2018 21st International Conference on Intelligent Transportation Systems (ITSC)
Maui, Hawaii, USA, November 4-7, 2018

A bicycle simulator for experiencing microscopic traffic flow simulation in urban environments

Andreas Keler[1], Jakob Kaths[2], Frederic Chucholowski[2], Maximilian Chucholowski[2], Georgios Grigoropoulos[1], Matthias Spangler[1], Heather Kaths[1], Fritz Busch[1]

1. Chair of Traffic Engineering and Control, Technical University of Munich (TUM), Munich, Germany

2. TESIS Gesellschaft für technische Simulation und Software mbH, Munich, Germany

Email: andreas.keler@tum.de

***Abstract*— Urban environments often imply complex transportation infrastructures with manifold different traffic participant using various modes of transport. These traffic participants interact with each other in different ways, often in specific patterns of communication. One option for understanding these interactions may come from microscopic traffic flow simulations. Simulated traffic on modelled urban transportation infrastructures may deliver insights on general traffic-related problems or show specific locations of high risk of accidents or of low traffic quality. Besides having a general view on microscopic traffic flow simulation results, we propose one option for experiencing these simulations from a first-person perspective visualization as one interacting traffic participant on a non-moving physical bicycle. We introduce a procedure for implementing a bicycle simulator for testing various scenarios in three-dimensional environments. By including individual real-time bicycle movements of test subjects into ongoing traffic simulations, we are able to derive individual behavioral strategies to cope with the modelled transportation infrastructure and with simulated vehicle drivers, bicyclists and pedestrians from the point of view of an urban bicyclist. We aim to introduce a novel technique for (1) analyzing present problems of traffic and built infrastructural elements, and, (2) inspecting planned scenarios with variations in traffic compositions (participants and modes) and built infrastructure (inclusion of new design elements). One first test scenario is implemented for gaining first insights on the usefulness of the presented device.**

Keywords—bicycle simulator, microscopic traffic flow simulation, three-dimensional visualization, bicycle traffic, urban traffic

I. Introduction

Traffic in urban environments is complex in many ways. One aspect of this complexity are multiple different traffic participants that interact with each other while traveling through the environment. One option for getting more insights on specific recurrent traffic patterns and at specific regularities of traffic at selected locations of the road network is analyzing the trajectories of every traffic participant at site. Due to the densely-built urban infrastructure, this is often not possible due to restrictions of positioning devices (as for example in urban canyons) or due to restricted views during video observations. Another traffic analysis option that may be less data-driven is simulating microscopic traffic flow. By defining groups of traffic participant, assigning different movement and behavioral models, it is possible to simulate traffic for different investigation networks, which has a long tradition. Reconstructing road network partitions for simulating traffic for different traffic participants can be challenging, since vehicle roads, bicycle lanes and pedestrian paths have specific interaction spaces. After conducting simulations, the usual matter of analysis can consist of statistics of flows and individual movements. One option for having an alternative view on microscopic traffic flow simulations implies the inclusion of an interactive participation of ongoing simulations. We introduce an extension for this alternative view on traffic simulation in the form of an interactive bicycle simulator. This device consists of a physical bicycle that is connected to sensors that provide individual movements into the simulation environment. The simulation environment resembles present state investigation areas due to its three-dimensional visualization of built infrastructure and other moving traffic participants. The focus of the present work is to show the applicability of a bicycle simulator for conducting traffic-related research. Since the applications are traffic-related, one important property of the bicycle simulator is to model present state transportation infrastructure and to compare individual movement with real-world movement trajectories of traffic participants. While its application with test subjects, traffic participants are modelled and simulated for specific time windows. Variations of the built environment, as well as of the compositions of traffic participants are the options for gaining new insights into bicycle traffic and its impact on the environment. Therefore, this work inspects the applicability value of collecting reasonable data.

II. State of the Art in Constructing and Using Bicycle Simulators for Traffic-Related Research

In general, we have to distinguish between different types of simulators and simulations, and, clarify, which of the application has direct connections with modelling and simulating traffic. Similar to the idea of constructing car simulators, there are options for adapting to other modes of

978-1-7281-0323-5/18/$31.00 ©2018 IEEE

traffic as for example bicycles. Usually, the research questions on virtual reality (VR) applications can come from the field of psychology, partly traffic psychology, and, can imply qualitative data analysis, as tests can base on evaluations via questionnaires. Nevertheless, it is possible to acquire trajectories of bicycle trips of the bicycle simulator test subjects. Early work on interactive bicycle simulators ([1], [2]), as for example the KAIST bicycle simulator from 2001 [3], focus more on the perception of the VR simulator environment and how sensors are connectable to the experienced interactive movement. More recently, bicycle simulator applications have more traffic-related focuses, even though the perceptional aspect is still of high importance. Table 1 shows a few recent examples of constructed bicycle simulators used in traffic-related research.

TABLE I. SELECTION OF BICYCLE SIMULATORS USED IN TRAFFIC-RELATED RESEARCH

Institution with bicycle simulator	**Properties**		
	Simulator and simulation software	***Visualization representation***	***Project aims***
Technical University of Brunswick	SILAB[a]	2 x 3 monitors	Inspection: navigational concepts and perception of infrastructure
University of Missouri	ZouSim	1 monitor (in usage)	Evaluation: bicycle traffic control, facilities design (lane markings)
ETH Zurich, Future Cities Lab	VISSIM, Unity	VR glasses	Evaluation: planned bicycle infrastructure
Technical University of Munich	DYNA4, DYNAani-mation	1 to 3 monitors, VR glasses	Evaluation: bicycle highway designs, countdown timers and interactions to vehicles

a. SILAB software by WIVW, URL: https://wivw.de/en/silab

b. DYNA4, DYNAnimation are products of TESIS DYNAWARE GmbH, URL: https://www.tesis-dynaware.com/en/products/dyna4-framework/overview-benefits.html

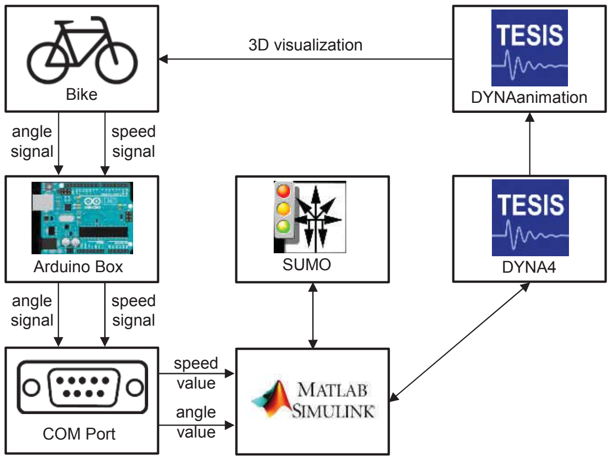
The Future Cities Lab in Singapore has a bicycle simulator that is used for experiencing planned bicycle infrastructure in the city [4]. By designing new transport infrastructure for bicyclists within densely-built urban residential areas in the simulator environment, it is possible to experience modified present states. This experience is supported by sounds coming from other traffic participants as vehicle drivers. Another bicycle simulator makes use of ZouSim, a simulator software that is successively developed by the University of Missouri. The main research focus of applying ZouSim is recently the evaluation of bicycle traffic control and facilities design [5].

III. Describing the Bicycle Simulator with its Hard- and Software Components

The bicycle simulator at the Chair of Traffic Engineering and Control, Technical University Munich, has the purpose of collecting trajectories of test subjects for answering various research questions. Recently, the simulator is used for different research projects that focus on aspects of bicycle traffic: design and evaluation of bicycle highways, countdown timers for bicyclists at urban road intersections, and, inspecting interactions between bicyclists and autonomous vehicles in urban environments.

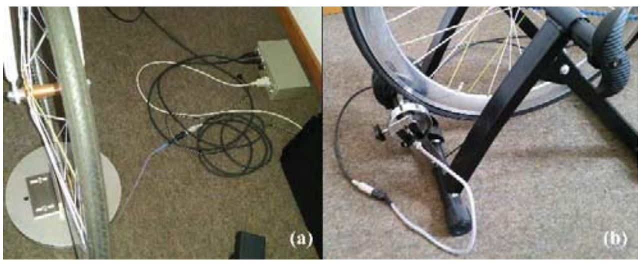
The present state of the used bicycle simulator, which is successively further developed, has hard- and software components that are shown in Fig. 1. Fig. 1 shows as well the workflow of the recent state of the used bicycle simulator construction. Fig. 2 pictures the two sensors that acquire the angle and speed signals.

Figure 1. Flowchart of the data acquisition and processing within the bicycle simulator hard- and software.



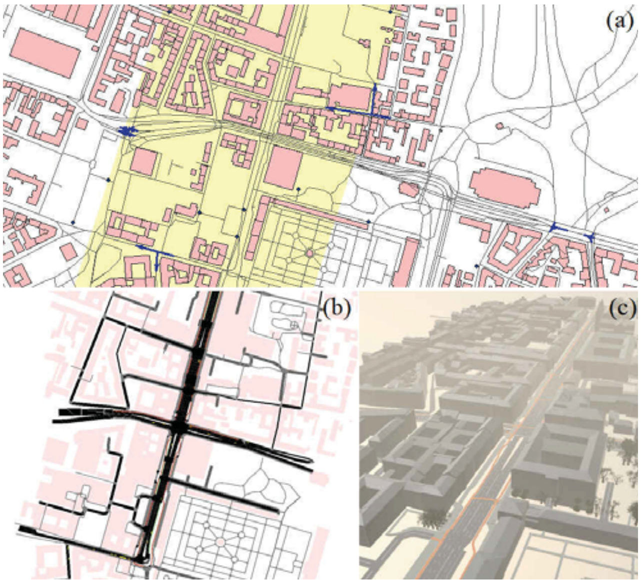
Starting with a physical bicycle that is connected to two identical sensors, magnetic rotary encoders, the information is read out via a microcontroller and sent via COM port to a processor. The incoming data is handled within a model (MATLAB Simulink) that connects the microscopic traffic flow simulation, via the software SUMO ([6], [7]) with the simulator software DYNA4 and DYNAanimation coming from the company TESIS.

Figure 2. Recent construction of the sensors of the bicycle simulator at the Chair of Traffic Engineering and Control (Technical University of Munich), with (a) steer angle, and, (b) speed value acquisition.



The animation of the simulator environment appears in connection with the sensor data coming from the two sensors on the steering plate (Fig. 2a) and the roller trainer (Fig. 2b) attached to the bicycle. As pictured in Figure 1, there is an additional software component for the visualization part: DYNAanimation. The simulator software and the software for microscopic traffic flow simulations have two kinds of connections. The first is the conversion of the road network geodata. This is a critical point of the whole workflow in Fig. 1, since the quality of the created network, its guaranteed connectivity and semantic information is of manifold importance for the later traffic simulation and its visualization. Starting with an extraction step of freely available geodata as from the OpenStreetMap (OSM) project (Fig. 3a), it is possible to imply road network information into the construction of a simulation network as pictured in Fig. 3b. After extraction and conversion, there is a connectivity check required, since this is not guaranteed within the OSM project. Subsequently, the simulation network in Figure 3b is converted into the OpenDRIVE format [8], which is supported by DYNA4 directly without conversion and by SUMO through the integrated conversion tool NETCONVERT. A visualization example of the same investigation area is shown in 3c including building geometries provided by the Bavarian Agency for Digitisation, High-Speed Internet and Surveying.

Figure 3. Road networks in different data formats with (a) OpenStreetMap data extract of the investigation area, (b) resulting and manually adapted microscopic traffic flow simulation network, and, (c) 3D visualization of the converted network in the OpenDRIVE format.

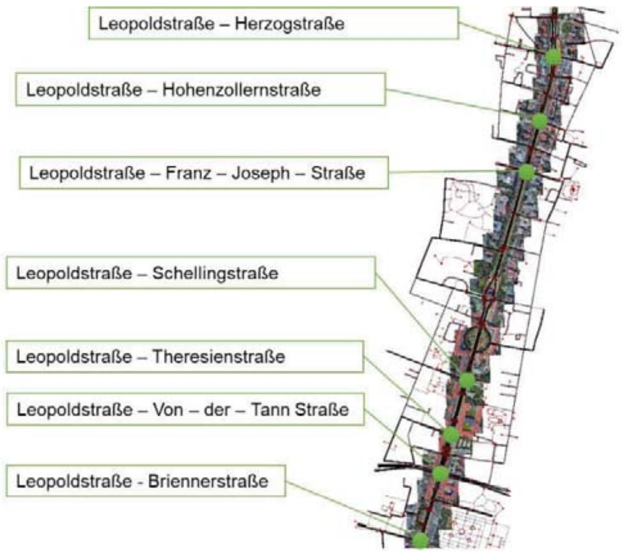


The second connection between the simulator and the simulation software depicts simulated traffic participants via specially designed interface that enables representing movement trajectories in three-dimensional views. The idea is to simulate traffic of vehicles, bicyclists and pedestrians for a selected time window. The bicycle simulator test subject is then assigned as one bicyclist within this simulation. In the respective fields of view within the simulated 3D perspective as in Figure 3c, the other traffic participants are visible and it is possible to interact with them. Every traffic participant type (vehicle, bicycle and pedestrian) has recently a different model for the microscopic traffic flow simulation in SUMO, and, bicyclists can be modelled externally based on the vehicle model [9]. One recently introduced extension of this interface is the transfer of traffic light signaling data for different types of traffic lights (vehicle drivers, bicyclists, pedestrians).

IV. TESTING THE BICYCLE SIMULATOR AND FIRST RESULTS

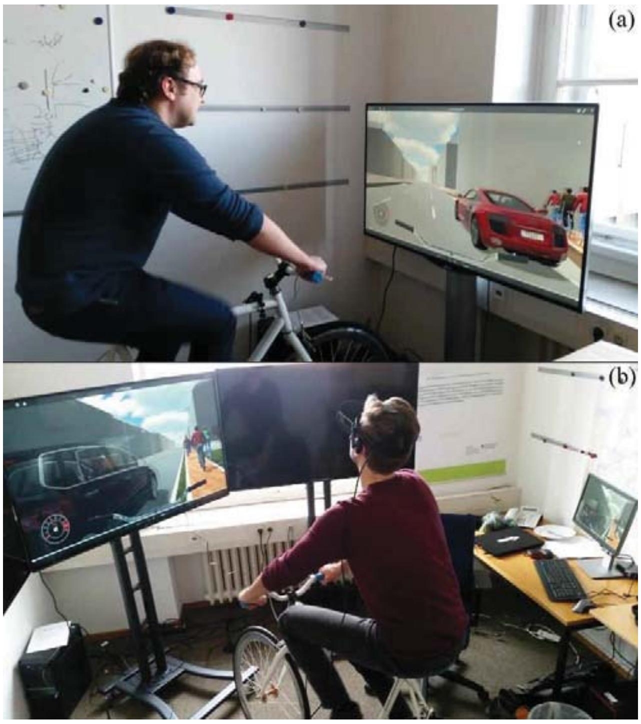
One conceptualized scenario that is successively advanced for applying the bicycle simulator is the implementation and testing of different bicycle highway design elements within the simulator environment. The idea is to modify the already established present state bicycle infrastructure of a densely-built urban environment in the simulation network data. This consists of not only modifying the bicycle roads and lanes into bicycle highways [10], but as well of adapting the traffic light signaling, together with an eventual introduction of bicyclist prioritization. The recently used investigation area is pictured in Fig. 4 and consists of two frequently used roads of the main network in Munich. The investigation area implies a total of 10 road intersections. For every road intersection the city of Munich provided the used traffic signaling plans, and for four intersections the traffic count data for different modes of travel.

Figure 4. Road intersections of the investigation area with traffic light signaling information.



These input data are the base for representing more or less realistic traffic flows and volumes. Nevertheless, varying traffic flow and volumes according to different cross sections and widths of bicycle highways is part of the analyses. Every scenario has specified times of the day and predefined vehicle and bicycle type compositions for covering differing conditions in comparison with the present state conditions that rely on real traffic data observations. For guaranteeing comparable conditions, one has to focus on the measures of investigation that can be compared throughout the different scenarios for one investigation area. These measures can be classified into two groups, which focus on traffic safety and traffic quality aspects for the test subject. Additionally, important measures are different interactions with the present traffic rules, as red light violations or leaving the bicycle paths onto the vehicle roads as pictured in Figure 5a. One extension of experiencing the traffic situation on one monitor, as in Fig. 5a, is to include audio data into the simulation environment, which is helpful for interacting with vehicles. Since the following vehicle behind a riding test subject is not visible, audio information can help orientating in a complex and dynamic environment. Another, possibly more realistic, option is the usage of VR glasses, which allows the test subjects to turn their heads while riding the bicycle as pictured in Fig. 5b.

Figure 5. First bicycle simulator tests with test subjects experiencing the simulator environment with (a) one monitor, and, with (b) VR glasses.



The option in Fig. 5b allows closed test conditions without observers being noticed by test subjects, since eyes and ears are visually and acoustically consumed by the simulation.

Currently, the usage of the presented bicycle simulator focusses on different research questions that can be classified into two different groups. One group of research questions consists of inspecting the feasibility in mapping the real environment in a detailed (specific static and dynamic objects) and accurate (georeferenced and precise measurements of the infrastructural elements) manner. The evaluation of the reproduced static and dynamic objects of the real world is possible via test rides on the simulator. More specifically, by comparing resulting distances to lane markings or speed value differences for maneuvers approaching intersections. Additionally, including varying traffic situations (varying number of traffic participants) might deliver further insights on typical and usual movement dynamics. In case of designed bicycle highway infrastructural elements, this means that the test subject has to move on the roads and lanes designated to bicyclists and inspect the perceived simulation environment for specific scenarios.

V. Outlook

The presented bicycle simulator is used, in different technical constellations in simulator studies with test subjects. Depending on the focus of analysis, different types of test subject studies are conducted. Within the project RASCH, we analyze the differences in bicycle traffic safety and quality, when designing and implementing two different types of bicycle highways in the simulation environment.

Acknowledgment

The presented bicycle simulator was constructed within the ongoing research project RASCH ("RASCH RAdSCHnellwege: Gestaltung effizienter und sicherer Infrastruktur") on designing efficient and secure bicycle highway infrastructure funded by the BMVI (Federal Ministry of Transport and Digital Infrastructure).

References

[1] Q. He, X. Fan, and D. Ma, "Full bicycle dynamic model for interactive bicycle simulator," J. Comput. Inf. Sci. Eng., vol. 5, no. 4, pp. 373–380, 2005.
[2] S. Yin and Y. Yin, "Implementation of the interactive bicycle simulator with its functional subsystems," J. Comput. Inf. Sci. Eng., vol. 7, no. 2, pp. 160–166, 2007.
[3] D.-S. Kwon et al., "KAIST interactive bicycle simulator," in Robotics and Automation, 2001. Proceedings 2001 ICRA. IEEE International Conference on, 2001, vol. 3, pp. 2313–2318.
[4] F. Schramka, S. Arisona, M. Joos, and A. Erath, "Development of a Virtual Reality Cycling Simulator.," JCP, vol. 13, no. 6, pp. 603–615, 2018.
[5] C. Sun and Z. Qing, "Design and Construction of a Virtual Bicycle Simulator for Evaluating Bicycle Traffic Control and Facilities Design," in TRB Annual Meeting Washington, D.C. January 2017, 2017.
[6] D. Krajzewicz, J. Erdmann, M. Behrisch, and L. Bieker, "Recent development and applications of SUMO-Simulation of Urban MObility," Int. J. Adv. Syst. Meas., vol. 5, no. 3&4, pp. 128–138, 2012.
[7] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "SUMO–simulation of urban mobility: an overview," in Proceedings of SIMUL 2011, The Third International Conference on Advances in System Simulation, 2011.
[8] A. M. Orozco Idrobo, "Extension of the Geospatial Data Abstraction Library (GDAL/OGR) for OpenDRIVE Support in GIS Applications for Visualisation and Data Accumulation for Driving Simulators," Technische Universität München, 2015.
[9] H. Twaddle, G. Grigoropoulos, and F. Busch, "Integration of an external bicycle model in SUMO," in SUMO 2016–Traffic, Mobility, and Logistics Proceedings, 2016, pp. 93–102.
[10] FGSV, "Einsatz und Gestaltung von Radschnellverbindungen," 2014.