LOADt: Towards a Concept of Level of as-is Detail for Digital Twins of Roads

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Abstract. Building Information modelling has recently reached broader adoption in the AEC industry. The benefits of digital planning for process optimization in the construction phase as well as the improvement of building maintenance during the life-cycle of an asset, are the key drivers of digitalisation in the construction industry. Digital twins are gaining great attention at the same time, due to the requirement of smarter models for decision making and automation of varying tasks especially in the operation phase. In this work we introduce a multi-LoD-concept for digital twins of the road environment, to structure the different applications of a digital twin in a clear way. We also try to unravel the different and partially contradicting definitions of LODs that currently exist and create misconceptions which therefore hinder the faster adaption of digital methods in construction and maintenance, also slowing down progress in the development of digital twins.

1. Introduction

The benefits the correct use of digital planning has for process optimization in the construction phase as well as the improvement of building maintenance during the life-cycle of an asset, are the key drivers of digitalization in the construction industry (Vignali et al. 2021). The concept of Building Information Modelling exists since more than two decades, still the adoption of the BIM method in practice is slow due to multiple reasons. A major hurdle to the widespread use of BIM is the need for training on both sides, the client and the contractor. Especially for open BIM the complexity of processes and information exchange is constantly increasing. Amongst others, this results from the aim of using open standards like IFC, which however, are not yet available for all fields of construction.

For the road infrastructure domain, the adoption of digital methods for planning, construction and monitoring is developing slower, than in the building construction domain, making it possible to put thought into design decisions of interoperable standards for data modelling, in a much earlier stage. The learnings and current challenges in building construction and management can be adapted to develop a better connectivity of BIM for design and construction and BIM for management, as well as the development of digital twins of road infrastructure with BIM data serving as geometric-semantic foundation.

Considering the fact that road construction is the second-largest subdomain in construction in general, the adaption of digital methods for optimization and monitoring road networks is due and has great potential for improving efficiency in the process of road construction (Guo et al. 2022). In the case of road infrastructure, the large spatial extent of a construction site poses challenges for the digital representation. Since both, digital planning and also digital twinning of road assets are rather new subjects, there is a need for a concept to structure the digital representation of roads. Due to the fact that there exist various closely related, but differing concepts for the Level of Detail term, there are many misconceptions and misinterpretations of what is meant by LoD (Abualdenien and Borrmann 2022). This is especially important for the road infrastructure domain, since it is closer related to GIS than the building construction domain, which also introduces Level of Detail specifications from the field of GIS (Tolmer et al. 2017). Defining representations for different use cases like road asset management or even the various applications of digital twins, can support the development of a logically consistent definition, which in turn improves the applicability of the BIM method for the road domain, by clarifying similarities as well as differences between the concepts used in different applications.

Digital twins in general consist of four components: The first component of a digital twin is onsite sensor technology that transfers data to a data storage and analysis system, being the second component. The third component enables the interaction between the real world sensor system and the digital representation in form of a geometric-semantic model, being the fourth component (Jiaying Zhang1 et al.). When the interaction between real and virtual world is implemented only as a one way data stream from real world to virtual world, the system is called digital shadow, solely mirroring the real world environment without providing data flow back into the real world (Sepasgozar 2021).

The research question that we are addressing in this article is: How can the different requirements that various use cases place on the digital representation of a digital twin be structured in a transparent and meaningful way, so that a digital twin is able to represent several use cases simultaneously?

In the next sections, we will first introduce the LOD-concepts that exist in different domains to differentiate their scope, then we will introduce our concept for the geometric-semantic as-is representation for digital twins of the road, by discussing the concept with respect to similarities and differences to other concepts. Lastly, we discuss the next steps, for our concept to be applicable to the process of digital twinning in the road context. It can be noted that this contribution aims to be viewed as a first proposal to start discussions in the research community to collaboratively evolve the proposed idea into an applicable framework in the future.

2. State of the art: LOD/LoD

that fits the demand of a specific use case in the best possible way. The geometric representation serves the purpose of enabling the reduction of unnecessary details, that solely slow down the application. However, instead of only focusing on the geometry, our concept also involves the semantic side of a model, meaning that we also specify the classifications of elements in a hierarchical way with rising semantic granularity. Though fundamentally aiming at a comparable use

“Level of Geometric Representation” as we call it (following: LoGR) has to be specified for each single object. On the other hand, fixing all objects at a similar LoGR results in suboptimal models for the use cases they were generated for. Combining structure and comprehensibility into one concept that is suited for all possible use cases, is no trivial task. Keeping the purpose of a digital twin in mind, we deal with that trade-off by defining groups of objects that behave alike and assign one LoGR to each group, which we call functional units, while the LoGR can be shifted between those units. We therefore define functional units that are likely important as a collective for specific use cases, while being negligible for others.

As shown in (Abualdenien and Borrmann 2022) there exist several attempts to define new concepts resulting in rising confusion and complexity. Defining a concept for a new domain will always result in rising complexity,

quantify the uncertainty introduced in model errors and miscalibration of a model, the LoSU is necessary, since it holds information on the potential risk of erroneous object information. As example, if a model holds information on the driving rules of a road segment through the classified road signs, the LoSU has to be high, hence if a stop sign was labeled a speed limit sign this error would pose a high danger compared to the same setup in the context of obstacle detection where the main goal is avoiding a crash. It is also likely that object classes in a higher LoSG will be segmented with higher uncertainty. Additionally, if the geometry is derived from segmented point clouds, the LoGU of the chosen representation also depends on the LoSU,