A Digital Twin platform for purpose-driven modelling

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Une plateforme jumeau digital pour une modélisation axée sur ses objectifs

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RÉSUMÉ

Une plateforme jumeau numérique, développée dans le cadre du projet de recherche "Zwille" en Allemagne, est présentée. Elle prend en charge une large gamme de tâches de gestion des eaux urbaines d'une société de traitement des eaux usées. Des concepts fondamentaux, tels que les problèmes d'intégration des modèles, la prise en compte de différents cas d'utilisation à différents niveaux de complexité, les problèmes liés à la configuration et à l'application des modèles, ainsi que leur communication avec l'environnement réel, sont discutés. En outre, la contribution à la conférence explique comment ces questions ont été abordées et mises en œuvre en tenant compte des besoins particuliers d'une société de services d'eaux usées.

ABSTRACT

A Digital Twin platform, developed within the “Zwille” research project in Germany, is presented, which supports a wide range of urban water management tasks of a wastewater utility. Fundamental concepts, such as model integration issues, addressing different use cases by different levels of complexity, issues related to model setup and application as well as interfacing it with the real environment are discussed. Furthermore, the conference contribution elaborates on how such issues have been addressed, and implemented considering the particular needs of a wastewater utility company.

KEYWORDS

jumeau numérique, intégration, modélisation, système d'égouts, station d'épuration des eaux usées

Digital twin, integration, modelling, sewer system, wastewater treatment plant

1 MOTIVATION

The use of digital twins is gaining increasing popularity also in stormwater management. However, several challenges need to be addressed for a successful implementation and application. Neglecting or ignoring such challenges might lead to unsuccessful approaches and implementations and possibly lead to the rejection of these otherwise good ideas and concepts. Hence, careful consideration of these issues is of utmost importance.

This conference contribution presents and discusses various issues related to digital twin implementations of urban wastewater systems, which include models of different degree of complexity of sewer system and wastewater treatment plants, fed by measured and predicted rainfall data. Applications of the digital twin covers several use cases, ranging from strategic planning to rapid decision-making based on data and models during extreme rainfall events.

These concepts form core of the “Zwille” digital twin system developed during course of the “Zwille” project funded by the Ggerman Federal Ministry of Education and Research (BMBF). This project sets up a digital twin for the wastewater system of a major city in Germany.

A digital twin is understood in this conference contribution as a virtual image of the physical water management system aiming at reflecting the current state of the real system in order to facilitate awareness for the operators and to provide a useful tool for decision making. In addition to that, forecasting capabilities need to be provided, i.e. how will the state of the water system change given future rain falls as predicted by real-time, high-resolution (temporal as well as spatial) rain forecast (Jasper-Tönnies *et al.*, submitted).

Methodological development and experiences in digital twin development within the “Zwille” project can be grouped in five topics, which are discussed in the conference contribution:

- Different use cases might require different digital twins
- Setting up models of different degree of detail
- Successful twinning requires successful connection to SCADA systems / to the real system
- A user-friendly model setup supports development and application of digital twins
- Systems Analysis routines support setup of digital twins

This conference contribution discusses these challenges and presents how these are being tackled within a modelling and simulation environment currently being set up for a major city in Germany. Methods and tools have been developed in a general way, so that they can be easily transferred also to other case studies.

2 CHALLENGES ENCOUNTERED AND RESOLVED WHEN SETTING UP DIGITAL TWINS

2.1 Variety of use cases

Management of wastewater systems (sewer system, wastewater treatment plant and receiving river system), in particular with the focus on extreme events (including extended dry periods as well as intense and/or long-duration precipitation events), covers a range of different questions. These range from long-term strategic planning (e. g. modification or extension of infrastructure to enable the wastewater system to better cope with future events) over operation of the system during or in preparation of predicted rainfall events (e.g. real time control of the integrated wastewater system) to coping with emergency situations caused by extreme events (e.g. flooding). Whilst each of these tasks poses different requirements on modelling and data (for example with regard to the degree of required model complexity), care should be taken not to develop different and completely independent software packages for these tasks related to the same system. Some modelling and data processing modules are set up in an interchangeable way and provides common interfaces for interaction with the user (user interfaces) and with the system (e.g. connection to SCADA).

2.2 Setting up models of different degree of detail

With this variety of use cases, it becomes evident that for the same system (e.g. stormwater and wastewater management system of a city), different models (each with a different degree of complexity) might be required. In engineering practice, so far, for example in sewer modelling, the use of detailed hydrodynamic models for

detailed analysis of individual measures and the use of simpler hydrological ("conceptual") models of a drainage system for long-term analysis or as internal model of a real time control system (e.g. Schütze *et al.*, 2022) has become established practice. These often use different, and not always interchangeable, modelling packages (e.g. hydrologic / hydrodynamic model of an urban drainage network). Whilst there obviously is no "one fits all" model, their implementation and usage under a unified user interface and communication interface appears desirable.

Furthermore, setting up simulation models or deriving models appropriate for being used within a digital twin often requires substantial effort. The presentation illustrates how such model setup, based on existing GIS data and existing detailed models, to derive at models of different degrees of complexity, appropriate for the given use case, has been achieved for the given case study.

2.3 Communication with the real world / SCADA system

A digital twin can only be established when there is a real-time communication link to the real world. The preferred approach for implementing this communication link is by interfacing the SCADA system of the water management system via standardized communication protocols. The particular implementation of the communication depends on where the digital twin is located in relation to the SCADA system. One option is the co-location of the digital twin with the SCADA system, i.e. as an extension or add-on. In this case, a typical communication protocol used would be OPC UA as defined in IEC 62541. The advantage of OPC UA as compared to other SCADA protocols is the high level of security, the rich semantic capabilities and the increasing adoption among automation vendors. Instead of co-location of the digital twin with the SCADA system, a cloud-based implementation can be pursued. In this case, all parts of the digital twin are run on a virtual computer in the cloud and the real time data from the SCADA system are communicated via the IoT protocol MQTT via a secure TLS-encrypted TCP/IP channel. Both approach offer advantages and need to be considered carefully by acknowledging the constraints and requirements of the regulatory framework of the water system operators, especially in terms of security and availability of critical infrastructure.

The conference contribution discusses and reports on these aspects relevant to practical implementation of digital twins under the particular framework conditions of a wastewater company, forming part of critical infrastructure.

2.4 Importance of unified user interface

Integration of models and data processing routines under a unified framework with unified user interface not only benefits the user and the ease of application, also under different use cases. The interchangeability of modules of different complexity has been suggested earlier on (e.g. Mannina *et al.*, 2018); however, this conference contribution illustrates such implementation for a practical application example. Important, yet often neglected issues, also include the linkage of different modelling principles and related solution algorithms (e.g. discrete and continuous time modelling) when modelling sewer systems, wastewater treatment plants and receiving water bodies; concepts presented by Schütze and Alex (2022) are incorporated in the unified modelling user interface. Furthermore, a unified and user-friendly interface also allows new regulatory frameworks (such as the new A102 guideline on stormwater management of the German Water Association (DWA, 2022) to be considered.

2.5 Systems Analysis routines

Model building involves, to a considerable extent, also system analysis of the system to be represented in the Digital Twin. This includes, *inter alia*, the assessment of model validity as done, for example, in calibration and validation exercises and also the assessment of modelling results, as required for decision making. The conference contribution discusses, in an exemplary way, two key tasks related to systems analysis and how they are integrated in the "Zwille" Digital Twin platform.

2.5.1 Supporting model calibration and validation

The conference contribution discusses and presents various criteria for the assessment of the fit between measured and calibrated data. It is argued that the use of the popular Nash-Sutcliffe Efficiency criterion alone as a measure of goodness-of-fit might lead to misleading conclusions. How complementary criteria could be used and applied in a user-friendly context will be presented in the contribution.

2.5.2 Assessing modelling results

In some of the use cases, in particular those which require a long-term evaluation of scenarios, such evaluation should cover a wide range of "representative" load cases, in order to ensure that a proposed solution measure is appropriate for a wide range of conditions. This section of the conference contribution demonstrates that the selection of individual events (as often done as the only means of assessment) can lead to very different results (depending on how the events have been selected) and, thus, to misleading conclusions and wrong decisions. The paper illustrates that the evaluation of longer time series might be necessary and discusses the practicability of this approach.

Overall, the conference presentation illustrates and discusses how all these aspects are integrated under a common framework of the "Zwille" digital twin system for a city in Germany. Integration of these aspects ensures that urban water management is more consistent and, thus, contributes to improved stormwater management.

3 ACKNOWLEDGEMENTS

Financial support for the research described in this paper by the German Federal Ministry of Education and Research (BMBF, grant reference: 02WEE1627B) for the ZwillE project is gratefully acknowledged. Furthermore, the authors would like to express thanks to the project partners for fruitful discussions.

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