Oil Spill Detection

Problem Statement

Oil spills in marine environments pose significant threats to ecological systems, economic interests, human health, and maritime operations. These incidents can result in long-lasting damage to marine biodiversity, fisheries, coastal communities, and water quality. The complexity and scale of maritime operations make manual detection of such spills time-consuming and inefficient. There is a critical need for an automated, real-time system capable of detecting potential oil leaks or vessel distress events that may lead to environmental disasters.

The integration of Automatic Identification System (AIS) data and satellite-based remote sensing provides a promising solution for proactive monitoring of maritime environments. AIS offers continuous, real-time vessel tracking, while satellite imagery facilitates spatial analysis of ocean surfaces to identify oil slicks. However, the challenge lies in effectively correlating AIS anomalies with satellite observations to detect and confirm oil spill events promptly.

Objectives

The primary objective of this project is to develop an **automated oil spill detection system** that leverages AIS and satellite datasets for early identification and monitoring of potential oil leaks or vessels in distress.

1) **AIS Anomaly Detection**:
   Develop a Python-based module that continuously analyzes AIS data to detect anomalies in vessel behaviour, such as abrupt course deviations, erratic speed changes, and unexpected stops, which may indicate distress or potential oil spill scenarios.

2) **Satellite Data Integration**:
   Integrate high-resolution satellite datasets to monitor the spatial area around the detected AIS anomalies for signs of oil slicks and leaks using remote sensing techniques and image processing algorithms.

3) **Data Correlation and Spill Confirmation**:
   Implement a methodology to correlate AIS-derived distress signals with

satellite imagery to confirm the presence of oil spills, ensuring reliability and reducing false positives.

4) **Visualization and Alert System**:
    Design a user-friendly interface or dashboard to visualize vessel trajectories, detected anomalies, and confirmed oil spills, along with geospatial coordinates and timestamps.

Technical Content & Implementation

1. AIS Data Acquisition & Preprocessing

- **Input**: Real-time or historical AIS data (CSV, API, or database format).

- **Process**:

  - Parse AIS messages: MMSI, IMO, coordinates (lat, lon), speed over ground (SOG), course over ground (COG), heading, timestamp, vessel type, destination.

  - Clean and filter data (remove duplicates, invalid coordinates, missing values).

  - Time-series formatting for each vessel's trajectory.

2. Anomaly Detection in Vessel Movement

- **Goal**: Detect suspicious vessel behavior indicating distress or potential oil leak.

- **Features**:

  - Sudden speed drop

  - Sharp turn or erratic movement

  - Sudden stop

  - Long idle time in open sea

- **Output**: Flagged anomaly coordinates (lat, lon) and timestamp.

3. Satellite Data Retrieval & Processing

- **Input**: Coordinates and timestamps from anomaly detection.

- **Source**: Sentinel-1 SAR (Synthetic Aperture Radar) or Sentinel-2 optical datasets (open-source via Copernicus, Earth Engine, etc.).

- **Process**:

- o Download or access SAR/optical images for the flagged area and time.
- o Preprocess images (noise removal, radiometric correction, land masking).
- o Extract potential oil spill patterns (dark spots on SAR or discoloration on optical images).

4. Oil Spill Detection in Satellite Imagery

- **Techniques**:
  - o Image classification (unsupervised/supervised)
  - o Edge detection
  - o Thresholding
- **AI/ML Option**:
  - o Train model to differentiate oil spills vs. normal water patterns using labeled data.
- **Output**: Confirmed spill area, location, timestamp, and affected zone.

5. Correlation and Decision Module

- Match AIS anomalies with detected oil slicks from satellite images.
- If correlation threshold met, confirm oil spill and issue alert.

6. Visualization & Alert System

Build a GUI/dashboard.

Show:

- o Vessel movements
- o Anomalies
- o Satellite overlays of spills
- o Spill metadata (vessel ID, coordinates, time, extent)
- Send alerts to regulatory authorities (email, SMS, API endpoint).

➢ Tools & Technologies

Programming & Environment

Python – Core programming language

Jupyter Notebook– Development environment

Data Sources

AIS Data: historical AIS CSVs

Satellite Data: **Sentinel-1 SAR**: via Copernicus Open Access Hub

> ➢ Algorithms to be Used

Anomaly Detection

- **Isolation Forest** (for detecting outliers in speed/course)

Oil Spill Detection from Satellite

- **SAR Image Thresholding** (Otsu's Method for dark spot detection)

- **Supervised Classification**

  - Random Forest / XGBoost / CNN