Integrating Topographical Map Information in SUMO to Simulate Realistic Micromobility Trips in Hilly and Steep Terrains

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**Micromobility**
Micromobility is an auspicious approach and an alternative way of travelling that can reduce the use of private vehicles.

**Number of automotive vehicles**
The number of automotive vehicles increases more and more in urban areas, cities are faced with congestion, noise and pollution.

**Growing population**
Two thirds of the world’s population live in cities.

**Challenge: Elevations**
Micromobility gets challenging if there are altitude differences that have to be overcome during a trip.
- This causes imbalance problems (stations are more full or empty)
- This implies that users cannot freely borrow or return vehicles anymore
- Stations at higher altitudes are more likely to face a shortage of vehicles
- Altitudes have an additional effect on the battery consumption in steep terrain

**Requirement:**
These challenges need to be taken into account and should be further investigated using Simulation.
Introduction
Parts of the work

- This paper investigates micromobility for electric vehicles in combination with hilly and steep terrain.
- There are three important parts this work is dealing with:

**Part 1:**
Defining Workflow

**Workflow**, which describes steps to prepare and define a simulation model for the tool SUMO in the context of cities with steep terrain.

**Part 2:**
Creation of a Scenario

Creation of a **micromobility simulation scenario** using the presented workflow.

**Part 3:**
Validation

**Validation** by analyzing the results of the simulation scenario.
Micromobility Scenario with Topographical Map Information
Using Stuttgart as Example

- For the simulation of micromobility a map with different altitudes is necessary
- We choose an area of Stuttgart as Stuttgart has the following characteristics
  - Interesting topographic structures with altitude differences of more than 300 meters
  - The center of Stuttgart lies in a sink at a height of 245 meters
  - There are different valleys with various lengths and different elevations

Figure 1 shows the different altitudes in and around Stuttgart. Especially, the southeast of Stuttgart has various and changing altitudes.
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Part 1: Defining Workflow

The workflow consists of **three steps**:

1. **Building the simulation model**
2. **Integration of elevation data**
3. **Integration of micromobility stations**

*Figure 2. Steps and validation of the workflow*
Part 1 – Defining Workflow
Building the simulation model

1. Building the simulation model
2. Integration of elevation data
3. Integration of micromobility stations

OSMWebWizard → Initial Net File
Part 1 – Defining Workflow
Building the simulation model

<?xml version="1.0" encoding="UTF-8"?>
  <vType id="e_bicycle" length="1.6" width="0.65" height="1.7" minGap="0.5" accel="1.2" decel="3" emergencyDecel="7" maxSpeed="13.89" desiredMaxSpeed="5.56" emissionClass="Energy/unknown" vClass="bicycle" speedDev="0.1" color=""/>
  <param key="has.battery.device" value="true"/>
  <param key="Device.Battery.capacity" value="400"/>
  <param key="maximumPower" value="250"/>
  <param key="vehicleMass" value="100"/>
  <param key="frontSurfaceArea" value="0.5"/>
  <param key="airDragCoefficient" value="1.1"/>
  <param key="internalMomentOfInertia" value="0.01"/>
  <param key="radialDragCoefficient" value="0.1"/>
  <param key="rollDragCoefficient" value="0.01"/>
  <param key="constantPowerIntake" value="100"/>
  <param key="propulsionEfficiency" value="0.99"/>
  <param key="re recuperationEfficiency" value="0.1"/>
  <param key="stoppingThreshold" value="0.1"/>
</vType>
<trip id="test_ebike" type="e_bicycle" depart="0.00" departLane="best" from="4821805#1" to="96266013#0"/>
</routes>
Part 1 – Defining Workflow
Integration of the Elevation Data

- **SUMO provides** a capability to process elevation data from the OSM data by using the “ele”-tag
- However, the **elevation** is used for **prominent topological areas** (mountain ranges and peaks)

- For a more **realistic** simulation model, we add the topography information to **all available geographical locations** within the SUMO model
- We used an Open Topo Data REST-service
- We divided it into three parts

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**Figure 4. Overview over the steps to integrate elevation data**
Part 1 – Defining Workflow
Integration of the Elevation Data

Extraction
- Extracts five plain files from the osm.net.xml.gz file using the netconvert -s command with the --plain-output-prefix attribute.
- The plain files contain concrete information about the network topology and geometry.

Figure 4. Overview over the steps to integrate elevation data
Part 1 – Defining Workflow
Integration of the Elevation Data

Integration

- The node.xml and edge.xml are the files of interest as they contain geographical information.
- For the node.xml and edge.xml the elevation are fetched from the API.

node.xml file:
- All nodes have geographical points \((x, y)\)
- The elevation is added by a “z”: \((x, y, z)\)

edge.xml file:
- An edge has geographical points within a shape: \((x_1,y_1 \ x_2,y_2 \ x_3,y_3)\)
- The elevation is added by a “z”: \((x_1,y_1, z_1 \ x_2,y_2, z_2)\)

Figure 4. Overview over the steps to integrate elevation data
Part 1 – Defining Workflow
Integration of the Elevation Data

Converting
- Uses the `netconvert` command to convert the five plain files back to the `osm.net.xml` file
  - by using certain command attributes for the existing plain files such as `--node-files` for the node file.
- **Result:**

Figure 4. Overview over the steps to integrate elevation data

Figure 5. SUMO model enriched with elevation data displayed in sumo-gui with 3D view
Part 1 – Defining Workflow
Integration of Micromobility Stations

Integration
- Using OSM data or General Bikeshare Feed Specification Data (GBFS)
- GBFS Advantages:
  1. Up-to-date station data
  2. Possibly further data like number and type of available vehicles at the station
- RegioRadStuttgart
- Process:
  1. Reads station_information.json and the SUMO net file
  2. Maps station locations to SUMO edges
  3. Outputs an xml file with stations as points of interest

Figure 6. Workflow to utilize GBFS-Data for SUMO Micromobility Simulations
Part 2
Creation of a Scenario

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Validation
What and Where

- With micromobility trips between docking stations
- **Validation of the workflow**
  - By checking:
    - Altitude differences
    - Availability of docking stations
    - Energy consumption of the e-bicycle
- Route between two elevated docking stations
  - Route lowest point at 276m
  - Route highest point at 472m

*Figure 8. Route for validation of the implemented workflow*
Validation

Comparison

- Comparison
  - With elevation data
  - Without elevation data
- Electricity consumption without elevation data grows linearly with time – unrealistic
- No recuperation -> no negative electricity consumption
  - Still, reduced consumption
- Electricity consumption dependent on the slope

Figure 8. Consumption and elevation change over time

(a) Electricity consumption over time  
(b) Elevation change over time
Conclusion

- **Workflow for the inclusion into SUMO simulation models**
  - Elevation data
  - Docking station data

- **Elevation data from REST API**
  - No need for expensive topographical map data

- **Validation with a scenario using an e-bicycle vehicle type in a hilly area**
  - Comparison with and without elevation
Future Work
Possible working contents for the future

More infrastructure
Considering of more infrastructure details such as bridges or tunnels

Elevation feature
Integration of an elevation feature within the OSMWebWizard (without request limitation)

Tool for micromobility fleet scenarios
Tool to generate shared micromobility fleet scenarios from origin-destination tables representing customer interests

Driving behaviour
Considering of the driving behaviour (speed and acceleration) of micromobility behaviour
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Related Work (Damir)

Topic elevations and bicycles

In reference to elevations

- **Monaco SUMO Traffic (MoST) Scenario** [1]
  - First freely-available mobility scenario for SUMO with elevation
  - The scenario covers an area of approximately 70 km²
  - It contains predefined routes for pedestrians, for different kinds of vehicles and the local public transport system

- **SUMO Activity Generation (SAGA) framework** [2]
  - Is based on the MoST scenario
  - Provides a workflow and a tool chain to create complex multi-modal activity-based simulation scenarios
  - SAGA extracts streets infrastructure and environmental features (e.g., parking areas, buildings, and PoIs)
  - It supports multiple travel modes (i.e., walking, cycling, public transport, on-demand mobility and user-defined vehicles)

In reference to bicycle modeling

- **The State of Bicycle Modeling in SUMO** [3]
  - Stated that micromobility vehicle types are becoming more and more important within simulations

- **Framework for Simulating Cyclists in SUMO** [4]
  - Allows a more realistic modelling of cyclists by allowing a higher degree of freedom of movement
  - They considers cyclists and their behavior intermediate between motorized vehicles and pedestrians.

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**Commands**

**Converting Plain Files**

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**Extract plain files from OSM File**

```
"netconvert -s PATH_TO_OSM_FILE+ " --plain-output-prefix " + PATH_TO_PLAINFILES_DIR + "/PLAIN"
```

**Convert plain files to OSM File**

```
netconvert
  --node-files=PATH_TO_PLAIN-NODE-FILE
  --edge-files=PATH_TO_PLAIN-EDGE-FILE
  --connection-files= PATH_TO_PLAIN-CON-FILE
  --type-files= PATH_TO_PLAIN-TYPE-FILE
  --tllogic-files= PATH_TO_PLAIN-TLLOGIC-FILE
  --output-file=PATH_TO_OSM_FILE + osm.net.xml
```