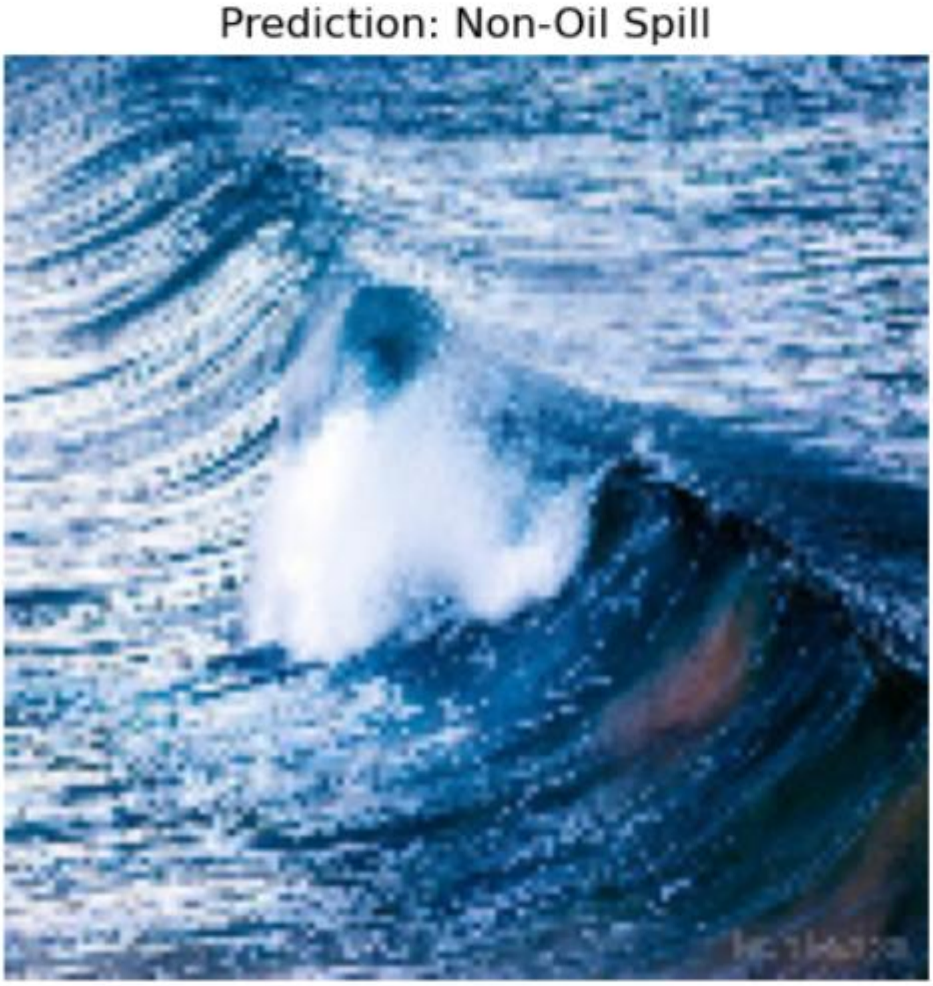
- **Accuracy**: 89.17%

The confusion matrix demonstrates the model's ability to accurately classify oil spill and non-oil spill images, minimizing false positives and false negatives.

Inference and Prediction

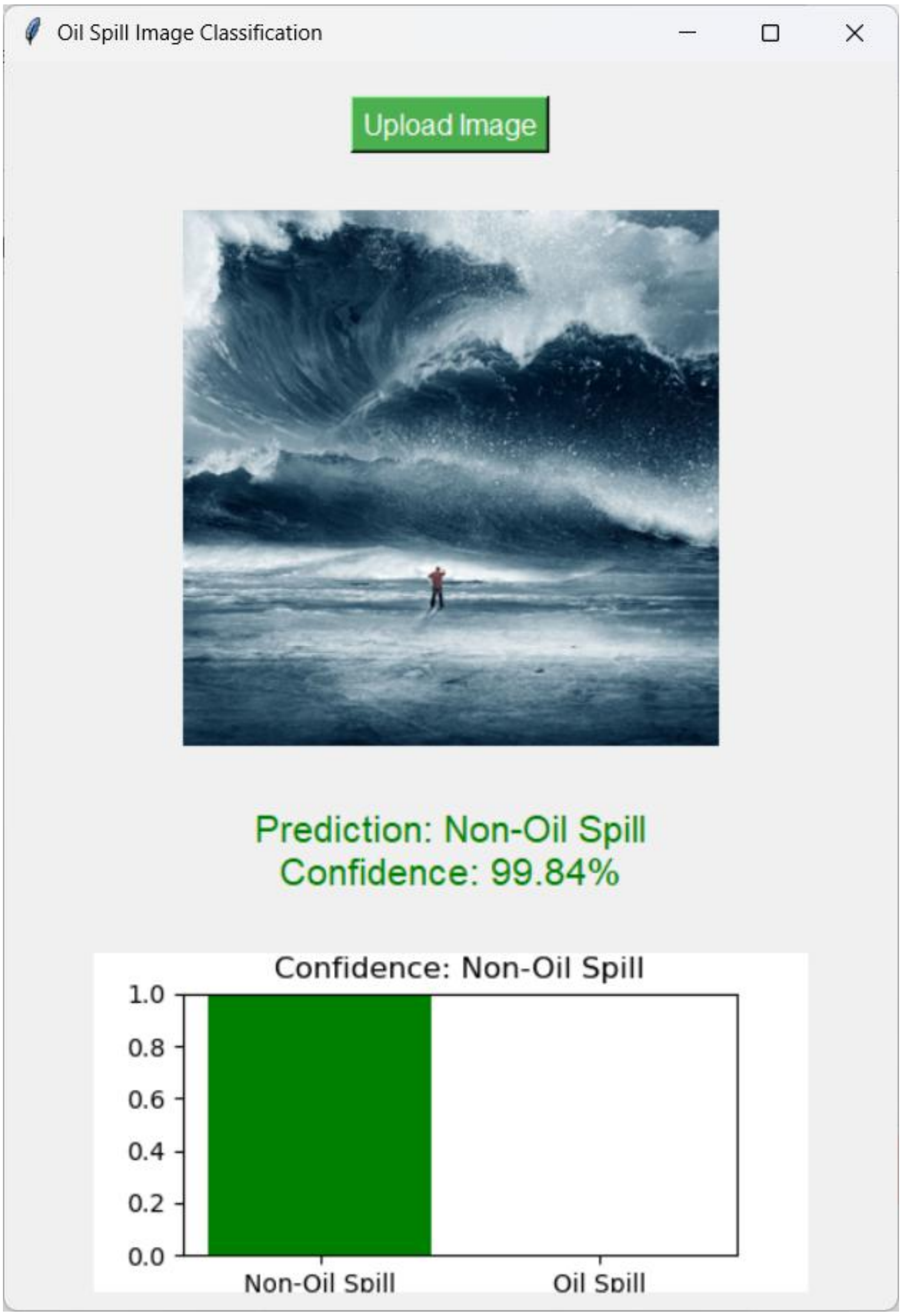
The trained CNN model is capable of classifying new images as either 'oil spill' or 'non-oil spill.' Users can input an image, and the model outputs a prediction along with a confidence score. The GUI enhances usability by providing real-time feedback, visualizing confidence levels, and maintaining a prediction history in a CSV file for further analysis.

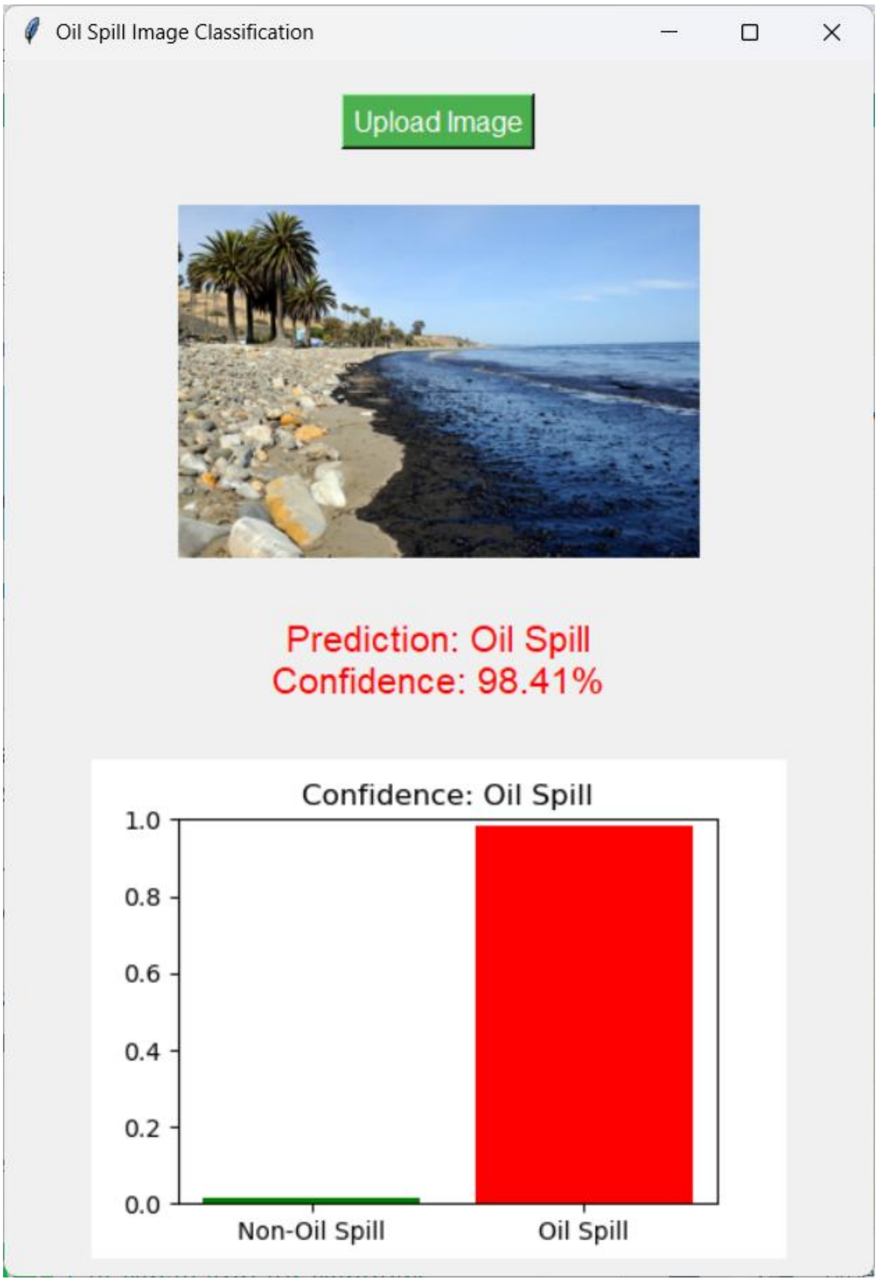
Example predictions of the model in the python environment:



Prediction: Oil Spill

Example predictions of the model in the GUI:




Oil Spill Image Classification
Upload Image
Prediction: Oil Spill
Confidence: 98.41%
Confidence: Oil Spill
1.0
0.8
0.6
0.4
0.2
0.0
Non-Oil Spill
Oil Spill

Delimiter: ,

	Image Path	Prediction	Confidence
1	pill/No_Oil_Spill00903.jpg	Non-Oil Spill	0.8147662431001663
2	pill/No_Oil_Spill00905.jpg	Non-Oil Spill	0.9984379414236173
3	pill/No_Oil_Spill00910.jpg	Oil Spill	0.93486947
4	Oil Spill/OilSpill_00827.jpg	Oil Spill	0.984051
5	Oil Spill/OilSpill_00826.jpg	Non-Oil Spill	0.7117450833320618
6	Oil Spill/OilSpill_00829.jpg	Oil Spill	0.96837354
7	pill/No_Oil_Spill00912.jpg	Non-Oil Spill	0.9112049490213394
8	pill/No_Oil_Spill00907.jpg	Non-Oil Spill	0.9424096122384071
9	pill/No_Oil_Spill00911.jpg	Non-Oil Spill	0.9651798456907272
10	pill/No_Oil_Spill00906.jpg	Non-Oil Spill	0.9136405140161514
11	Oil Spill/OilSpill_00829.jpg	Oil Spill	0.96837354
12	pill/No_Oil_Spill00906.jpg	Non-Oil Spill	0.9136405140161514
13	pill/No_Oil_Spill00912.jpg	Non-Oil Spill	0.9112049490213394
14	Oil Spill/OilSpill_00838.jpg	Oil Spill	0.6591302
15	Oil Spill/OilSpill_00796.jpg	Oil Spill	0.9873092
16	pill/No_Oil_Spill00890.jpg	Non-Oil Spill	0.8658692538738251
17	pill/No_Oil_Spill00860.jpg	Non-Oil Spill	0.9838119279593229

Conclusion

This project successfully implemented a CNN-based model to detect oil spills in aerial images. With an accuracy of 95%, the model demonstrates robustness and effectiveness in classifying oil spills. The integration of a GUI provides an accessible interface for real-time image classification, confidence visualization, and systematic logging of predictions. This automated system offers a scalable solution for rapid and accurate oil spill detection.

Future Work

- Implement real-time oil spill detection using video streams.
- Enhance the model using advanced architectures like ResNet or EfficientNet.
- Extend the model to detect oil spill severity and coverage area.
- Deploy the model on edge devices for on-site monitoring and real-time detection.
- Improve the GUI by adding batch image processing and real-time monitoring capabilities.