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IoT and Machine Learning Enhanced Techniques for Early Ocean Pollutant Detection and Tracking Systems

Miquel Massot-Campos, Ayodeji O. Abioye, Loitongbam Gyanendro Singh, Arturo Vazquez-Galvez, Yan Wu and Henrik T. Sykora
University of Southampton, United Kingdom
{a.o.abioye, gyanendro.loitongbam, miquel.massot-campos, h.t.sykora, a.vazquez-galvez, yan.wu}@soton.ac.uk

Extended Abstract

Pollution in water bodies such as rivers, ports, and estuaries often go unnoticed until its detrimental effects become evident. This delayed response contrasts with the more immediate detection methods available in urban air quality monitoring. The environmental impact in less populated regions, crucial for local economies reliant on natural resources, can be long-lasting and devastating [1-2]. This study introduces a sophisticated method for promptly detecting pollution and identifying its sources in aquatic environments. The method combines Internet-of-Things (IoT) technology with advanced machine learning techniques. We employ a network of IoT devices equipped with Long Range (LoRa) radio transceiver modules, covering a range of 15-20km. These devices, designed to be either stationary (buoys) or mobile (shipborne), are outfitted with sensors to monitor air and water quality. Through a customized printed circuit board design integrating the sensors and microcontroller, an initial prototype has been developed to gather water quality data and transmit it to the cloud via the IoT infrastructure for analysis. Data from these sensors are wirelessly transmitted to a central hub, which uploads it to the cloud in real-time. Our sensors track a range of pollutants, such as volatile organic compounds, carbon dioxide, particulates in air, and waterborne substances like dissolved oxygen and hydrocarbons. Utilizing this data, we can spot unusual environmental changes and trace back to potential pollution sources, like ships. This process is enhanced by integrating data from Automatic Identification Systems (AIS) with our sensor data, including air and water current data [3].

Building on this foundation, to quantify and trace the pollution dispersion from potential sources, at the current stage of this study, we employ a physics-informed machine learning (PIML) approach. This PIML method has two key steps that involve initial pollution dispersion modelling from source candidates followed by adjustment of the model to align with the sensor data. We simplify the complex interaction between pollutant dispersion and environmental factors, assuming homogenous and isotropic pollutant diffusivity, and constant laminar wind/current velocity [4]. In addition to PIML, we use a traditional feature-based machine learning approach to categorize sensor data into 'pollutant' or 'non-pollutant' classes based on predefined expert thresholds. This categorization is then compared with AIS data to pinpoint passing vessels as potential pollution sources. This streamlined approach focuses on vessels that repeatedly appear in polluted areas allows for more accurate identification and reduces the resources needed for monitoring. The integration of IoT technology with machine learning provides a robust framework for real-time environmental surveillance. This approach allows for the efficient identification of pollution sources, contributing significantly to the preservation and protection of aquatic ecosystems. These experiments were conducted in a controlled simulated environment. Future work will integrate data collected with a prototype in real-world scenarios.

This study introduces a significant advancement in environmental monitoring by integrating cost-effective IoT technology with machine learning to identify and track pollution sources in aquatic environments efficiently. With its lightweight and affordable approach, this method enables early detection and efficient source identification, promising to enhance environmental protection efforts and supporting sustainable management of natural resources, marking a crucial step forward in ecological conservation efforts.

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