Introducing Data-Format-Dependent Road Network Conversion Techniques – Lessons Learned from the Digital Twin Munich

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GISRUK 2023

Summary

The Digital Twin Munich project (DZ-M) aims to depict complex urban environments through the use of static and dynamic components, and their semantic relationships. The project focuses on the development of a street network model and urban mobility simulation, utilizing the open source microscopic traffic flow simulation software SUMO. The transport demand is provided by the VISUM model of the city of Munich, and the data structure developed is compatible with standards such as OpenStreetMap, OpenDrive, CityGML, and GTFS. The project also includes the use of physical VRU simulators for data collection purposes, and the integration of these simulations into a 3D VR environment in Unity.

KEYWORDS: urban digital twin, geodata conversion, road network representation, traffic flow simulation, virtual reality

1. Introduction

Urban digital twins have the purpose to depict complex urban environments together with static and dynamic components, and their semantic relationships (Dembski et al., 2020).

Within the Digital Twin Munich project ("DZ-M"), we focus on the two selected components (1) street network model and (2) urban mobility simulation. Both components imply development of various traffic simulations based on a city-wide lane model, which is influenced by the Road2Simulation guideline (Richter and Scholz, 2018). Nevertheless, to comply with the open source microscopic traffic flow simulation software SUMO (Lopez et al., 2018), we introduced specific additions for the purpose of enabling conversion options for creating routable networks.

Currently, OSM is often the source for creating the road networks for the SUMO simulations, but in the first year of the project, a first data structure has already been defined and described in the form of an XML schema document, which allows generating road networks from the lane model to be used in various traffic simulation programs. In the second year, this framework was further developed and integrated into various ETL processes.

The transport demand is additionally provided from the VISUM model of the city of Munich, which is converted into a suitable format for SUMO simulations. The multitude of models has different input data, which are also important for the definition of demand and network calibration procedures.

The developed data structure is compatible with standards such as OpenStreetMap, OpenDrive, CityGML and GTFS for public transport as well as with the lane model of the city of Munich. Furthermore, the microscopic simulation SUMO is supporting bicycle and pedestrian simulation (e.g. TUM-VT bicycle simulator as in Keler et al., 2018), and other types of vulnerable road users (VRUs)

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such as wheelchair users.

2. Methodological Approaches

Within the project, several milestones were defined for enabling selected functionalities for interfaces to the data model, data processing options and demonstrators for providing interactive visualization options. The initial milestones were defined as:

1. Development of the interfaces for creating the road network from the Lane model
2. Development of the interfaces for creating the transport demand from the VISUM model of the city of Munich
3. Development of ETL processes
4. Creating clones (of the overall data model) and implementing (physical) demonstrators

These milestones served as the framework components for defining the workflow pictured in **Figure 1**.

The components pictured in grey are open source, in violet physical setups, in green available historical databases of the city of Munich, in yellow raw data coming from recent data acquisition campaigns, and in black computational products and micro simulation outcomes.

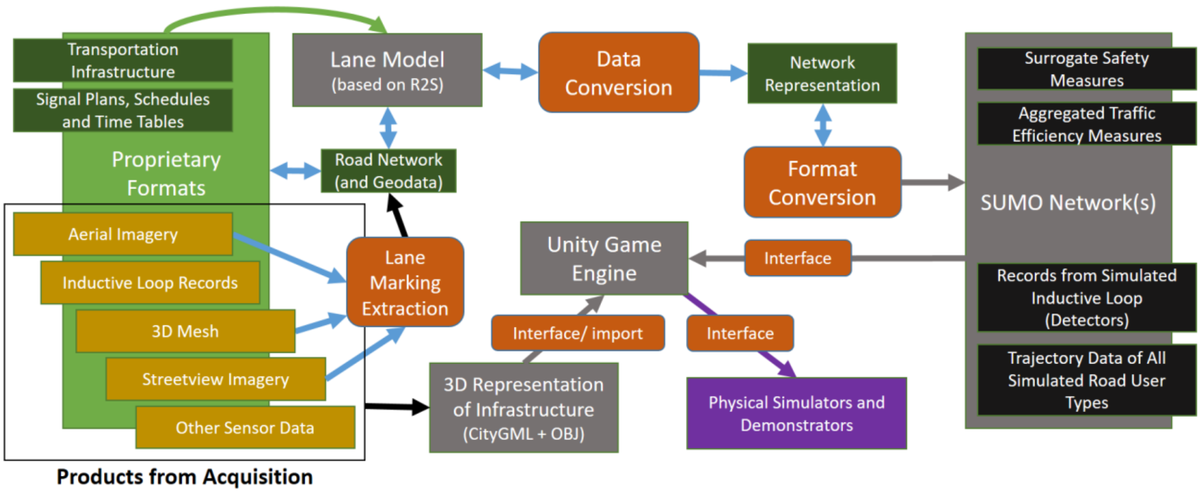

Figure 1 Generalised views on the workflows used for transportation segment within the Digital Twin Munich (DZ-M).

Within this workflow, there are data conversion steps enabling using polygonal features of the lane model of the city of Munich as input for recreating a routable network representation, which is subsequently used for converting into the SUMO network format "PlainXML" including the network topology and geometry. In addition to this, we are importing CityGML representing matching city areas into the game engine Unity and provide interfaces for translating the simulation outcomes and running simulations into VR animations experienced through the usage of physical simulators.

The interfacing of an ongoing SUMO simulation is pictured in **Figure 2** and respectively shows a central area in Munich, Germany, with the typical visualizations of the two different software.

Figure 2 Interfacing an ongoing SUMO simulation (left) into a 3D VR environment in Unity (right).

3. Usage of physical VRU simulators for data collection purposes

After performing the different geodata conversion steps of the workflow shown in **Figure 1**, were are using the generated 3D VR environment (as pictured in **Figure 2** on the right) for implementing simulator test studies, as for example for the case of a multi-modal simulator in **Figure 3** or an electric cargo bicycle simulator (Lindner et al., 2022) in **Figure 4**. The idea behind these simulator studies is to provide trajectory and gesture data collection. The latter is implemented via using depth cameras and its subsequent processing of depth information into skeletons of the test subjects (Keler et al., 2021).

In addition to the behavioral data collection from observing test subjects, simulator test studies can help evaluating the geodata conversion quality of converted transport infrastructure representations. Common problems often occur in converting road network representations as artifacts of the lane shapes, which subsequently leads to methodological adjustments of respective geodata converter implementations. Besides this, it is also possible, within experiencing VR visualization through VR glasses or screens, to find unrealistic movement patterns of simulated (and translated) road users and unexpected conflict points experienced from the ego of every test subject.

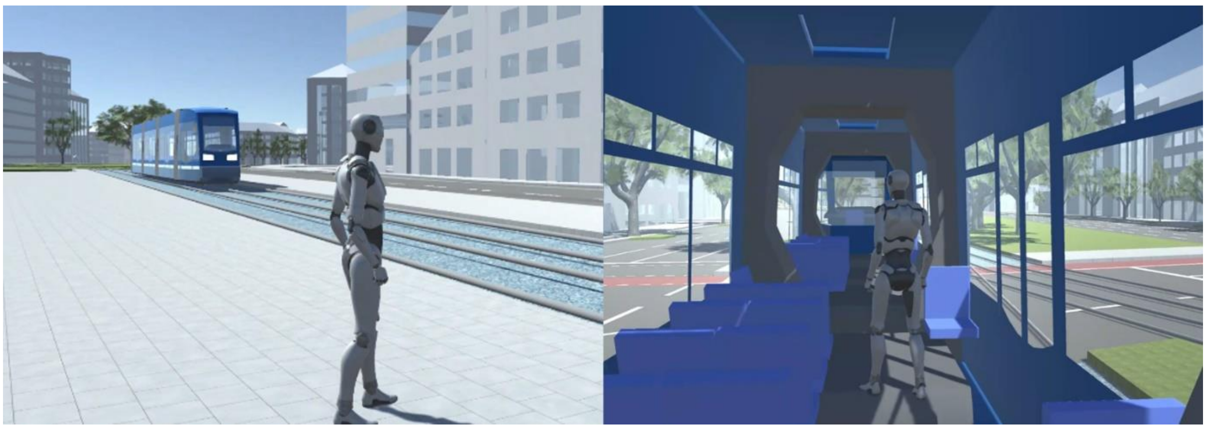

Figure 3 Third-person views from the multi-modal simulator – currently operated via an Oculus Rift CV1 and hand controllers.

Figure 4 Depiction of a test subject operating the electric cargo bicycle simulator with typical sensor setup and usage of a Varjo XR-3 (left) and of the virtual electric cargo bicycle in VR environment in Unity (right).

4. Discussion

This ongoing project of implementing an urban digital twin for the city of Munich has currently very specific characteristics, which allows to provide various types of geodata conversion and validation options. Besides this, physical VRU simulators allow inspections of the road network conversion outcomes via very interactive possibilities.

It is to mention that the calibration and validation of the simulation networks of the city with travel demand information is a complex task. As the purpose of the calibration steps is to provide realistic microscopic traffic flow simulations, there is a high dependency on the spatial accuracy of the road network representations.

Future work will focus on implementing a physical wheelchair simulator for experiencing accessibility, the usage of specifically assigned infrastructure, mode change and the presence of potential travel barriers.

5. Acknowledgements

The presented work is part of the accompanying research for the city of Munich, namely the “GeodatenService”, within the project Digital Twin Munich, DZ-M (“Digitaler Zwilling München”), which is funded by the Federal Ministry for Digital and Transport. For more information please visit: https://muenchen.digital/twin/ .

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Biographies

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