An operational Digital Twin for the drainage system and natural waters in the city of Hanover

Un jumeau numérique opérationnel du réseau d'assainissement et des eaux naturels à Hanovre

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RÉSUMÉ

Dans le cadre du projet collaboratif « ZwillE », financé par le Ministère Fédéral allemand de la Recherche, de Technologie et de l'Espace (BMFTR), un jumeau numérique de la ville de Hanovre a été développé, donnant une image virtuelle du réseau d'assainissement et, sur cette base, de fournir des mesures et des recommandations d'action en cas d'événements pluvieux extrêmes. Nous présentons les éléments constituant la plateforme d'accès aux informations actuelles et prévues relatives aux domaines de la pluie mesurée par radar, du réseau d'assainissement des inondations en surface et des eaux naturelles en rivière. Les résultats des simulations donneront comme conséquences des recommandations pour des mesures à prendre par les opérateurs du système.

ABSTRACT

In the joint project « ZwillE », funded by the Federal Ministry of Research, Technology and Space (BMFTR), a digital twin for the city of Hanover has been developed, providing a virtual image of the drainage system, and, based on this, providing measures and recommendations for action in the case of extreme rain events.

We present the elements which constitute the user access platform providing an overview over the current and immediate future situation in the domains of radar-based precipitation, of sewer system, of surface flooding and of natural water bodies, mainly rivers. Consequences of these results are formulated as recommendations to the municipal staff.

KEYWORDS

Digital twin, precipitation extremes, visualisation, radar nowcasts, inundation forecasts

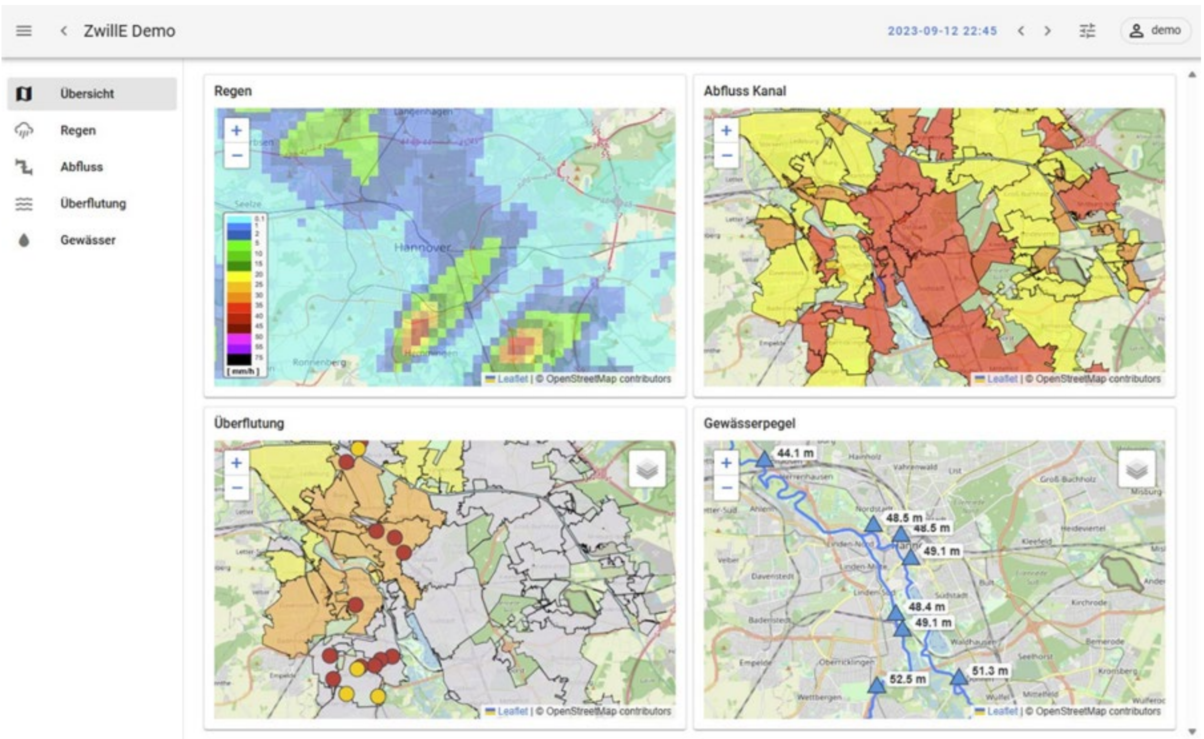
1 INTRODUCTION

A digital twin has been developed for the city of Hanover giving an integrated view of the current state of the drainage infrastructure with sewer system and sewage treatment plants. It includes measurements in real-time as well as simulation models and forecasts based on precipitation forecasts, providing the basis for an anticipatory scenario analysis as well as a proactive handling of extreme precipitation events. The digital twin also proposes actions to the operational staff during rainfall events, for example to reduce flood damage or combined sewer overflows.

2 OVERVIEW

The visualisation of the digital twin results is presented with GIS tools on maps for the current state and for the near-future state of the system. Thus, the operating staff in the control room directly sees the consequences of the rainfall situation in the different sectors of the draining system: (a) the current and future loading situation in the sewer system with pumps and waste water treatment plant, (b) the consequences on surface flooding of the current and future precipitation situation, highlighting the situation at critical infrastructure, (c) the situation in the rivers Leine and Ihme concerning quantity and quality including the expected overflows from rainwater and combined sewers. Finally, action items are proposed to the staff to better manage the current and immediate future precipitation event. For example, actions can be the traffic interdiction for underpasses which might flood, or the implementation of local flood barriers.

For the development of the digital twin, care was taken to create a tool with a high degree of transfer potential to other municipalities as well as a very transparent approach to data visualisation. Therefore, the adaptation workload for a transfer to other locations should be moderate. Important are in such cases the early definition of requirements for the critical infrastructure, the organisational and legal management of the potentially available measurement data as well as sewer system data along with the corresponding simulation models.



The basic user interface of the digital twin for Hanover. Copyright: ZwillE-Konsortium

3 VISUALISATION

Visualisation is playing a major role for the operational staff of the city: only the important items shall require consideration. Therefore, the top-level visualisation of the digital twin comprises of four map views which give an overview of the main four topics as well as the entry point to a more detailed map view for thorough analysis of the situation:

- The current precipitation situation with a forecast for the upcoming two hours (upper left)
- The sewer system with its current flow situation and the loading expected with the forecast precipitation (upper right)
- The surface flooding situation in the different municipal quarters including critical areas (lower left), and
- The situation in the rivers Leine and Ihme for the current time

For each of the maps, areas with increased risk or proposed actions are highlighted, important locations can be accessed at single dots and more detailed maps can be accessed by a double click. Colours in red or orange on the sewer map and the surface flooding map indicate states which require attention. Thus, staff can see immediately on one screen if an action is required or if the drainage system of the city of Hanover runs in regular mode.

4 METHODS

In the background of each of the four topical maps, sophisticated data treatment and modelling is taking place, all prepared for real-time processing.

4.1 Precipitation

Radar data in many places provide the best data source for current precipitation estimates. Particularly in real-time systems, compromises in data quality often have to be accepted, since rapid data availability is more important than the best possible preparation. In Germany, there are single site radar data with a resolution of 250 m x 1° from the German Weather Service (DWD), which are available via DWD Open Data and provide a good data basis for real-time systems. With the help of correction procedures prepared and adjusted using past data, a good correction of errors can be achieved in real-time. The radar data is corrected and quasi-adjusted in real-time using the software SCOUT from hydro & meteo GmbH and is used as input to calculate high resolution nowcasts and nowcast ensembles (Jasper-Tönnies et al., 2018). Further information on the processing of the data within the ZwillE project can be found in Jasper-Tönnies et al. (2023).

4.2 Sewer system

The development of a digital twin for real-time representation of the urban water system requires a powerful simulation model, especially if predictive simulations are to be created. Conventional hydrodynamic models are too complex and too slow for this purpose. A fully automated method based on domain knowledge and suitable for complex networks has been developed (Schütze et al., 2024), extended and applied in this work for the real case of Hanover. Hydrological models are unable to describe important hydrodynamic effects such as backwater in detail, thus not being sufficient in all cases. In Hanover, one of the most critical sewers is a shallow main sewer with high potential for backwater, overflow, and overload. Therefore, a combined hydrological-hydrodynamic model was developed that is integrated into the digital twin of the city. Based on the existing detailed hydrodynamic model of the combined sewer system and after including important elements of the drainage system, the method to create a simplified hydrological model (Schütze et al., 2025) was implemented.

4.3 Surface flooding

For Hanover, flooding simulations were conducted both for design storms and for real precipitation events using gauge-adjusted radar data as input. City-wide flood maps were produced through 1D-2D coupled simulations. Sewer flow was modelled in 1D. Surface runoff was computed by two-dimensional hydrodynamic calculations using realistic terrain conditions.

Flooded areas for observed or forecasted precipitation are obtained in real-time through RadEF (Jasper-Tönnies et al., 2025). The method uses radar precipitation data and precalculated flood maps based on design storms for return periods from 2 to 100 years. The precipitation input is used to calculate the maximum accumulated rain per grid point and duration, on a 500 m x 500 m grid. Then, the values are related to the equivalent highest return period using the corresponding values from the KOSTRA dataset (DWD, 2023), the Germany-wide atlas of rainfall return periods for all duration intervals. The return period map is transferred into a specific flood map for the rain event using the precalculated flood maps for the corresponding return periods at each grid point. The resulting city-wide flood map shows the maximum estimated water level with a resolution of 3 m. Radar-based ensemble precipitation forecasts (ensemble mean and maximum) up to 2 hours ahead are evaluated in the same way and transferred into two flood forecast maps for both the mean and the maximum expected flood levels.

4.4 River flow and quality

The focus for this topic is on the real-time representation of the hydraulic and water quality conditions of the water bodies in Hanover. The visualization of measurement data from sensors installed in the water bodies is performed by maps and time series graphics. The measured variables include physical and various chemical parameters. By combining measurement data and simulation results, both current conditions and forecasts can be visualized. The map offers interactive functions that allow users to inspect more detailed information on specific measuring points or sections of waterways, also for selected variables. If defined limit values are exceeded, information on the protective measures required by the flood emergency plan is displayed.

4.5 Decision support module

The decision support module proposes actions to the operational staff of the city and to other persons involved in the management of a precipitation event. These may include (manual) real-time control settings for the four main interceptors, such as a modification of the pump rates or a modification of valve settings. The main objective of these measures is the reduction of combined sewer overflows. However, the module also proposes actions to divert traffic, to activate warning signs or to evacuate areas that are likely to be flooded. These actions are relying on the sewer system simulation model implemented in the digital twin. This simulation is running concurrently and provides warning messages also to the staff if required.

5 OUTLOOK

The Digital Twin was initially implemented as a demonstrator with the use of historical events. Currently, it is being set up as a real-time demonstrator within SEH. In this way, it will be available to operational staff alongside the process control system, allowing information to be used and experience to be gathered relating to all system components. A demo version of the digital twin can be viewed on https://zwille-projekt.de/.

6 ACKNOWLEDGEMENTS

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