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Design of database systems for optimized spatio-temporal querying to facilitate monitoring, analysing and forecasting in the "Internet of Water"

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Monitoring, analysing and forecasting water-systems, such as rivers, lakes and seas, is an essential part of the tasks for an environmental agency or government. In the region of Flanders, in Belgium, different organisations have united to create the "Internet of Water" (IoW). During this project, 2500 wireless water-quality sensors will be deployed in rivers, canals and lakes all over Flanders. This network of sensors will support a more accurate management of water systems by feeding real-time data. Applications include monitoring real-time water-flows, automated warnings and notifications to appropriate organisations, tracing pollution and the prediction of salinisation.

Despite the diversity of these applications, they mostly rely on a correct spatial representation and fast querying of the flow path: where does water flow to, where can the water come from, and when does the water pass at certain locations? In the specific case of Flanders, the human-influenced landscape provides additional complexity with rivers, channels, barriers and even cycles. Numerous models and systems exist that are able to answer the above questions, even very precisely, but they often lack the ability to produce the results quickly enough for real-time applicability that is required in the IoW. Moreover, the rigid data representation makes it impossible to integrate new data sources and data types, especially in the IoW, where the data originates from vastly different backgrounds.

In this research, we focus on the performance of spatio-temporal queries taking into account the spatial configuration of a strongly human-influenced water system and the real-time acquisition and processing of sensor data. The use of graph-database systems is compared with relational-database systems to store topologies and execute recursive path-tracing queries. Not only storing and querying are taken into account, but also the creation and updating of the topologies are an essential part. Moreover, the advantages of a hybrid approach that integrates the graph-based databases for spatial topologies with relational databases for temporal and water-system attributes are investigated. The fast querying of both upstream and downstream flow-path information is of great use in various applications (e.g., pollution tracking, alerting, relating sensor signals, ...). By adding a wrapper library and creating a standardised result graph representation,

the complexity is abstracted away from the individual applications.