Probabilistic identification of water pipe network failure

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Introduction
Water is an indispensable resource for the daily needs of our society. Water pipe systems assure its supply to numerous destinations. However, these systems are complex, spatially distributed and cannot be fully monitored. There is a severe lack of information on pipe network properties, boundary values and parameters for describing the water flow inside the system, leading to bias and uncertainties in predictions. Unfortunately, water pipe systems have an inherent susceptibility to failures, which lead to water losses. The identification of a failure in a water pipe system is a challenging task, because the available methods are limited and there is no single tool that combines the relevant available information. The inability to deliver clear support in maintenance and repair scheduling implies growing maintenance costs. Thus, developing an adequate stochastic approach for uncertainty quantification of the system is pressing. It should assure a high probability of failure identification at acceptable computational costs.

Research environment
This project would be embedded within the research network of the SimTech cluster of Excellence (EXC310/1) and its permanent foundation, the Stuttgart Centre for Simulation Technology (www.simtech.uni-stuttgart.de). Additionally, SimTech has a parallel high-performance computing cluster which we plan to use during the work. The local network is complemented by the international research training group "Non-linearities and upscaling in porous media" (NUPUS, DFG IRTG 1398) and its strong international network (see www.nupus.uni-stuttgart.de, www.interpore.org). Due to the nature of the project, we plan to cooperate with the Water Services of TÜV SÜD Asia Pacific Company which have strong interest in water pipe systems. Overall, the current project will benefit from the exchange of experience and codes among the partners, and the in-house collaboration. Altogether this constitutes a critical mass to work on this problem.

Research goals
This proposal aims to develop a reliable tool for a probabilistic assessment of the state of pipelines, with the ability to confidently localize failures and estimate their severity under incomplete knowledge system. During the last years, a trend towards a statistical inference has been observed, but there has been no attempts to create a model that fuses soft and hard data (such as regression-type data and hydraulic simulation-based data). In the current
project we will introduce Bayesian statistical principles that will account for the scarcity of information in the pipeline networks and incorporate diverse information sources to improve accuracy of failure identification. This work will be the first attempt to combine all available sources of useful information into a single unified framework. We expect to improve the decision support process in water pipe systems, reducing the risks of taking inappropriate actions and consequently, reducing the losses of a scarce resource: drinking water.

Methods to be used
We suggest to perform a probabilistic identification of water pipe network failure via a combination of Bayesian principles for uncertainty quantification with hydraulic simulation. We target to establish a Bayesian Belief Network for each segment of the pipe system that will provide the probabilities for the segment to have a leakage of water. The suggested approach will join soft data and hard data into one modeling framework. The hydraulic testing results combined with hydraulic simulation models will provide the hard data which is usually unprecise due to a limited control of the test. Additionally, available soft data such as age of pipes, geographical information system, etc. will be taken into consideration. Thus the available sources of knowledge will be joined into one Bayesian framework. In scenarios, data availability will be analyzed in order to assess understand the utility of individual data types and data amounts.

References

Prerequisites
• Knowledge of fluid mechanics and pipe flow
• Affinity with numerical simulations, statistics and programming
• Willingness to learn German up to fluent level