Data-driven methods in application to flood defence systems monitoring and analysis

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Summary

Modern society fully depends on properly functioning energy, communication and other types of systems. Natural or technological hazards can cause great losses if these systems are functioning improperly. Condition monitoring of objects protecting us from possible hazards becomes nowadays more and more important problem.

The problem of the flood defence structures condition monitoring is considered in this thesis. Analysis of levee behaviour using the measurements collected from the sensors installed inside the dams provides the early warning indicators. Available time before the possible levee collapse can be used for mitigation of possible effects of the flood. The goal of this work was to make a new step in investigation of the concepts of levee condition monitoring for providing on-line alerting. We developed a data-driven approach for levee condition monitoring.

Data-driven methods require high-quality of input data. The discovered issues (e.g., gaps, asynchronous measurements) required application of the specific pre-processing procedures that increased quality of data.

The main problem in application of data-driven methods for condition monitoring is absence of patterns of levee failures. In this case we evaluate deviation of the new gathered measurements from the historical as an anomaly. We formulated the problem of flood defence structures monitoring as the anomaly detection task.

We tested the developed approach in application to the several real-world levees. The results of non-destructive experiments analysis showed operability of the anomaly detection approach. The event of the real levee leakage was successfully detected. The developed data-driven approach was implemented as a component of the UrbanFlood early warning system.

Combination of this approach with the computationally heavy (not applicable for on-line monitoring) physical model was considered. The goal of detection of the artificially generated anomaly was successfully achieved.

Further testing was carried out during the full-scale dike failure experiment (All-in-One Sensor Validation Test) organised by the ILkdijk foundation. Combination of the data-driven methods with physical modelling provided early generation of the warning signals. The physical model generated expected behaviour of the sensors. Deviation of real sensor values from the expected behaviour was interpreted as the anomaly.

We demonstrated that it is possible to monitor the levee behaviour using the data-driven models independently and in combination with physical modelling. The developed approach can be used by the domain experts as an alerting tool in order to reduce time for decision making.