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Smart predictive digital twin in multiservice architecture for water supply systems

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Abstract: Water supply systems (WSS) are essential infrastructures that ensures reliable and safe distribution of water. An important feature of these systems is the implementation of efficient pump scheduling operations that minimize energy costs, while respecting the network's constraints (e.g., water tank levels, minimum pressures). An optimal predictive control requires an accurate representation of the system, which can be achieved by using a digital replica (i.e., a digital twin) which allows simulating or forecasting the system's states. For an effective and efficient pump control, the system needs to be able to integrate data streams from several sources, such as sensors and prediction models, driving the design of service-based frameworks. The original contribution of this work is to present a multiservice framework that aggregates data from several sources, and a smart predictive digital twin for pump scheduling. The developed system assesses the performance of each service and its corresponding contribution to the overall system's performance.

Keywords: Digital Twins, Water Supply Systems, Forecasting, Multiservice Frameworks, Model Predictive Control, Machine Learning

1 Introduction

Recently, virtual representations of physical systems, commonly known as Digital Twins, have emerged as powerful tools in a multitude of disciplines that require emulation of complex real-world systems. In the field of Water Supply Systems (WSS) several studies have been made on the implementation of Digital twins, for example, for the prediction of infrastructure performance [1], water leakage control [2]. In regard to WSS, Digital Twins could be combined with optimal control techniques, such as model predictive control, for the execution of pump scheduling. Due to the nature of existing WSS, real-time processing is considered to be in the order of minutes, which makes model predictive control a suitable option. In addition to the control paradigm, WSS increase the complexity of the problem by the need of integrating multiple sources of information that need to be processed. SCADA or simlar technologies are often used for handling the streaming of data from several sensors throughout the water system network. Designing a framework that handles large amounts of information (big data), and ensures data interoperability, impacts factors such as scalability, observability, and cost, as discussed in [3]. In addition to sensor data, the system could incorporate data from prediction models, such as forecasts of water demand, energy cost,

and weather. This culminates in the design of multiservice frameworks, in which the system uses several modules that function independently, but work towards the same goals.

2 Proposed solution

This research presents a smart predictive digital twin integrated in a multiservice architecture that aggregates data from several sources (sensors and model outputs), and manages pump controls, minimizing costs. The proposed system is implemented in a real-time context and the predictive digital twin (which will be a machine learning model) is trained with simulated data (from EPANET software [4]) representing the real-world physical system. The system deploys models that predict water demand in each water junction, power cost, and the digital twin itself which uses the previous data to forecast tank levels, and energy used by pumps.

3 Conclusion

The developed multiservice system is capable of scheduling efficient pump controls that minimize energy costs, while respecting the WSS's constraints. Data management in services facilitates an independent evaluation of each model's performance. It also makes it possible to monitor the impact of each module on the overall system performance. This consequently helps in optimal resource and time allocation during development of each component.

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