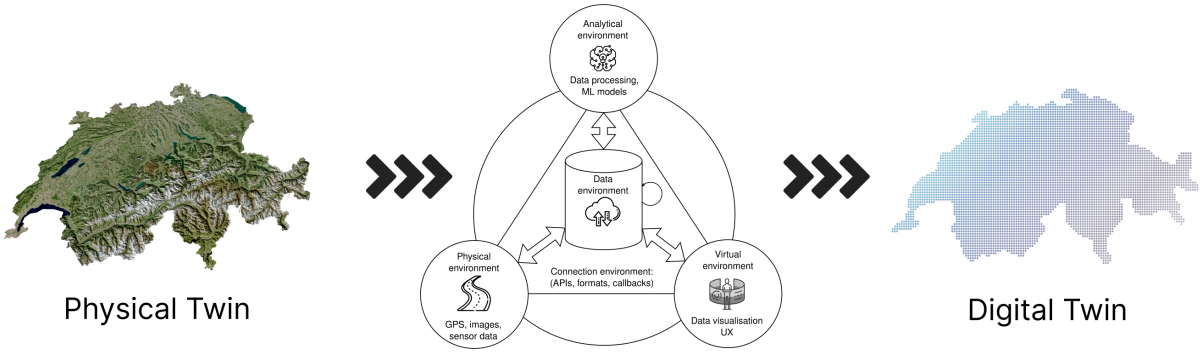

MATSim in the Open Digital Twin Platform

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Abstract

MATSim simulations play a crucial role for research, industry, and governance. However, simulating mobility systems within MATSim requires large-scale efforts of data and software preparation, data transformation, computing hardware and data visualization. Digital twin offers a novel paradigm on how to manage the data and infrastructure efficiently and make the simulation results available in a reproducible manner with a low barrier to entry. We introduce the first prototype of a digital twin integrating MATSim to enable a common baseline for transport research and beyond. The Open Digital Twin Platform (ODTP) generates specific digital twins dynamically using containerization, loose coupling, and micro-services. In our first iteration, the prototype provides simulations for Switzerland called "CH on the move" consisting of an easy-to-use version of the eqasim pipeline for MATSim. We make it possible to initiate simulations of Switzerland with one click. Future versions of ODTP-based digital twins aim to include a rich set of relevant data sources and analytical pipelines related to transport and mobility and make them easily accessible to research, industry, and governance.

Keywords

Digital Twin, Open Research Data, Mobility Simulation, eqasim, MATSim

Suggested Citation

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Contents

List of Tables 1

List of Figures 1

1 Introduction 2

2 System and Implementation 3

3 Discussion and conclusion 6

4 References 6

List of Tables

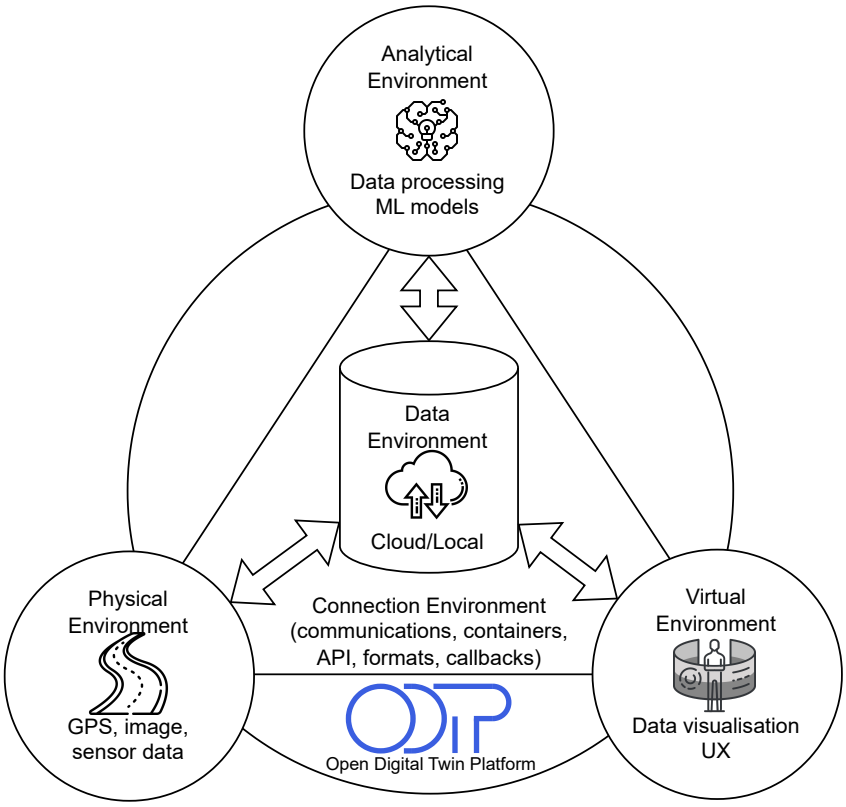
List of Figures

1 ODTP Overview 2
2 ODTP Implementation 3
3 ODTP Micro-services 4
4 ODTP Trace 5

1 Introduction

We introduce a new project for the creation of Digital Twins of mobility system based on MATSim. A first prototype of the Digital Twin for the Swiss Mobility System "CH on the move" is in the early alpha-testing. However, our underlying model for Digital Twins is agnostic and scale-free and therefore applicable beyond MATSim and mobility, see Fig. 1.

Figure 1: Open Digital Twin Platform Model (ODTP): The platform follows a five component model for Digital Twins (Grübel *et al.*, 2022; Tao *et al.*, 2018). Each key environment for interaction with data is represented by a component. In the physical environment, variables of interest are captured from the real world (phsical twin) as raw data. In the data environment, semantic meaning is related to the data enabling validation. In the analytical environment, data transformation from preprocessing to simulating and machine learning are conducted. In the virtual environment, end-user perpectives on the data from tables to dashboards to 2D and 3D visualisations are provided. Lastly, in the connection environment, interoperability of components and their hosting is ensured. Figure taken with permission from (Grübel *et al.*, 2023b).



Source: Jascha Grübel

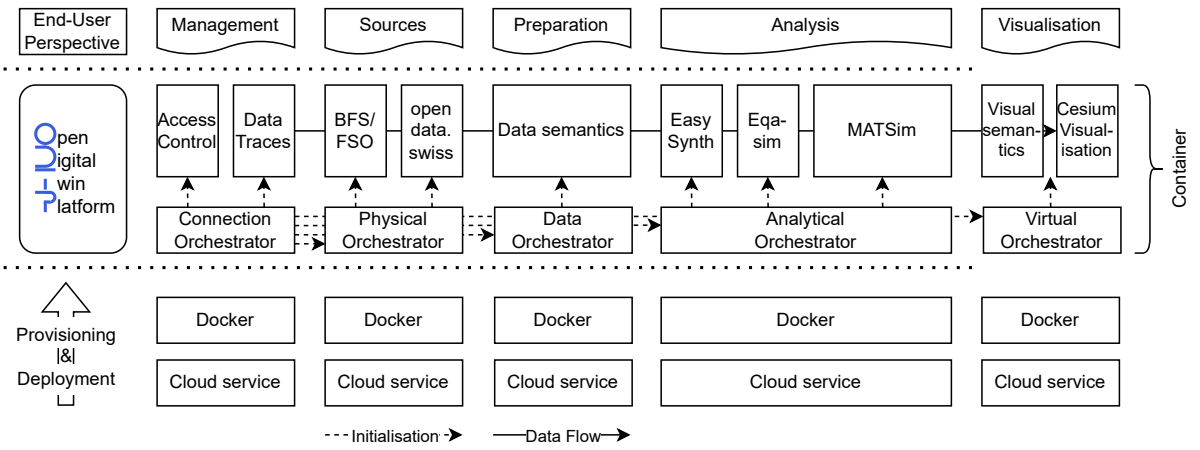
Indeed, the Open Digital Twin Platform (ODTP) works on all spatial scales and research

areas and therefore theoretically for any application area from academica to industry and governance. Interestingly, Digital Twins enable Open Research Data (ORD) (Nosek *et al.*, 2015) by design and therefore provide an implementation of Findable, Accessible, Interoperable and Reusable (FAIR) data (Wilkinson *et al.*, 2016) and advances reproducibility (Ioannidis, 2005; Stark, 2018; Aguilar *et al.*, 2022). In general, we propose the Open Digital Twin Platform (ODTP) as the foundation for ORD in all three areas research, industry, and government.

2 System and Implementation

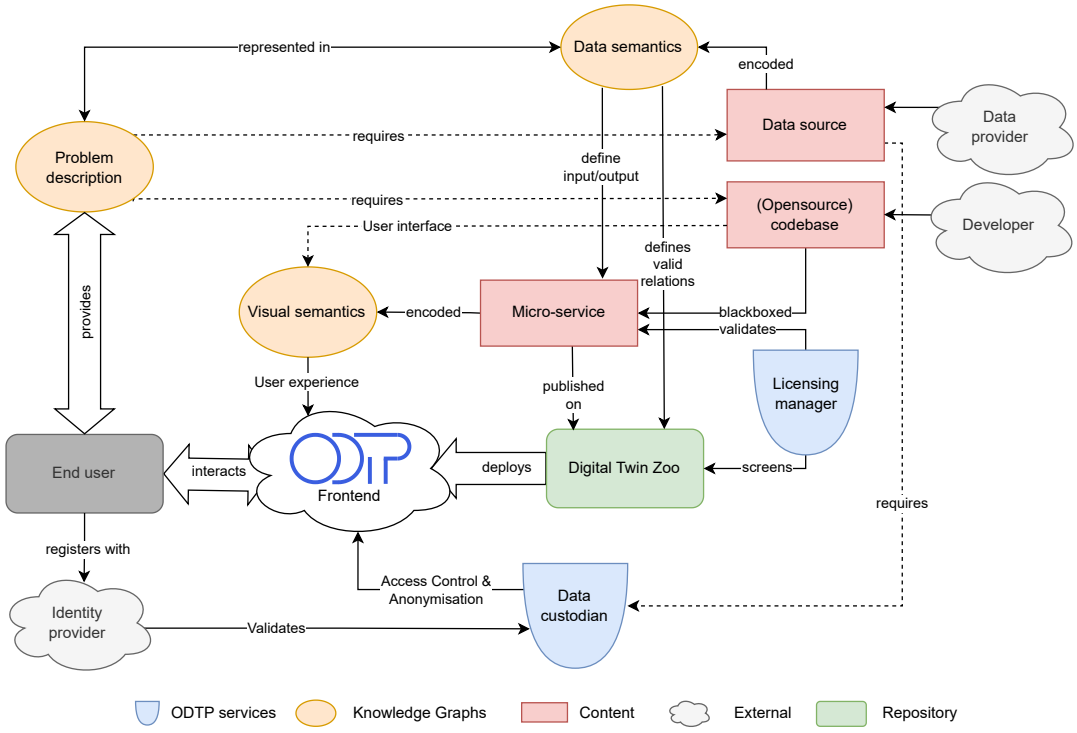
The overarching model of ODTP, see Fig. 1, is based on an analysis of existing digital twins (Grübel *et al.*, 2022). We make a distinction between data acquisition, data representation, data analysis and data visualisation. The abstract environments are not monoliths but are build with a large number of micro-services (De Lauretis, 2019), see Fig. 2. Specific Digital Twins are composed of different micro-services to enable performant yet general designs. In this prototype, we combine micro-services for eqasim Hörl and Balac (2021), MATSim Horni *et al.* (2016) with helper services for data Micallef *et al.* (2023) and visualisation.

Figure 2: ODTP Implementation (Grübel *et al.*, 2023a): Docker services in the cloud underpin ODTP. First, orchestrators for each environment are initialised which in turn initialise all containers used for a particular Digital Twin.



Source: Jascha Grübel

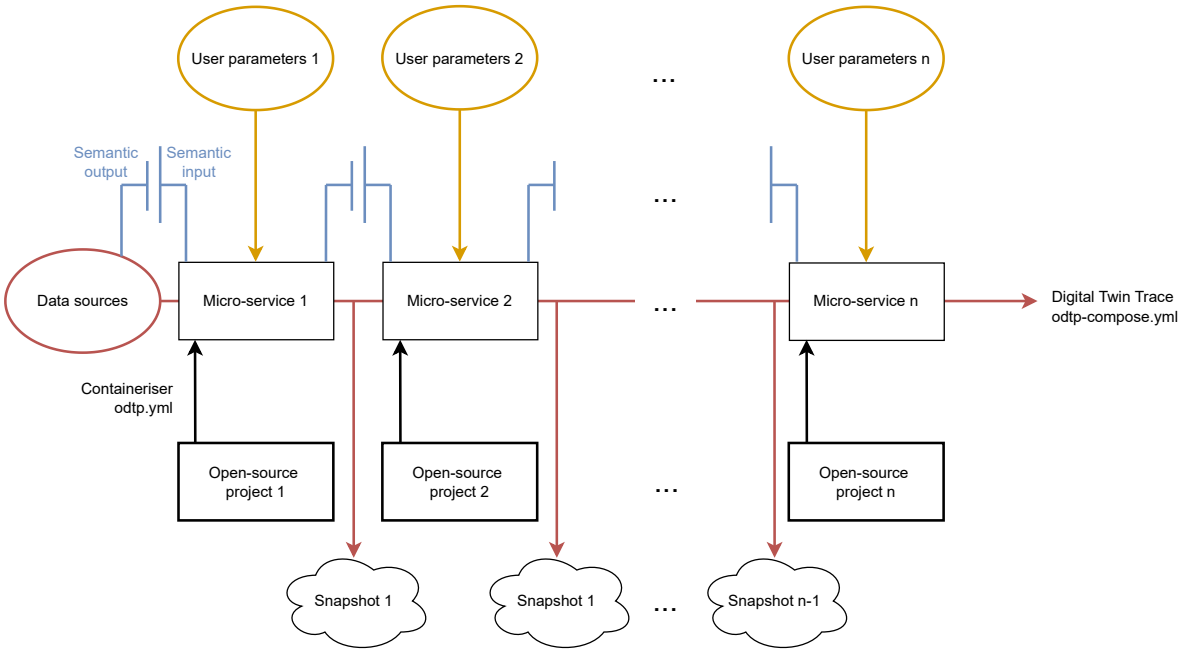
Figure 3: ODTP Micro-services: Opensource software is containerised into micro-services and available in the Digital Twin Zoo. A chain of micro-services is validated with semantics. Figure reused with permision from Grübel *et al.* (2023-06).



Source: Jascha Grübel

Micro-services run in a container-based virtualisation of operating system features (Amaral *et al.*, 2015), such as docker, and offer maintainability, modularity, scalability, implementation-independence, and blackboxing (Dmitry and Manfred, 2014). Inside a container, a service appears to be the only service in the system with no interaction with other services. ODTP orchestrates the micro-services to validate their semantics. Existing open-source projects are transformed into micro-services in ODTP, see Fig. 3. With containers, end users are not required to correctly install all dependencies. Instead, a user provides semantically the requirements for their Digital Twin to ODTP which loads the corresponding data and micro-service from the Digital Twin Zoo. In machine learning approaches, model zoos are a large collection of prepared models for immediate use made available via a simple web-front end or repository. Our Digital Twin Zoo will host all (open) micro-services containers and provide ODTP with the instructions to instantiate a particular Digital Twin. ODTP takes care of both licensing compatibility and access control Schultheiss *et al.* (2019)to help users.

Figure 4: ODTP Trace (Grübel *et al.*, 2023a): A trace follows the data from the source through transformation in micro-services like a red thread. Each micro-service is generated from a yml file from opensource projects. User-specific parameters are provided to micro-services and snapshots are generated between processing steps to reduce computational costs.



Source: Jascha Grübel

We implement a first prototype that demonstrates MATSim in Switzerland in combination with eqasim, see Fig.2. MATSim has been applied to many countries with different goals. However, the usability of MATSim is still low and the barrier to entry is large. Our prototype changes this by providing a "one-click" version of MATSim that can easily load various data sources. To create our Digital Twin, we use the ODTP infrastructure to run micro-services for MATSim, eqasim, EasySynth and Cesium. ODTP instantiates a Digital Twin based on a trace of its data transformations, see Fig. 4. These configuration files mirror the files for `docker` and `docker-compose`. Each micro-services has its own `odtp.yml` file describing how a opensource project is containerised and its semantics. The `odtp-compose.yml` for a complete Digital Twin that denotes all data snapshots between micro-services, user parameters and

3 Discussion and conclusion

We introduce the Open Digital Twin Platform (ODTP) as a vehicle to generate a Digital Twin for MATSim applications. Both ODTP and our MATSim example "CH on the move" are in their early development stages. This paper outlines the technology underpinning the system and our overall goals for future developments. We also showcase how the technology enables the creation of own Digital Twins within ODTP. ODTP is envisioned as a community project and its open source format will allow for the contribution of new (open) micro-services that enhance both reproducibility and reusability.

Acknowledgements

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4 References

Aguilar, L., M. Gath-Morad, J. Grübel, J. Ermatinger, H. Zhao, S. Wehrli, R. W. Sumner, C. Zhang, D. Helbing and C. Hölscher (2022) Experiments as Code, available on arXiv.

Amaral, M., J. Polo, D. Carrera, I. Mohomed, M. Unuvar and M. Steinder (2015) Performance evaluation of microservices architectures using containers, paper presented at the *2015 ieee 14th international symposium on network computing and applications*, 27–34.

De Lauretis, L. (2019) From monolithic architecture to microservices architecture, paper presented at the *2019 IEEE International Symposium on Software Reliability Engineering Workshops (ISSREW)*, 93–96.

Dmitry, N. and S.-S. Manfred (2014) On micro-services architecture, *International Journal of Open Information Technologies*, **2** (9) 24–27.

Grübel, J., T. Thrash, L. Aguilar, M. Gath-Morad, J. Chatain, R. W. Sumner, C. Hölscher

and V. R. Schinazi (2022) The hitchhiker's guide to fused twins: A review of access to digital twins in situ in smart cities, *Remote Sensing*, **14** (13) 3095.

Grübel, J., C. Vivar Rios, M. Balać, Y. Xin, R. M. Franken, S. Ossey, M. Raubal, K. W. Axhausen and O. Riba-Grofnuz (2023a) Open Digital Twin Platform, `https://csfm.ethz.ch/en/research/integrative-projects/digital-twin/odtp.html`.

Grübel, J., C. Vivar Rios, M. Balac, Y. Xin, R. M. Franken, S. Ossey, M. Raubal, K. W. Axhausen and O. Riba-Grognuz (2023b) "ch on the move": Introducing the prototype digital twin of the swiss mobility system. Swiss Transport Research Conference.

Grübel, J., C. Vivar Rios, C. Zuo, S. Ossey, R. M. Franken, M. Balać, Y. Xin, K. W. Axhausen, M. Raubal and O. Riba-Grognuz (2023-06) Outlining the open digital twin platform. IEEE International Conference on Digital Twin (Digital Twin 2023); Conference Location: Portsmouth, UK; Conference Date: 28-31 August 2023; Funded by swissuniversities under the grant ODTPR-SMS.

Hörl, S. and M. Balac (2021) Synthetic population and travel demand for Paris and Île-de-France based on open and publicly available data, *Transportation Research Part C: Emerging Technologies*, **130**, 103291.

Horni, A., K. Nagel and K. W. Axhausen (2016) *The multi-agent transport simulation MATSim*, Ubiquity Press, London.

Ioannidis, J. P. (2005) Why most published research findings are false, *PLoS medicine*, **2** (8) e124.

Micallef, D., M. Balać, S. Ossey, O. Riba-Grofnuz and J. Grübel (2023) Towards an automated, open, and reproducible syn- thetic population of Switzerland, paper presented at the *Swiss Transport Research Conference 2023*.

Nosek, B. A., G. Alter, G. C. Banks, D. Borsboom, S. D. Bowman, S. J. Breckler, S. Buck, C. D. Chambers, G. Chin, G. Christensen *et al.* (2015) Promoting an open research culture, *Science*, **348** (6242) 1422–1425.

Schultheiss, M.-E., E. Bouillet and O. Verscheure (2019) Introduction to the swiss data custodian, *Technical Report*, EPFL.

Stark, P. B. (2018) Before reproducibility must come preproducibility, *Nature*, **557** (7706) 613–614.

Tao, F., H. Zhang, A. Liu and A. Nee (2018) Digital twin in industry: State-of-the-art, *IEEE Trans. Ind. Informat.*, **15**, 2405–2415.

Wilkinson, M. D., M. Dumontier, I. J. Aalbersberg, G. Appleton, M. Axton, A. Baak, N. Blomberg, J.-W. Boiten, L. B. da Silva Santos, P. E. Bourne *et al.* (2016) The fair guiding principles for scientific data management and stewardship, *Scientific data*, **3** (1) 1–9.