Using Interactive Space-Time Cube Visualisation for Pattern Mining in Bicycle Trajectories and Traffic-Related Parameters

Andreas Keler[*1,2], Sylvia Ludwig[2] and Chenyu Zuo[3]

[1]Applied Geoinformatics, University of Augsburg
[2]Chair of Traffic Engineering and Control, Technical University Munich
[3]Chair of Cartography and Visual Analytics, Technical University Munich

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Summary

This work focuses on the visualisation of bicycle trajectories at an urban junction in Munich, Germany, using a Space-Time cube (STC) approach. The trajectories are obtained from a traffic observation using computer-vision-based approaches and pre-processed for analysis. A GUI implementation in MATLAB is introduced for evaluating the usefulness of the STC technique for transport planning and engineering purposes, with a focus on evaluating traffic safety. The visual patterns are evaluated by experts based on the quality of five interactive components of the implemented STC GUI.

KEYWORDS: data processing, data visualisation, space-time cube, traffic analysis, bicycle trajectories

1. Introduction

Long-term observations of road users at urban junctions can reveal different aspects of varying traffic efficiency, safety and comfort – especially for VRUs such as cyclists. Cities can benefit from novel and established visualisation techniques to address the needs of cyclists – by getting insights on for example red light violations, conflicts and delays (partially dependent on the present traffic control strategies) through obtainable spatiotemporal patterns.

In this work, we focus on the visualisation of bicycle trajectories in a Space-Time cube (STC) at the junction of Theresienstraße and Ludwigstraße in Munich, Germany. The trajectories have a high spatiotemporal resolution as they are obtained from applying computer-vision-based approaches for extracting detected, classified and tracked road users from video data coming from a traffic observation (with static video sensor). After pre-processing the extracted trajectories, we select only trajectories of the road user type cyclist based on the previous road user classification. Additionally, data of the traffic light signalling provided by the city of Munich was included as additional input for visualisation.

In the following steps, we introduce a GUI implementation in MATLAB with user-defined filtering functions and other visualisation options. This STC GUI implementation is used for evaluating the usefulness of the STC technique for transport planning and engineering purposes, which is practically realized by introducing the respective domain knowledge into the practical testing of the tool. This comes together with our initial motivation of evaluating traffic safety, which is usually differentiated into direct measures (traffic accidents, crashes) and indirect measures (traffic conflicts) as they are defined by Hydén (1987).

The detectable visual patterns are being evaluated by six experts based on the quality of five interactive components of the implemented STC GUI.

[*] andreas.keler@uni-a.de

2. Space-Time Cube for Visualizing Bicycle Trajectories - Methodological Approach

The trajectories of observed cyclists at an urban junction in Munich (signalized) originate from a data acquisition via window-mounted video camera(s) at the Bavarian State Library within the Project "RadOnTime" (2018), which is summarized in Kaths et al. (2021). The data was recorded with a frame rate of 30 frames per second. In general, there are various computer-vision-based options for extracting trajectories from raw video data such as the software "TrafficIntelligence" by Nicolas Saunier (Saunier et al., 2007). The procedure was partially outsourced via the software DataFromSky provided by RCE systems s.r.o.: after converting each individual video frame to an orthophoto, road users are detected using computer vision methods, localised and tracked between the georegistered video sequences (Adamec et al., 2018). A practical example is pictured in **Figure 1** with a raw video frame (left) and the resulting orthophoto with detected road users and respectively visualized trajectories (right).

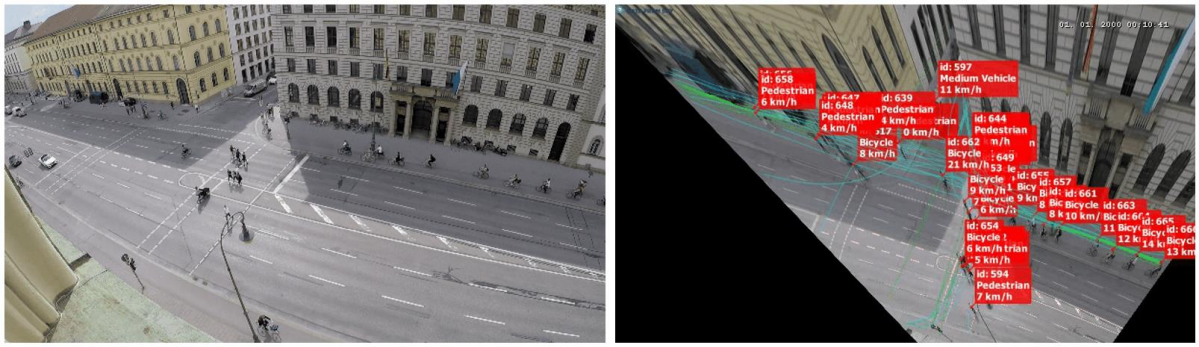

Figure 1 Raw Video Data (left) and Extracted Road User Trajectories after Data Pre-Processing.

For the upcoming visualisation of trajectories merely 260 bicycles of a total of 1113 detected road users are considered, which corresponds to one half of the recorded and detected motorcars in the selected time frame of 17 minutes and 40 seconds. The raw dataset is reduced and pre-processed into a transformed dataset of reduced memory storage to improve the performance of the further visualisation methods.

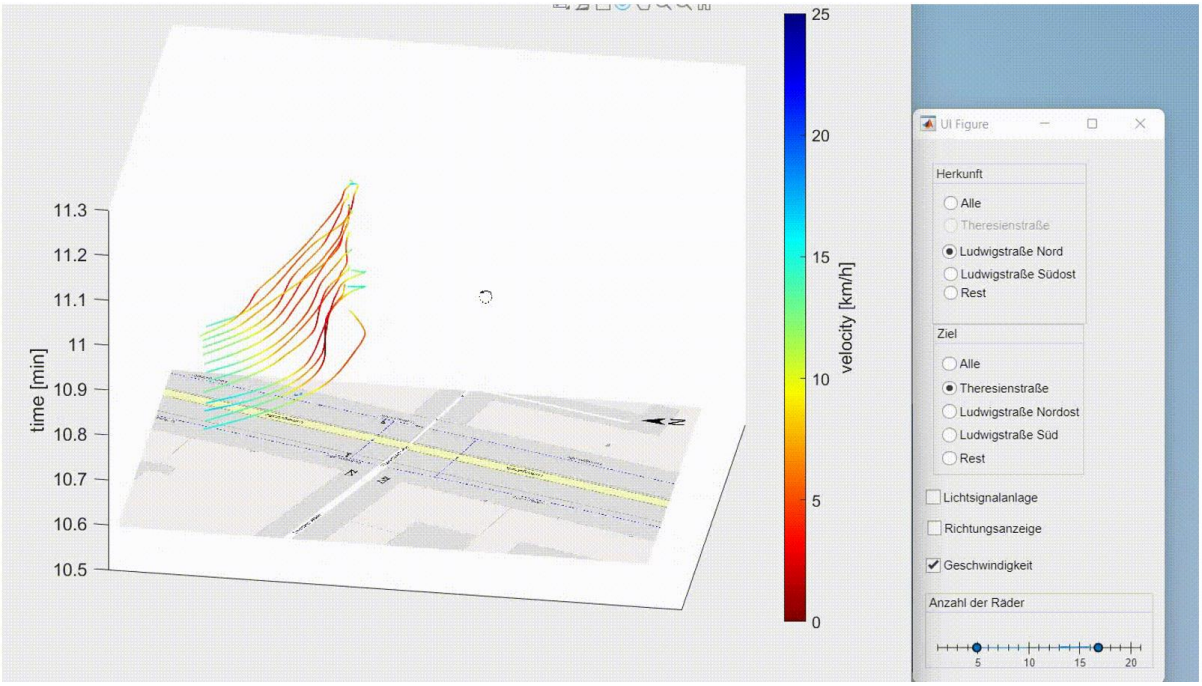

Figure 2 Example for the components of the STC GUI for visualizing cyclists at an urban junction.

An example of the STC GUI design is pictured in **Figure 2** with the components (a) origin and destination selections for all approaches of the junction, (b) phases of traffic light signals intersecting every respective trajectory, (c) movement directional values (arrow symbolisation), (d) speed values, and (e) preselection on number of cyclists. Via the active operation of these five interactive components by a user, it is possible to visually obtain red-light violations of two cyclists going straight marked by the numbers 1 and 2 on the left of **Figure 3**. On the right of **Figure 3** a pattern of one cyclist (marked by number 1) overtaking a group of waiting cyclists during a green phase is depicted.

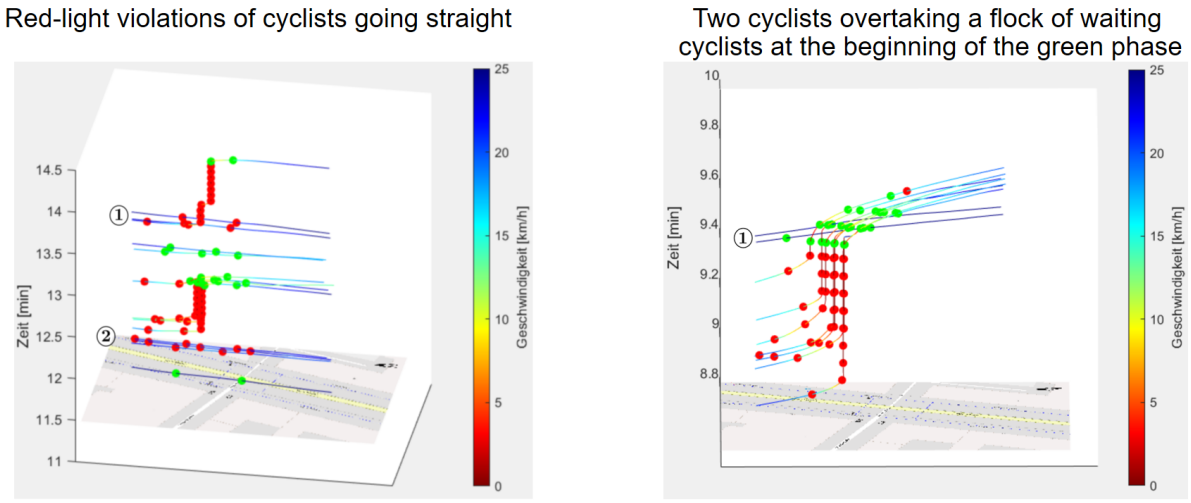

Figure 3 Example STC patterns of two cyclists committing red-light violations (left) and one cyclist overtaking a group of waiting cyclists during a green phase (right).

Other visualisation examples include the crossing behaviour of cyclist flows turning in the same direction but with differences in the manoeuvre shapes as pictured in **Figure 4** on the left. This visualisation technique is also useful for finding misclassification or outliers such as presented in **Figure 4** on the right with trajectories marked in red with unusually low speed values. This is originating from a misclassification of detected road user type within the trajectory extraction steps from the raw video data.

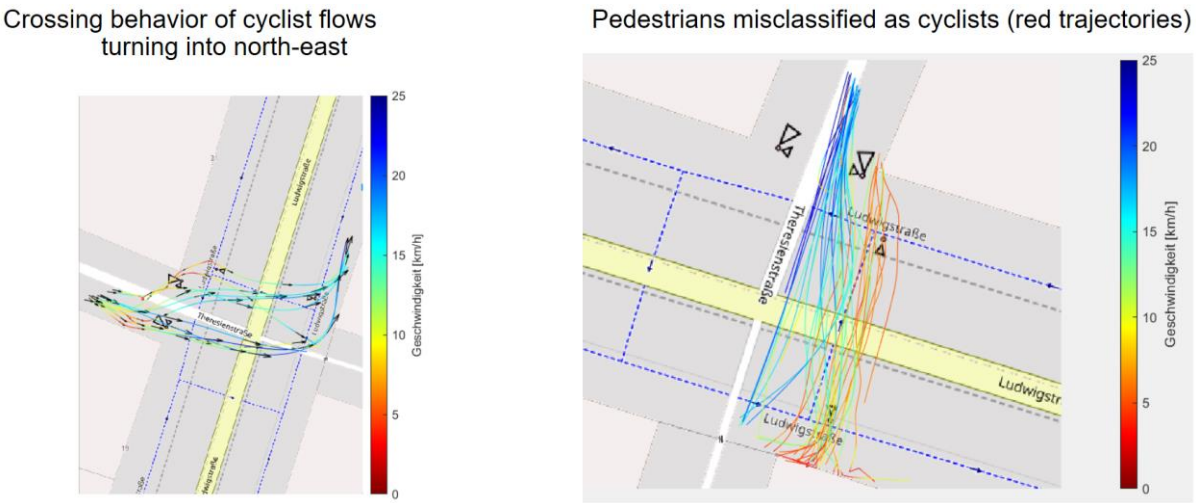

Figure 4 STC visualisation examples of crossing behaviour of cyclist flows (left) and the misclassification of pedestrians as cyclists (right).

3. STC GUI Evaluation

Besides the analysis of the dataset itself, an expert interview was conducted to assess the usability of the implemented GUI. The experts consisted of five traffic engineers and one cartographer, who evaluated the application after practical testing of the features of the GUI. **Figure 5** shows a diagram of the overall evaluation of the implemented GUI.

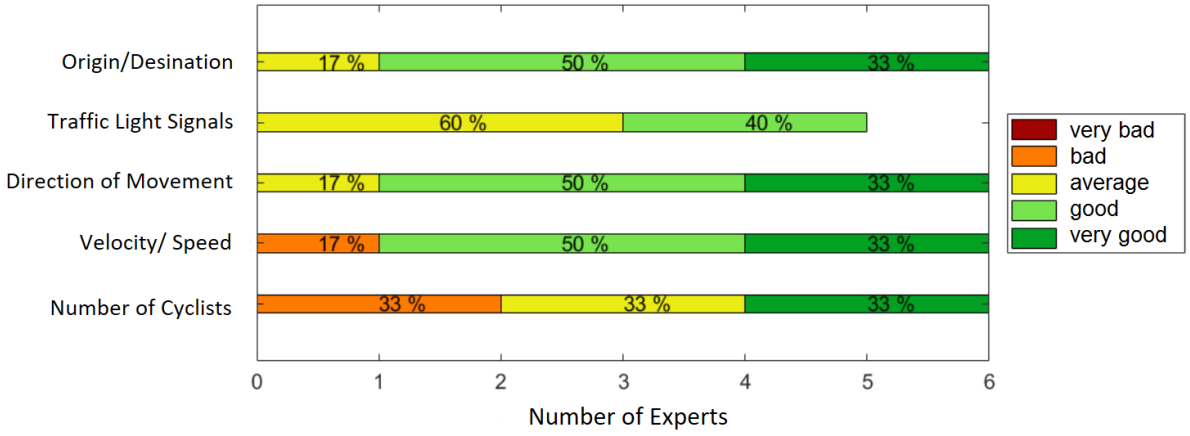

Figure 5 Diagram presenting the overall evaluation of the implemented STC GUI by the six experts.

It is visible that the GUI features related to the speed and the number of cyclists were regarded as partially less useful as the other features.

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Biographies

Andreas Keler, Dr. rer. nat., is a postdoctoral researcher at the at the University of Augsburg, Professorship of Applied Geoinformatics, and worked previously at the Technical University of Munich, Chair of Traffic Engineering and Control, with a focus on the topics modelling and simulation of VRUs.

Sylvia Ludwig, BSc, is a student research assistant at the Technical University of Munich, Chair of Traffic Engineering and Control, and implemented the STC GUI for bicycle trajectory visualisation.

Chenyu Zuo, Dr.-Ing., is a data scientist working previously at the Technical University of Munich, Chair of Cartography and Visual Analytics.