Real-world application of the dual model for model-based leak localization

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Topic: Leak detection technologies, strategies, equipment

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Brief abstract summary: (Limit – Max 100 words)

We introduce a dual modeling approach that is able to detect and locate leaks reliably by analyzing telemetry data from pressure and flow sensors of district metered areas (DMAs). The superiority of this approach to conventional model-based leak detection and localization algorithms arises from a transformation of pressure signals into virtual leak flows, which magnifies and localizes leak responses of pressure sensors. The dual model is applied on data from a DMA, where artificial leaks with small flow rates are created on various positions in the system by marginally opening fire hydrants.

Keywords: water distribution networks, leak sensitivity, hydraulic modeling

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One of the main challenges for Europe's water utilities is detecting and finding leaks in their aging water distribution networks since almost a quarter of treated water is lost before reaching the customer (EurEau, 2017). In addition to reducing financial costs in non-revenue water, early detection and management of leaks are critical to mitigate deterioration of pipes and surrounding infrastructure by preventing small leaks from turning into large pipe bursts (Gupta & Kulat, 2018).

Modern water utilities use model-based approaches to detect and locate leaks by analyzing telemetry data from pressure and flow sensors and combining this information with hydraulic models to find leaks in near-real-time (Perez et al., 2014). One of the main challenges for these model-based approaches is that the hydraulic models, as well as the measurements, are fraught with uncertainties (Hutton et al., 2012); and these uncertainties can be magnitudes higher than the leak signals, making a fast detection and an accurate localization almost impossible.

Recently, we developed a new duality-based approach to improve the sensitivity of the localization process to smaller leaks by formulating a dual network model. We translate pressure heads to virtual leakage outflows through a mathematical trick by adding virtual reservoirs and valves (Steffelbauer et al., 2020). This approach magnifies the leak signal in pressure measurements and provides a first estimate for the leak's size and location in the network. Analytical derivations of sensitivities with respect to these virtual leak flows are calculated, and used to estimate the leakage impulse responses at candidate nodes to locate the leaks. The dual model already proved to be superior to commonly used leak localization methods on a simulated benchmark water distribution system by winning the "Battle of the Leak Detection and Isolation Methods" in 2020 (https://battledim.ucy.ac.cy) (Vrachimis et al., 2020). However, the method has never been tested on real leaks.

We apply the dual model to detect and locate leaks on an actual district metered area (DMA) for the first time. The DMA is located in a rural area in the surroundings of the city of Graz (Austria), supplies around 2000 customers with an average total demand of 3.6 L/s through a single tank, and consists mainly of PE and PVC pipes with a total pipe length of 16.2 km (including household connections). An ultrasonic flow meter measures the inflow, and twelve additional pressure sensors are installed throughout the system. Artificial leakage scenarios are created on various positions in the system by slightly opening fire hydrants, producing different leak flow rates from 0.25 to 1.0 L/s. The hydraulic model is calibrated for demands and roughnesses and transformed into a dual model. Subsequently, the dual model is used to detect and locate the artificial leaks in the system.

The benefits and limitations of the dual model approach are investigated within this work and benchmarked against conventional model-based leak localization algorithms. Furthermore, we discuss how the dual model can help to improve optimal sensor placement algorithms (Steffelbauer & Fuchs-Hanusch, 2016).

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