Data Collection and Processing of Multimodal Trajectories Collected by Aerial Drones

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Abstract

This study focuses on the data gathered and processed by a large-scale aerial drone observation in the city of Munich, Germany, continuously for several hours a day and several days with all together twelve camera-equipped aerial drones. The aim was to generate a continuous data set including various interactions of different modes like manual and automated cars as well as active mobility users like pedestrians and cyclists. For this purpose, the urban area drone footage covers trajectories for all those traffic participants which were extracted from the video images and are merged continuously in time and space across several drone observation areas and subsequent time slots. The whole data set will be published open source to ensure global accessibility for further research.

Key Words: *Drone, Aerial Observation, Interaction of Different Modes, Big Data, Open Data*

Introduction

Traffic data nowadays becomes more and more important to understand the behaviour and the strategic, tactical, and operative manoeuvres of traffic participants and to increase with this knowledge traffic safety and traffic efficiency. The need for data is therefore interesting in the field of general traffic behaviour but also of individual traffic manoeuvres like turning, overtaking etc. It gets especially important when looking at the traffic behaviour of vulnerable road users (VRU) like cyclists and pedestrians, as proper data sets about those traffic participants are quite rare and therefore also knowledge about their behaviour in the traffic system is quite limited. For motorized traffic most large-scale datasets also stem from observations on freeways, where the sensor density and the need for traffic detection is also higher and therefore data generation is easier. For urban traffic systems with a much higher variety of different traffic participants and also a more complex road network structure it is rather difficult to use (existing) infrastructure-based sensors like on freeways (Motamedidehkordi 2017) to have a full data coverage of all traffic participants and their interactions. This present work goes one step further and elaborates the use of large-scale drone video footage in combination with innovative recognition algorithms to provide a temporal and spatial full overview of the complete set of all traffic participants. This enables further research to study in particular the interactions between different traffic participants especially motorized road users and VRUs with a focus on traffic safety and to better understand the multimodal traffic patterns. Such data contributes significantly to improve traffic safety and optimize the road network operations (Krajewski 2018, Bock 2019). Another benefit is the availability of such a data set to train further video recognition algorithms and neural networks (Barmpounakis 2020).

The data set was gathered within the Munich TEMPUS project (Kutsch 2022), a project to prepare the Munich urban and suburban road network for connected and automated driving.

Experimental Design

The drone surveys were conducted along Rheinstrasse in Munich, Germany, between Bonner Platz and Leopoldstrasse. Six locations were covered by two drones each, as shown in Figure 1. The drones had a flying altitude of 110 meter when taking the videos, resulting in a recording area of 143 meter on 75 meter for each drone location. With the need for an overlap in between the individual locations for reconstructing the whole trajectories throughout the whole stretch, a total length of 700 meter was recorded. The street is highly frequented and can be classified as a main street. The perimeter includes two signalized intersections, one right-of-way-controlled intersection, two non-signalized T-junctions and two signalized pedestrian crossings. Bicycle traffic in this area is mostly guided on a protective

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lane. For the general traffic and pedestrians in particular, there are several points of interest within the recording area and the immediate surroundings. In addition to a school and a kindergarten, several doctors and pharmacies, as well as numerous shopping facilities, both for groceries and drugstores, and recreational activities are also available. Several restaurants, a sports club and three hotels are located in the area. There are also several access points to public transport, namely a tram and several bus stops on Leopoldstrasse, as well as a Subway access point on Bonner Platz.

Figure 1. The six observation locations in the North of Munich.

Source: Own elaborations based on Google Earth.

Until today, drones have a maximum flight time of around 30 minutes due the limited battery capacity. Various systems, such as balloons and tethered drones with power supply, have been assessed but do not provide the necessary image stability or are not suitable due to the high costs and the approval process, which is difficult to implement in the city centre. Therefore, in order to create a continuous data set, two drones were used for each location, and a 'shake-hands' was performed in the air so that the drone to be replaced only descended when the following drone was in the air and had fixed the image section. Accordingly, a total of twelve drones were in use. They recorded a total of analysed videos amounting to almost 42 hours from their respective single locations. The recordings were performed on Thursday, October 6 and Wednesday, October 12, 2022. The days in the middle of the week were determined according to surrounding detector data in order to capture the most frequented days in the week. On both days, flights were performed in the afternoon in order to be able to depict the leisure traffic as well as the commuter traffic and therefore the peak-hour. On the first day, the last drone was in the air at 15:35, so that a complete image of the entire stretch could be generated. The recordings were carried out until 18:45. On the second day, the first shots were started even earlier to counteract the earlier sunset. Thus, from 15:00 on all drones were in the air, the end of recording was then accordingly at 18:25.

Due to their altitude and mostly unobstructed viewing angle towards the observed road and sidewalk segments, the drones were able to record all traffic participants in the area. The eleven different classified modes include passenger cars, busses, trucks, trams, motorcycles, (e-)bicycles, pedestrians and (e-)kick-scooters. In addition to that, truck trailers as well as bus trailers (in the city of Munich several high-capacity bus routes operate buses with bus trailers) were also recognized and categorized. In addition to those traffic participants the dataset also contains trajectories of an electrified bicycle Rickshaw from the TEMPUS project (Fehn 2023, Margreiter 2023), (E-)Cargo-Bikes and persons with a wheelchair.

Raw Dataset Description

The raw data consists of one data file per evaluated frame in each individual video, i.e., for each location and drone flight. The evaluation frequency was set to 12.5 frames per second, giving then updated information every 0.08 seconds. Within these files, all detected objects within the respective frame are stored with their attributes listed in Table 1. The object category is stored as a numeric value for each category mentioned in the preceding chapter. Category ID 1 as shown in the example would match to the classification as a car. The track ID is a unique number for an object within each video, making it possible to follow objects throughout the frames. The translation describes the location of the respective object, where the values describe the offset with respect to a reference point, which is given in the UTM 32 N (NIMA 1989) coordinate system and is uniform for the entire data set. The value refers to the centre of the bounding box and the bottom of the object, i.e., on the ground. Besides that, the object dimensions are given as length, width and height. The current velocity and acceleration are given as a vector in the respective coordinate system, as well as the rotation describes the current orientation in that system.

Table 1. Extracted data from drone video footage.

Parameter	Description	Example value	Unit
category	numeric classification ID	1	[-]
track_id	numeric unique ID	38	[-]
translation	[x, y, z]	[123.0319, 14.0211, 508.6254]	[m]
dimension	[length, width, height]	[4.2998, 1.9754, 1.4882]	[m]
rotation	[x, y, z]	[-0.0011, 0.0016, 0.1227]	[-]
velocity	[x, y, z]	[10.252, 1.2638, -0.0169]	[m/s]
acceleration	[x, y, z]	[0.0577, 0.0071, -0.0001]	[m/s²]

In addition to the raw dataset, frame matching is performed for each uninterrupted video time series per location. This means that for the videos recorded by two drones in sequence, it is known which frame of the ending video corresponds exactly to the frame of the starting video. Thus, the track IDs for the uninterrupted timelines are available and unique. Due to technical problems, which occasionally led to short interruptions with individual drones, two recording days and six locations, a total of 20 timelines were created. A matching between the locations, as well as further filter applications were not yet carried out and will be described in the next section.

Processing Steps

The raw dataset is cleaned and pre-processed before publication. First, the static objects are tagged. Those static objects which are geospatially outside the street space are sorted out, as they are due to misclassifications. In some places where errors are known to occur, for example at the subway stairways, manual post-processing is done. Static objects that appear temporary but do not move are also filtered out.

The resulting dataset is then merged across the various locations. As described above, the raw data set contains a unique ID for each video per location. To track individual trajectories across multiple locations, the respective track ID must be matched between the locations. Due to the maximum localization error of 15 cm, isolated classification errors, as well as deviations in the speeds, the linking of the trajectories is not quite trivial, especially for pedestrians and cyclists. The linking logic is implemented according to the following description, in order to guarantee a scalable approach.

To ensure the correct time for each location and since the default-times vary slightly between the drones, the dataset is matched on a frame level between the different timelines, choosing one location as a reference timeline, in this case location 2. For each first timestamp, all IDs in the overlapping area need to be determined. Based on their coordinates and thus the Euclidean Distance, their speed vector similarity and the object type, a cross comparison between each object in the respective two overlapping frames is performed and a score for being the same object is calculated. Objects with the respective highest scores are then marked with a global unique ID. Starting from this step, it is now necessary to check for each new frame whether new objects appear in the overlapping section. If this is not the case, the process continues with the next frame. If exactly one object moves into the scope, the IDs can be matched directly. If there are several new IDs in the area under consideration, the scores are determined in each case as before and an allocation is made accordingly. This procedure needs to be repeated for each location change, as well as for each observation gap, which have occurred on a single drone level.

Results and Conclusions

The highly detailed dataset allows applications in traffic flow theory to be developed, validated, and calibrated. For example, the immense ground truth data set can be used to develop car following models, turning behaviour models, link-level traffic flow models, or queue length estimators. In addition, the multimodal trajectories, which include non-motorized road users with a high level of detail, also depict interactions between VRUs and motorized vehicles, both on the open, non-disturbed link, as well as at signalized and non-signalized intersections. Consequently, especially in the presence of different levels of vehicles' connectivity and automation, important conclusions can be derived regarding the impact on traffic flow in urban environments.

Also, regarding traffic safety aspects, having each traffic participant together with the information on the underlying road network, different situations have been captured. Having several different types of intersections, as well as different types of bicycle paths and other infrastructure elements, the dataset is ideally suited for safety analysis.

To enable a wide and global access for scientists and practitioners the drone data set will be published open source. The open data set will include – in addition to the video raw material – all extracted trajectories for all traffic participants continuously in time and space through the whole area covered by all twelve drones at the six locations. It is planned to publish under the Creative Commons CC BY-NC 4.0 license to guarantee easy access and usability for further research.

In beginning of summer 2023 a similar dataset will be gathered in the city of Ingolstadt, Germany, via the KIVI project (Ilic 2022a. Ilic 2022b) funded by the German Federal Ministry of Digital and Transport. Likewise, this data set will be made available open source.

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