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# An Open-Source Platform for Deploying Operational Digital Twins in Water Resource Recovery Facilities (WRRFs).

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**Abstract:** The use of digital twins (DTs) in Water Resource Recovery Facilities (WRRFs) has grown significantly in recent years. Most commercially available WRRF simulators are evolving from static input-output models to systems where the simulator inputs are obtained real-time from online sensors. While commercial DT platforms often provide comprehensive systems with seamlessly integrated components, open-source solutions lack this level of cohesion. Although components such as process models, calibration algorithms, industrial IoT (IIoT) connectors, database management systems, and interactive user interfaces are available in open-source environments, these elements are not fully aligned in existing frameworks. This work introduces the development of an open platform specifically for creating operational digital twins tailored to WRRFs. The framework will integrate several open-source components and is fully integrated with a library of sensor connectivity protocols, process models for WRRF operations, and web-widgets for designing an interactive user interface. A use case is presented to demonstrate the feasibility and effectiveness of this framework in developing operational digital twins for WRRF operations.

**Keywords**: digital twins; open framework; industry 4.0

## 1. Introduction

The rapid growth of online monitoring, low-cost telemetry devices, and advancements in data-driven-machine-learned (ML) modelling techniques have brought forth a digital transformation in the water sector. Technologies such as big data, Industrial Internet of Things (IIoT), and Artificial Intelligence (AI) are increasingly being adopted, enabling the creation of operational Digital Twins (DTs) that replicate the conditions of WRRF's. Operational DTs have a wide range of applications, including real-time monitoring, optimal control, predictive maintenance, and decision support systems, as highlighted in the literature [1]. These tools provide real-time insights to help operators maintain plant efficiency, ensure regulatory compliance, and achieve sustainability targets [2].

Several commercially available WRRF simulators (e.g., SUMO, TwinPlant) now integrate real-time operational data into process models using data connectors and recursive model update systems. While mathematical models for WRRF processes are commonly implemented in proprietary software like MATLAB, Hydromatics, and WEST, similar functionalities are available in open-source platforms like Modelica, Julia, and STOAT. Communication protocols enabling the connection of these model inputs to real-time data from online sensors are also available in open-source device connectivity suites [3]. Additionally, programming languages such as Python offers several free libraries that can preprocess and consolidate streaming data and can provide training algorithm for model recalibration. Front-end frameworks such as Flask or Dash provide intuitive interfaces for visualizing real-time sensor data, WRRF layouts, and simulation outputs and inputs callback to interacts with the model in the backend.

Despite these advantages, open-source systems often lack the cohesion needed to integrate these components into a unified DT platform [4], [5]. This work proposes an open-source framework that facilitates the development, training, and deployment of operational DTs for WRRFs, leveraging readily available open-source tools and technologies. In this work we made one such attempt to develop a framework which facilitates the development, training, and deployment of operational digital twins entirely using open-source components.

## 2. Materials and Methods

A simplified architecture of the proposed open-source DT framework is illustrated in Figure 1.1. The platform integrates the key components to enable real-time simulation, data management, dynamic model update, and interactive visualization.

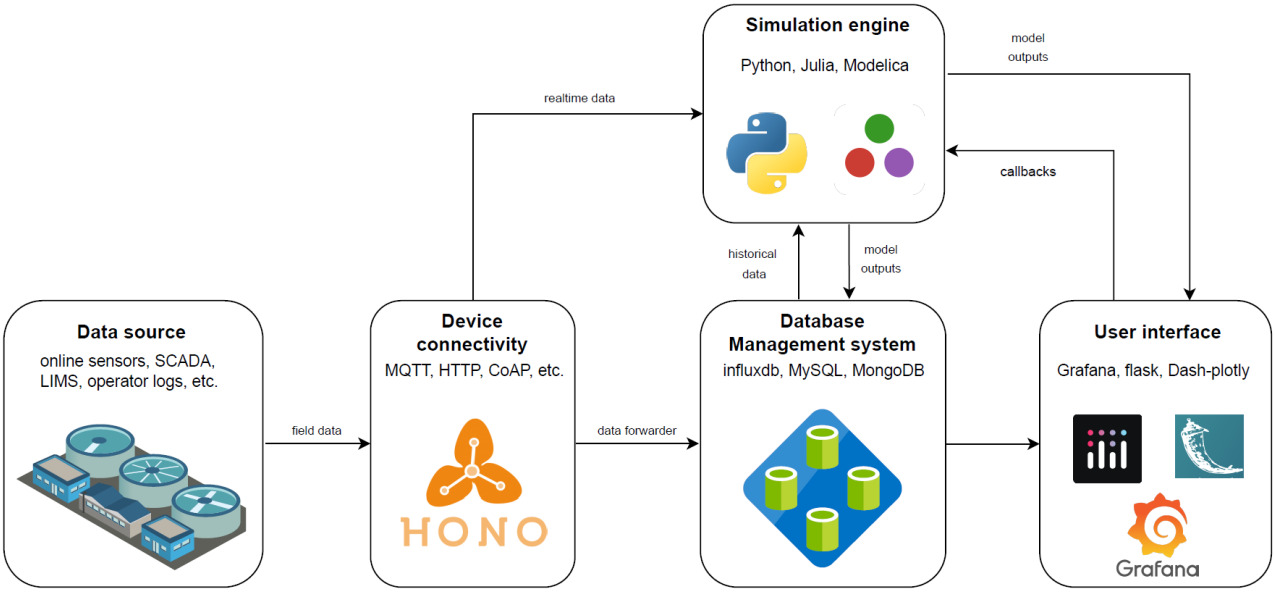


**Figure 1.1 A simplified architecture of the proposed operational digital twin framework.**

The submodules necessary for the function of the operational DT are as follows.

*Simulation engine*
The open-source programming language Python is used to simulate various processes in WRRF operations. A free library provided by EWAG, called PeePyPoo [6], is utilized for simulating WRRF processes effectively.

*IoT Connectivity*
Eclipse Hono [7] acts as the IoT middleware, securely collecting real-time data from a multitude of online sensors, WRRF's SCADA systems, LIMS, and operator logs through various communication protocols. It bridges physical devices and other data sources with the DT, forwarding data to the simulation models and an internally hosted local database for storage and analysis.

*Data Management*
MongoDB [8] serves as the database, storing both historical and real-time data. It efficiently handles large-scale data streams, enabling quick queries for real-time model predictions and supporting long-term analysis.

*Interactive Visualization*
Plotly Dash [9] provides a user-friendly interface for operators to interact with the DT. The dashboards visualize real-time sensor data, simulation outputs, and key performance indicators (KPIs). They also allow operators to modify parameters, explore "what-if" scenarios, and optimize plant operations seamlessly.

Real-time data from the WRRF is collected via Eclipse Hono and forwarded to both MongoDB and the simulation engine. The simulation engine processes the data and generates real-time predictions, which are displayed through Dash. This seamless integration of components ensures actionable insights and the ability to run various operational scenarios. This capability fosters improved operator interaction, enabling better WRRF performance and informed decision-making. By leveraging open-source technologies, the framework not only bridges the gap between standalone tools to create a unified, scalable system but also fosters a sense of ownership among developers contributing to its evolution.

Work is underway to deploy the system in a real WRRF and further results and analysis shall be presented in the draft article with submission of full paper.

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