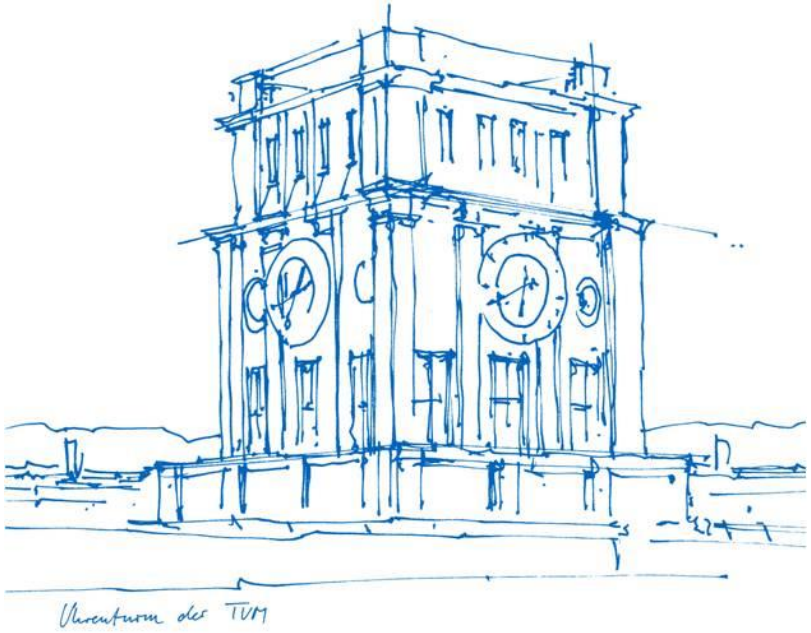
Technical University of Munich
TUM School of Engineering and Design
Chair of Traffic Engineering and Control

Experimental Digital Twins: Unlocking Insights for Multimodal Transportation Systems through Targeted Data Collection

Prof. Dr.-Ing. Klaus Bogenberger

Johannes Lindner, M.Sc.

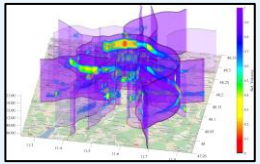
Dr.-Ing. Mathias Pechinger



Introduction TUM-VT: Tools and Methods

Data Analyses

- Detection
- Evaluation
- Artificial Intelligence
- Assessment
- Prediction



Simulations

- Microscopic
- Mesoscopic
- Macroscopic

SUMO

aimsun.

PTV GROUP
the mind of movement

Simulators

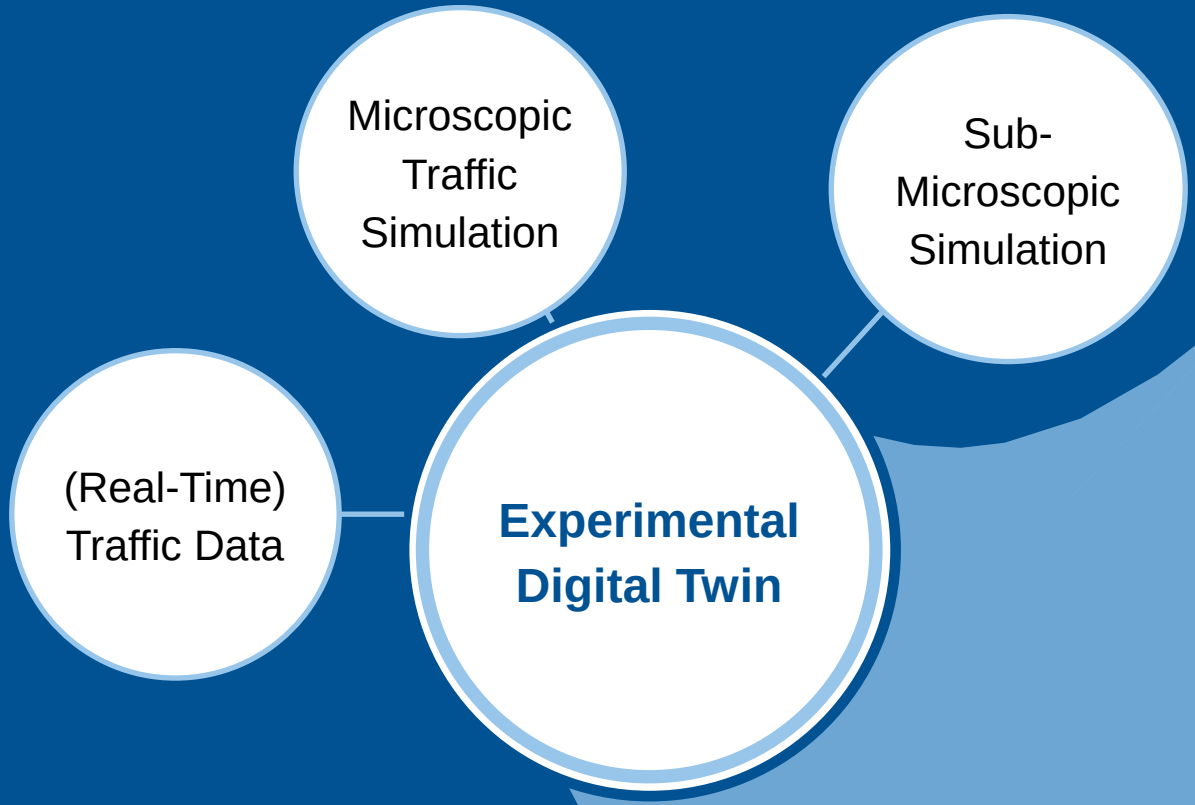
- Hard- & Software
- Sensors




Test Beds

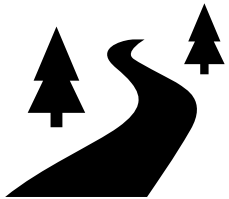
- Living Labs
- Field Experiments



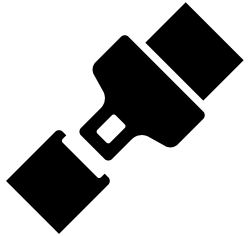

Microscopic Traffic Simulation
Sub-Microscopic Simulation
(Real-Time) Traffic Data
Experimental Digital Twin

Why Experimental Digital Twins?

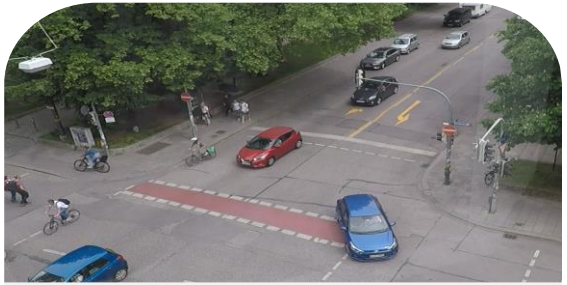
Reproducible Results



Controlled & Valid Conditions
(Near-Real World)

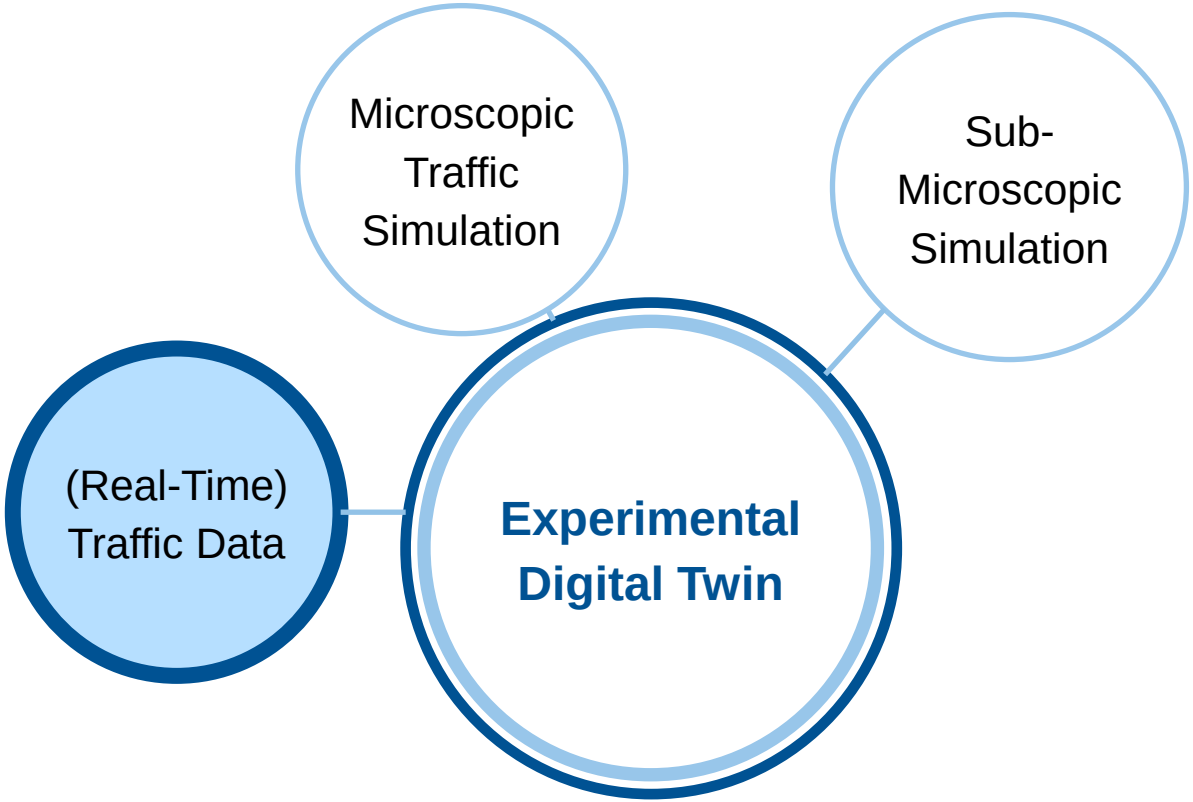


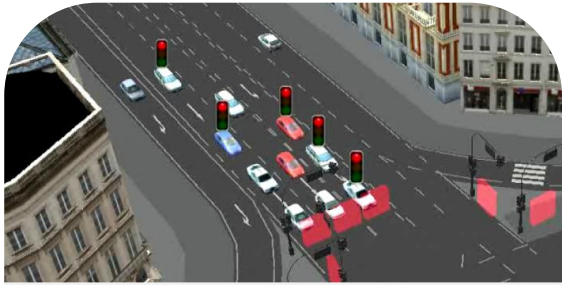
Safe Testing
→ Human-Vehicle Interaction
→ Cybersecurity
(e.g. GPS-Spoofing on AVs)



Real-time (or offline) detection and processing

- Stationary Camera & Lidar
- Stationary Detectors
- Drone observations



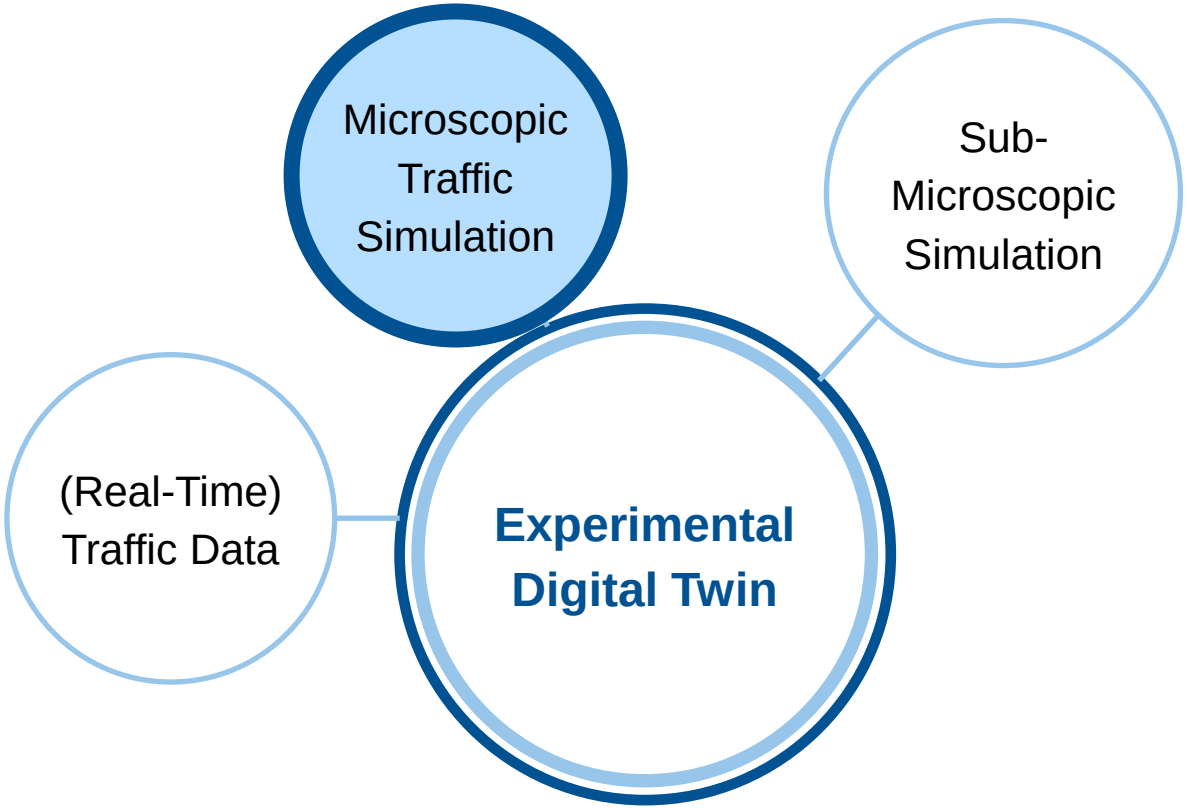


Microscopic Traffic Simulation for

- Traffic Control
- Road User Behavior Models

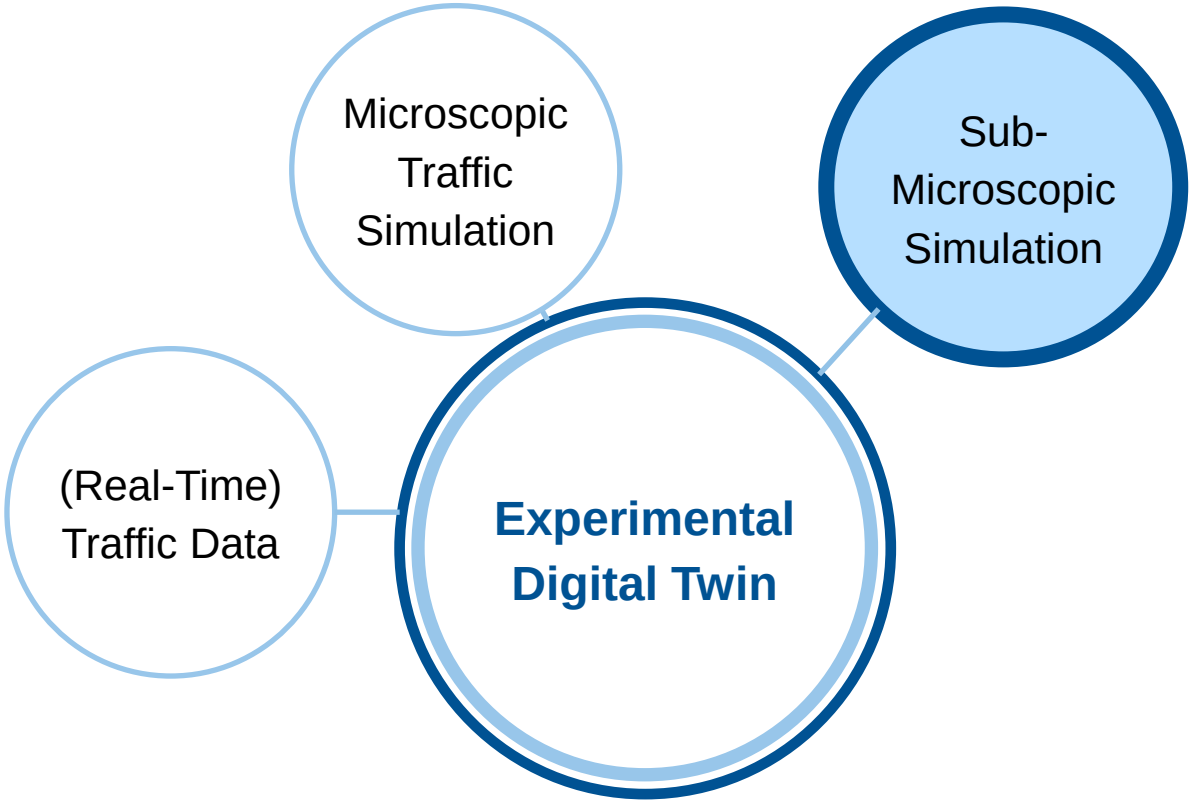
<u>Tools</u>

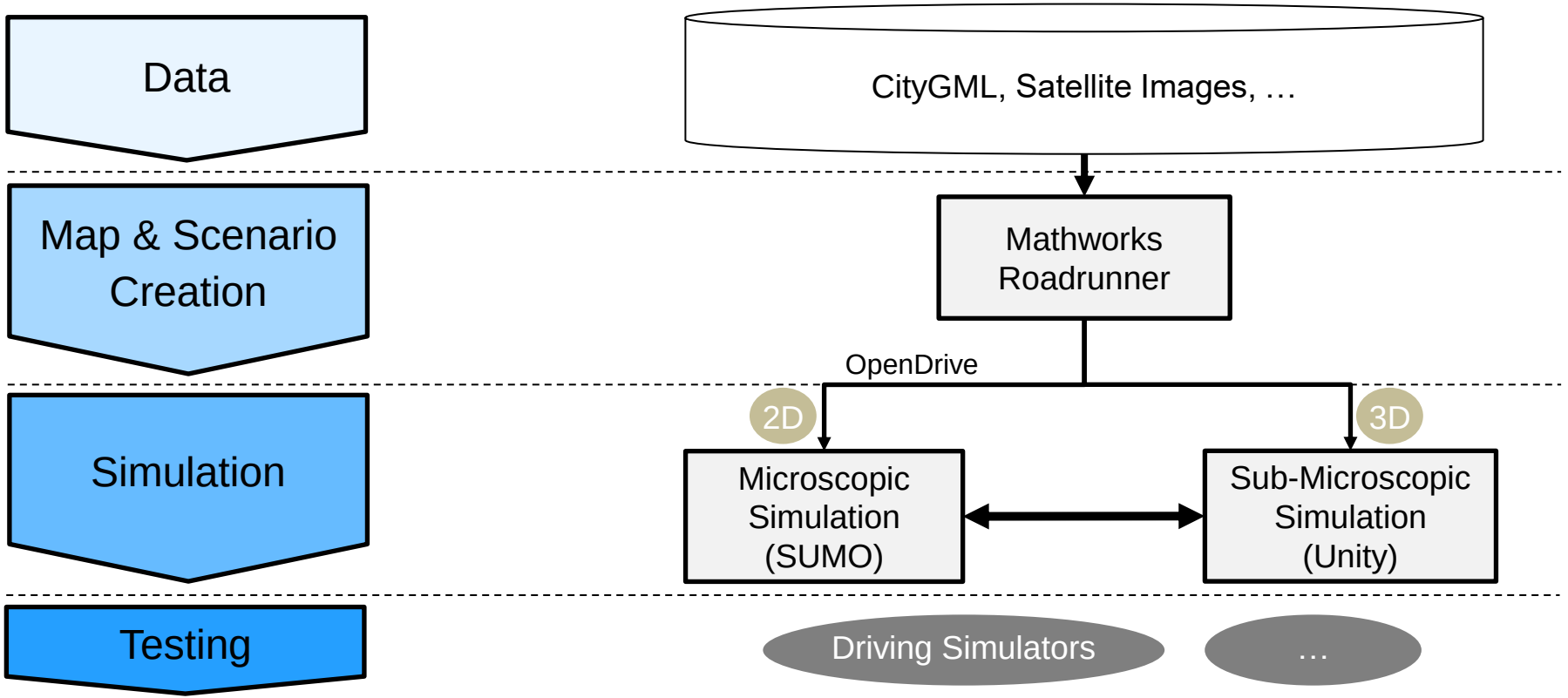
SUMO, PTV Vissim, Aimsun



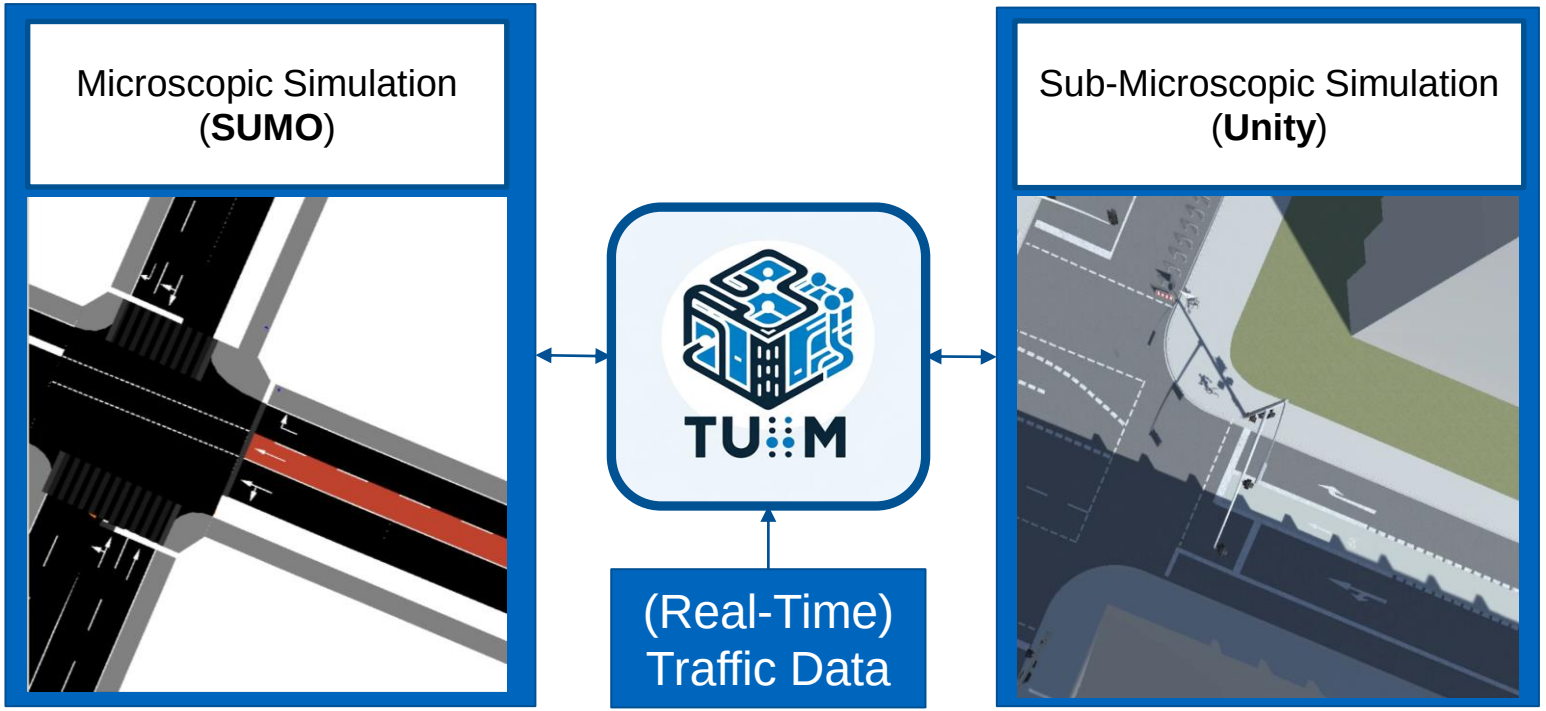
Utilization of *Rendering, Physics Simulation, and Interaction* Capabilites of Game Engines.

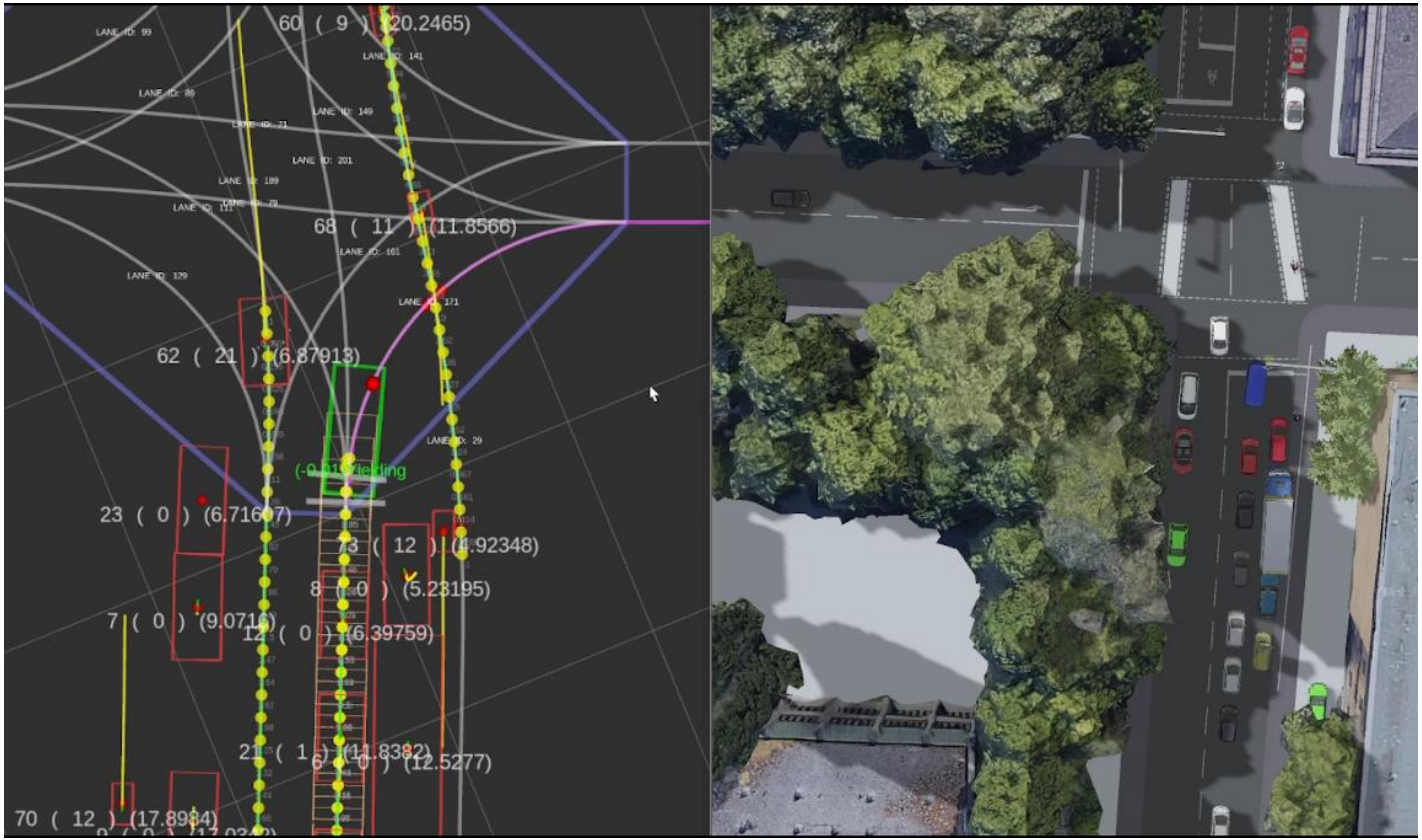
Tool: Unity 3D

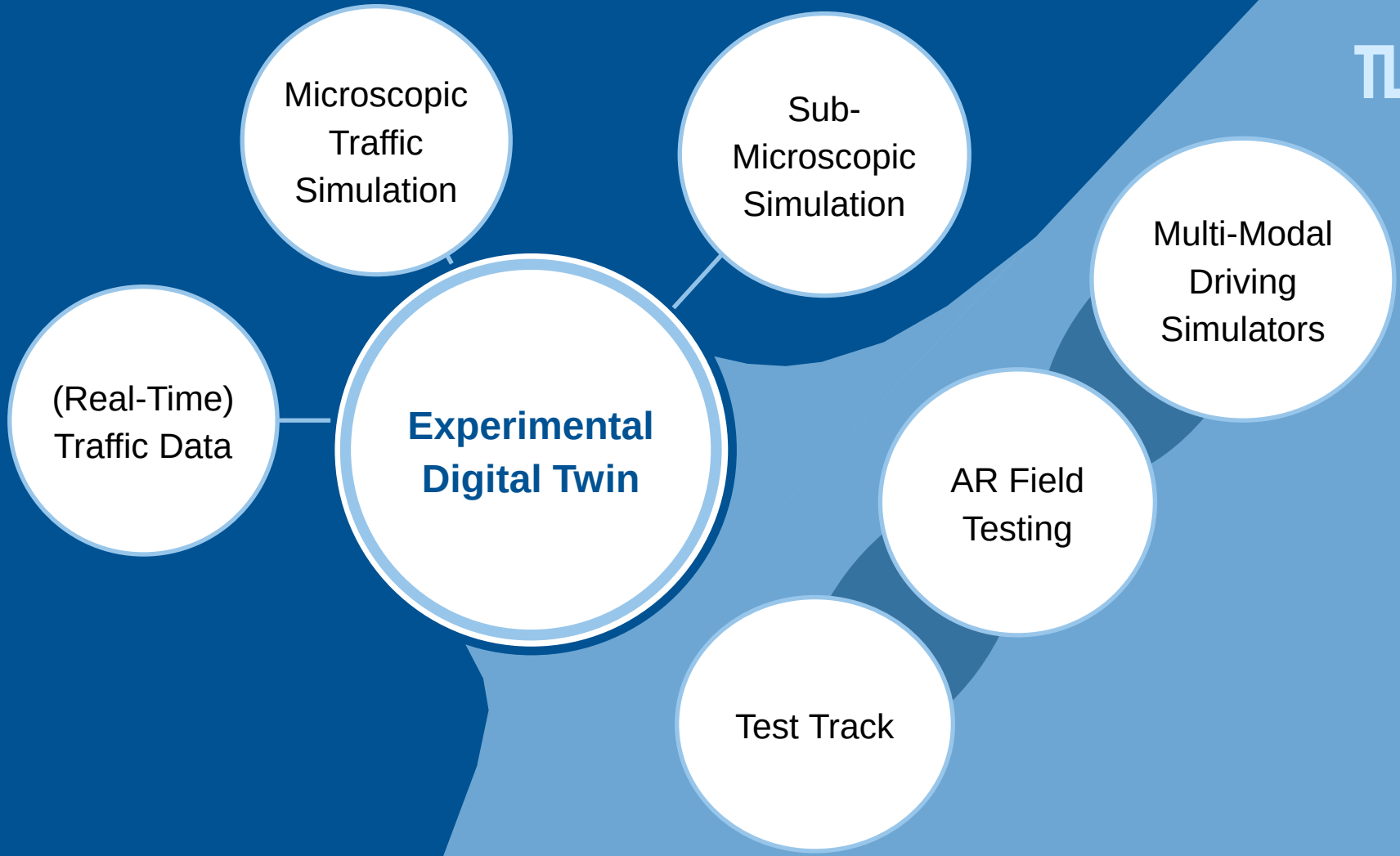


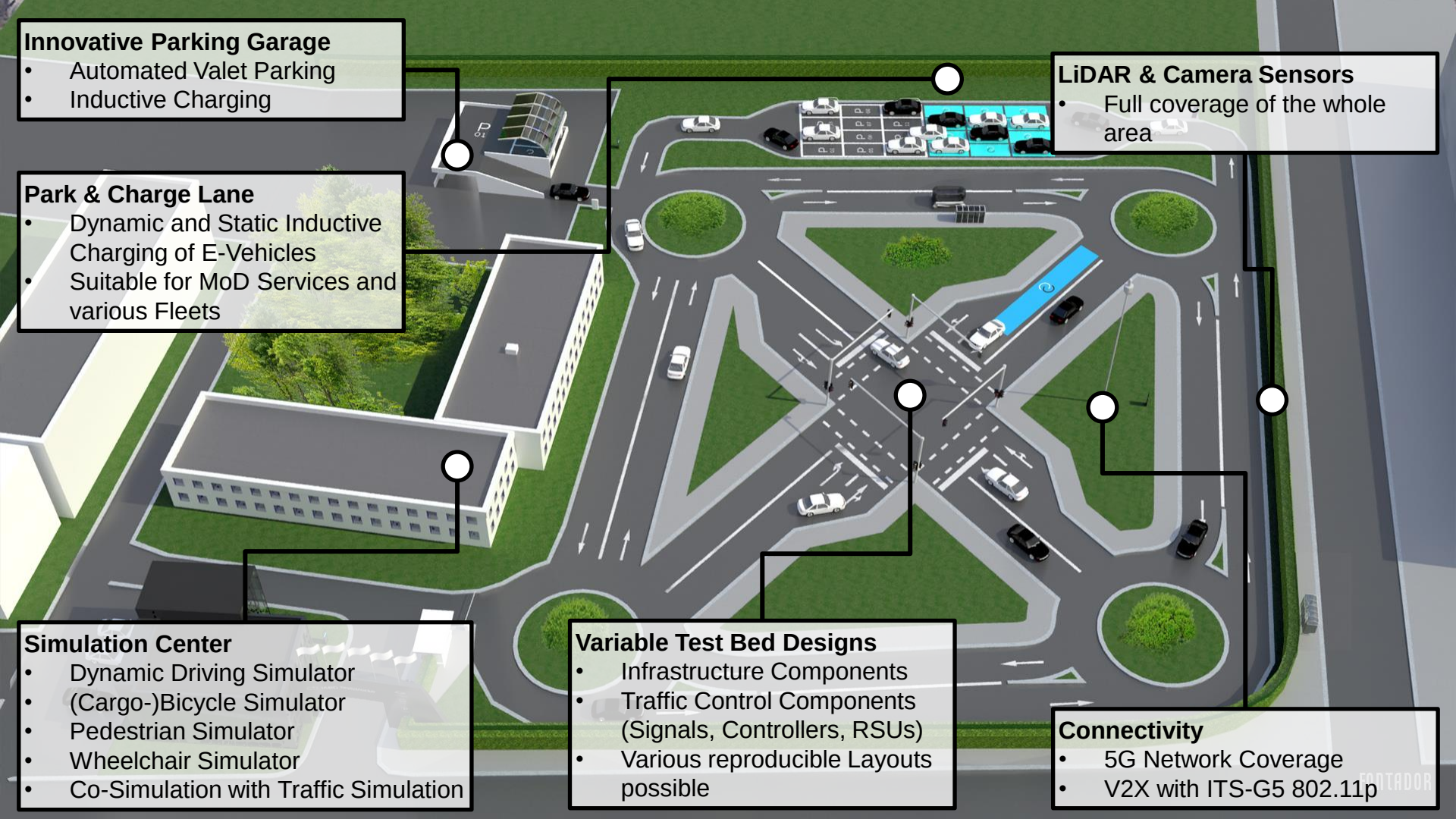

Data
Map & Scenario Creation
Simulation
Testing
CityGML, Satellite Images, …
Mathworks Roadrunner
OpenDrive
2D
3D
Microscopic Simulation (SUMO)
Sub-Microscopic Simulation (Unity)
Driving Simulators
…

TUM Open Traffic Simulation Interface




60 (9) (20.2465)
68 (11) (11.8566)
62 (21) (6.87913)
23 (0) (6.71607)
73 (12) (11.92348)
8 (0) (5.23195)
7 (0) (9.0716)
12 (0) (6.39759)
21 (1) (11.8382)
6 (0) (12.5277)
70 (12) (17.8984)


Microscopic Traffic Simulation
Sub-Microscopic Simulation
Multi-Modal Driving Simulators
(Real-Time) Traffic Data
Experimental Digital Twin
AR Field Testing
Test Track


Innovative Parking Garage
- Automated Valet Parking
- Inductive Charging

Park & Charge Lane
- Dynamic and Static Inductive Charging of E-Vehicles
- Suitable for MoD Services and various Fleets

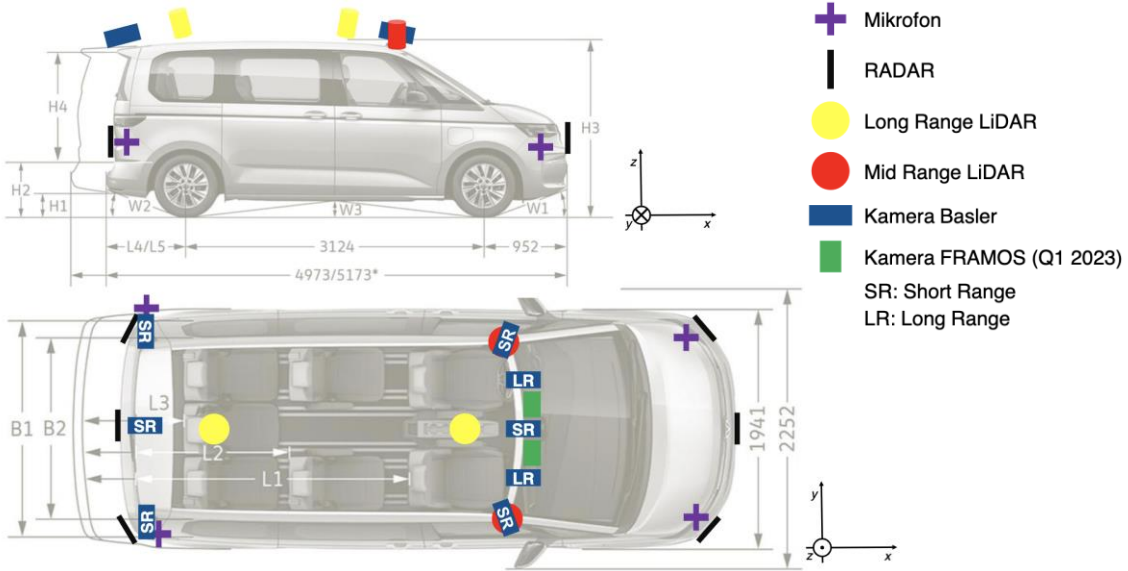
LiDAR & Camera Sensors
- Full coverage of the whole area

Simulation Center
- Dynamic Driving Simulator
- (Cargo-)Bicycle Simulator
- Pedestrian Simulator
- Wheelchair Simulator
- Co-Simulation with Traffic Simulation

Variable Test Bed Designs
- Infrastructure Components
- Traffic Control Components (Signals, Controllers, RSUs)
- Various reproducible Layouts possible

Connectivity
- 5G Network Coverage
- V2X with ITS-G5 802.11p

EDGAR self-driving car



Self-driving Rikshaw

Self Developed Vehicle

Use-Cases:

- Data Collection as Multimodal Moving Observer
- Student Projects on Autonomous Driving

Speed limited to 25 km/h to operate on bicycle tracks and roadsways.

Other Research Vehicles

Scaled (1:10) Automated Vehicles

Sensor Bicycle (Boreal Bike)

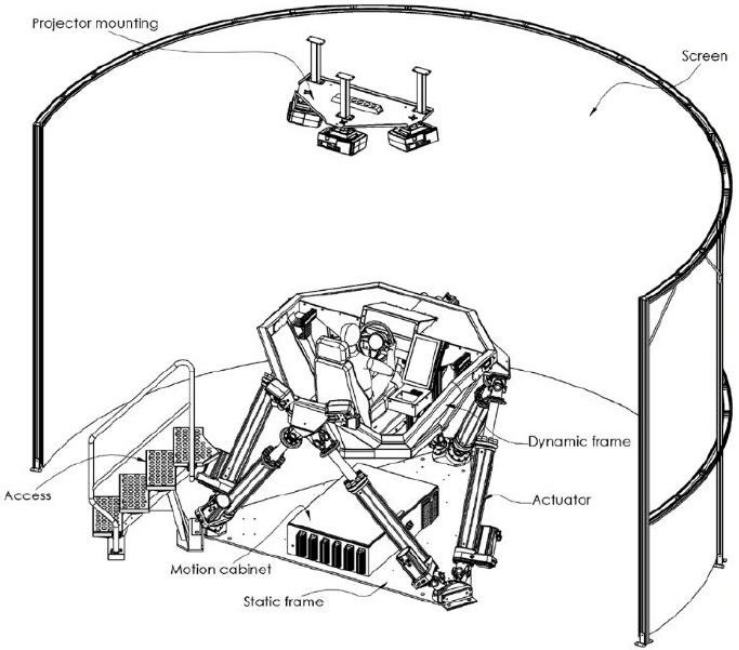
Sensor E-Scooter

Driving Simulator

Manual Driving & Autonomous Mode

<u>Technical Details:</u>

- Motion System: 6 Degrees of Freedom (DOF)
- Visual System: 200° Field of View, 4K per Beamer + Configurable HMI Screen
- Software: Unity, Panthera, SUMO



VRU Simulators

Augmented Reality Co-Simulation

TUM Test Intersection

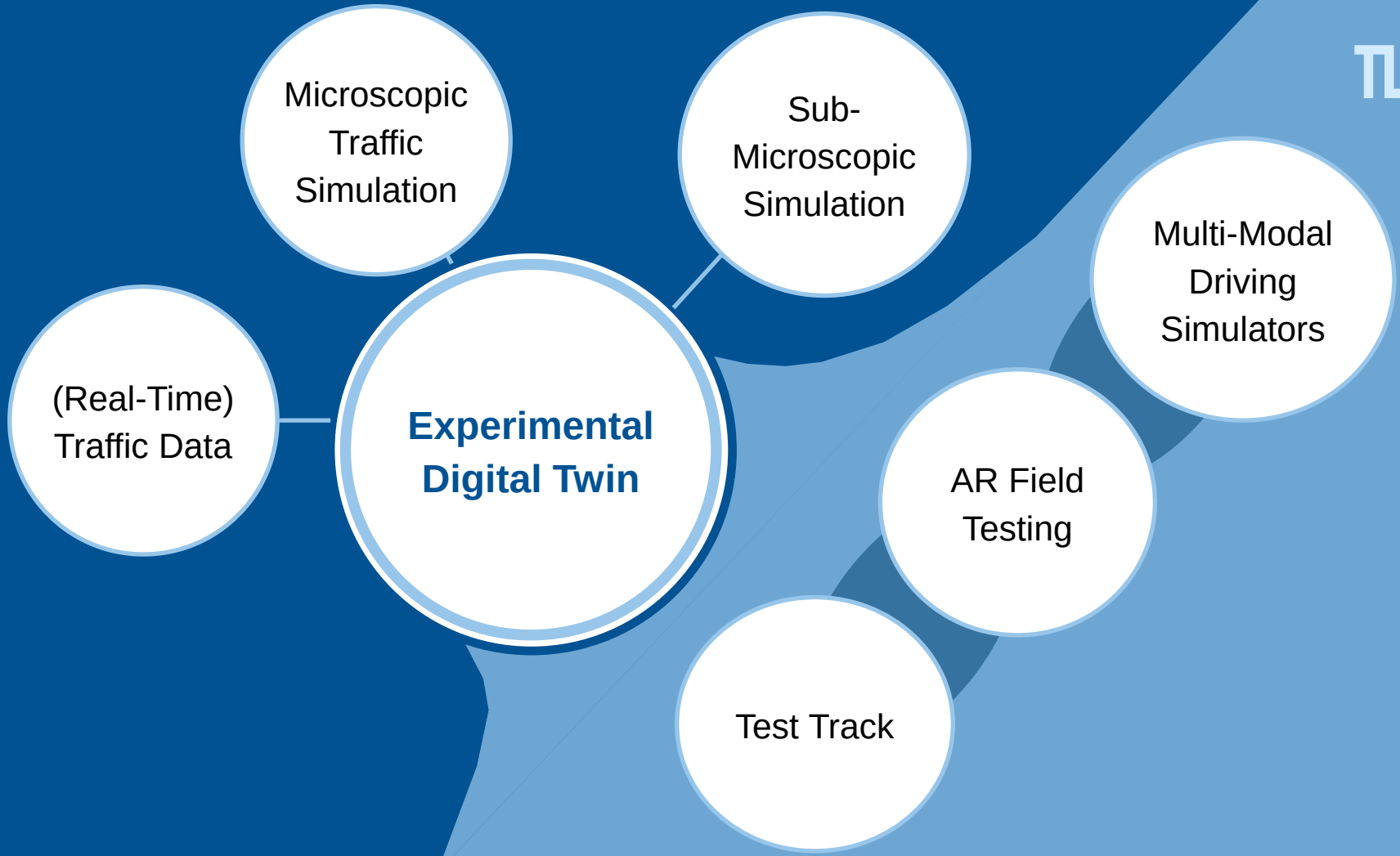
Microscopic Traffic Simulation

- **SUMO**
- VISSIM
- AIMSUN

Human in the Loop (HIL) Simulators

- Bicycle Simulator
- Wheelchair Simulator
- Escooter Simulator
- ….

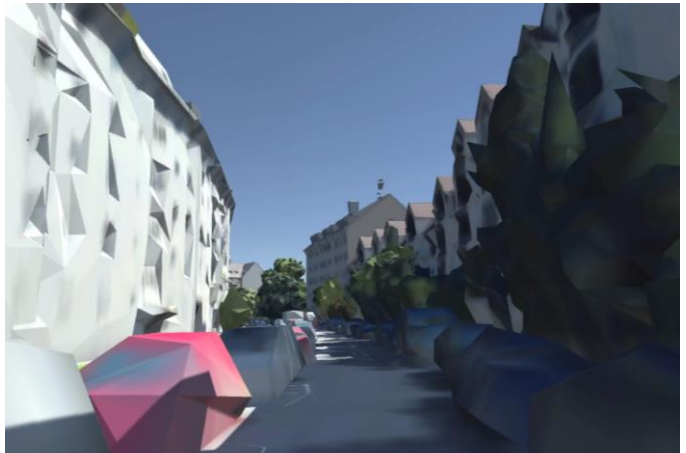
Reality | **Mixed & Augmented Reality** | **Virtuality**


Microscopic Traffic Simulation
Sub-Microscopic Simulation
Multi-Modal Driving Simulators
(Real-Time) Traffic Data
Experimental Digital Twin
AR Field Testing
Test Track

Different Use-Cases have different Requirements

- Not usable for sub-microscopic testing in driving simulators, but for some microscopic use cases and visualizations
- Lack of data collection methods on street level → Manual Modelling Required

Arial Flight Mesh Data (Geodata-Service Munich)
Location: Leonrodplatz, Munich



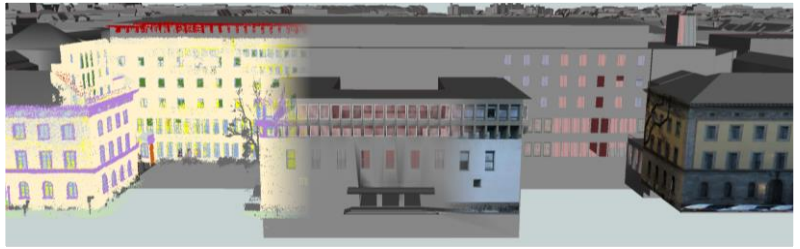
Ego-Perspective on Street Level of same dataset

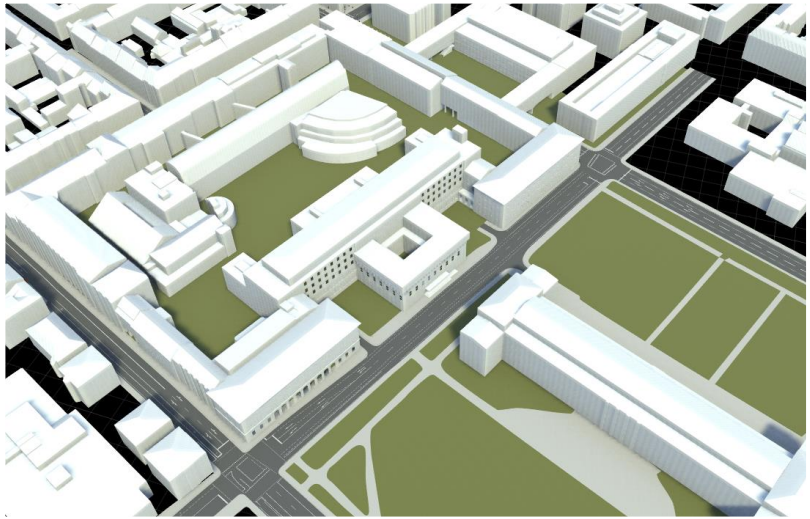
TUM 2 TWIN

The interdisciplinary project at TUM for creating high-quality digital twin.

Creating detailed digital twins is **time-intensive** and requires a wide range of **expertise**.

Five research groups from the engineering and computer science department.





Reference: https://github.com/tum-gis/tum2twin/blob/main/docs/screenshot.png

Prof. Dr.-Ing. Klaus Bogenberger
Johannes Lindner, M.Sc.
Dr.-Ing. Mathias Pechinger

Connect with us!