Modelling, Simulation, Visualization and Decision Support for *UrbanFlood* Early Warning System

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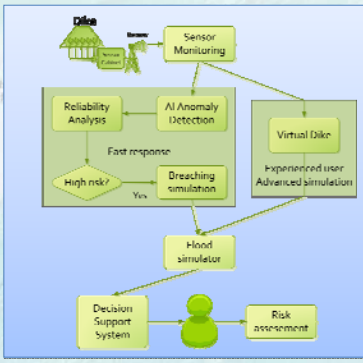
Introduction

UrbanFlood FP7 project develops an Early Warning System (EWS) for reducing flood risk. The EWS detects alarming conditions, predicts the onset of dike damage and provides real-time information to a Decision Support System (DSS) during a catastrophic event. Modelling, simulation and visualization plays a crucial role in the DSS. We present a cascade of models developed for scenario-based predictions of dike failure, inundation and damage assessment. Simulation and visualization components are integrated into an interactive graphical environment that helps making informed decisions in case of emergency and in routine dike quality assessment.

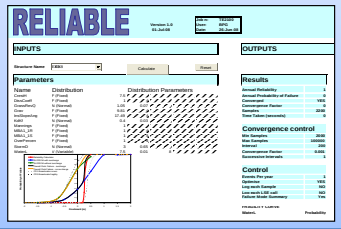


Modelling workflow

UrbanFlood Early Warning System consists of a number of components. A 'Sensor Monitoring' component receives sensor data from the dike. Raw sensor data is filtered by an 'AI Anomaly Detector' that detects abnormalities or sensor failure. A 'Reliability Analysis' module calculates the probability of dike failure. If there is a high risk of failure a 'Breaching Simulator' calculates the dynamics of a possible breach, including the amount of water that can go through the dike and an approximate flooding time. After that the 'Flood simulator' is invoked which predicts the inundation dynamics. The simulation results are visualized on a Decision Support System (DSS) that helps decision-makers in making informed decisions in an effort to minimize damage in the case of emergencies. For the advanced simulations and experienced users the 'Virtual Dike' component is available. It can provide more fundamental and accurate simulations but requires more time.

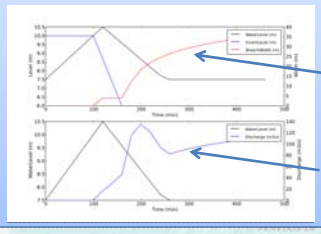
Dike Reliability analysis

Calculates the failure probability of a dike, based on the real-time sensor data for water level at the sea-side of the dike. The tool implements a set of possible failure models developed by the HRW experts.



Dike Breaching simulation

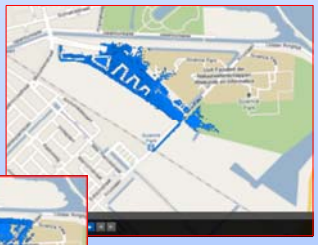
Given a predicted water level, the 'Breaching Simulation' model calculates the amount of water flowing through a breach into an inundated area.



Flood simulation

Given a set of locations where a breach has occurred and given the amount of water that flows through each of these locations, the 'Flood Simulator' model calculates the water level of inundated areas over time after the breach occurred. The Flood Simulator uses a Digital Terrain Model (DTM) that describes the elevation of the topography at the area selected for simulation, in this case the Amsterdam Watergraafsmeer area. The DTM is pre-processed into a simulation grid consisting of Inundation Zones (IZ). The output of an inundation simulation contains the time series of water level and discharge velocities in all IZ. The simulation output data can be visualised either on a web page or on a Microsoft Surface where it can be interactively explored using its multi-touch interaction capabilities.

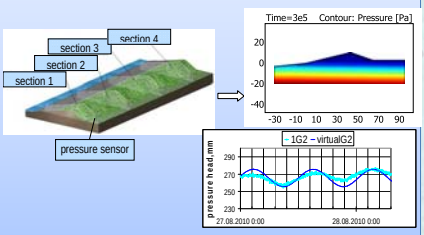
Simulated flood in the Amsterdam Science Park (Watergraafsmeer area)



Interactive exploration of the flooded area on a multi-touch table

Virtual Dike

The 'Virtual Dike' model is an advanced multi-scale multi-model simulation lab for expert users and model developers. It is used for validation of all the models involved in the modelling cascade and serves as a research field for experiment planning and understanding the underlying physical processes influencing dike stability and failure. Real-life experiments are used to develop and validate the models of dike macro-stability, erosion, wave over-topping, seepage and piping effects. Comparison of simulation results with the experimental data allows determining the material properties and computational model parameters that best represent real-life dikes, with all their inhomogeneities and special features.



Decision Support System

Decision Support System assists in making informed decisions in case of emergencies and in daily dike quality assessment. The system includes several simulation modules and visualization components that are integrated into one interactive graphical environment.

Implementation

The Early Warning System (EWS) components have been wrapped as plug-ins and integrated in the *UrbanFlood* Common Information Space (CIS). CIS is a generic framework for creating and hosting EWS systems.

The Early Warning System components are deployed on Virtual Machines. That means they could be easily copied or moved to other Virtual Machine services or Cloud computing services. We have already ported the Virtual Dike, the Breaching simulation and Flood Simulator components to the SARA Clouds.

Future work

- Development of a web-based interface to the Decision Support System that will provide added flexibility and convenience to stakeholders and public authorities;
- Flood simulations for the 2 new areas: Amsterdam Gaasperplas and Eemshaven LiveDike;

For the Virtual Dike:

- 3D simulation of the LiveDike structure;
- Modeling different failure mechanisms based on the IjkDijk experiments;
- Prediction of sensor data dynamics based on external data (seasonal changes in tides, meteorological forecasts);
- Integration of the Virtual Dike into the Common Information Space.

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