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Urban Digital Twins for Adaptive Water Quality Monitoring in Smart Cities: A Robotics-Based Approach

Umar Alfa[1], Auwal Shehu Tijjani[1], Raymond Houe Ngouna[2], Luc Fabresse[1], Eric Duviella[1]

[1] IMT Nord Europe, Institut Mines-Télécom, Univ. Lille, Centre for Digital Systems, F-59000, Lille, France,

email: {umar.alfa, auwal.shehu, luc.fabresse, eric.duviella}@imt-nord-europe.fr

[2] École Nationale d'Ingénieurs de Tarbes (ENIT), Tarbes, France

email: raymond.houe-ngouna@enit.fr

Abstract

Urban water resources are increasingly at risk due to pollution, climate change, and rapid urban growth. Consequently, adaptive management of water quality is crucial for maintaining ecological health in urban planning. This research work presents an innovative approach that integrates a Surface Aquatic Drone (SAD) with Urban Digital Twins (UDTs) to facilitate real-time water quality monitoring in advanced smart cities. The proposed system integrates a sensor-equipped SAD, a modular communication layer, and a UDT platform into a cohesive framework for dynamic visualization and predictive modeling of water quality data. A machine learning-based approach is used for detecting anomalies and forecasting trends. An adaptive remediation loop is triggered in response to identified pollution incidents to ensure prompt action. Technically, the system architecture utilizes open-source tools like ROS, Gazebo, and OpenFOAM to improve modularity, scalability, and sustainability. This method offers a cost-effective and intelligent solution for managing urban water systems under increasing ecological stress. This initiative is part of the CPER ECRIN/CAP'Eau regional project, supported by the Hauts-de-France Region, which seeks to develop innovative tools for monitoring and preserving water resources in the face of climate change.