7 Predicting Travel Time of a Vehicle in Occluded Area with SUMO

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7.1 Abstract

The work aims to develop robust continuously vehicle-tracking algorithms with aerial images. It concentrates on predicting travel time of a vehicle travelling in occluded areas, such as tunnels and roads under bridges. Microscopic traffic simulation is used to estimate the movement of vehicles on roads, in the case that available information is limited or a large amount of factors are involved, such as intersections with traffic lights and accidents. According to preprocessed data from aerial images, roads, flows and traffic signals are defined and calibrated. Ultimately, the travel time exported from the simulation is regarded as the time to guide a glider to track the vehicle at the end of the occluded area. With outputs of the simulation, the queue length and speed entering a tunnel is compared and assessed by detecting and tracking data from aerial images, which are taken above Munich by 3K cameras on a glider of DLR.

Keywords: vehicle-tracking algorithms, microscopic simulation, SUMO, travel time in tunnels, Altstadtringtunnel in Munich, 3K cameras, aerial images, detecting and tracking data

7.2 Introduction

The work is carried out by the Department of Photogrammetry and Image Analysis in German Aerospace Center (DLR) under the project Chicago, which focuses on tracking vehicles with aerial images [7]. The work concentrates mainly on predicting travel time of a vehicle passing through occluded areas, such as tunnels and roads under bridges, since images taken by cameras in a glider cannot monitor positions of vehicles there. The predicted travel time provides guidance-information for a glider to track a vehicle continuously.

As one of the predictive approaches, microscopic traffic simulation is used to estimate the movement of vehicles on roads, in the case that available information is limited or a large amount of factors are involved, such as intersections with traffic light and accidents. The other approaches are statistical analysis and the cell transmission model [2][3]. For the microscopic traffic simulation, flows and traffic control methods are defined and calibrated according to preprocessed data from aerial images with SUMO [1]. The availability of databases for networks and traffic-control methods determines the feasibility of the microsimulation for tracking vehicles continuously.

The elementary traffic information coming from the images are taken above Munich by 3K cameras on a glider of the DLR [6]. Preprocessed data for detection and tracking from the aerial images are the basic information. Based on the preprocessed data, aggregated traffic data, such as traffic volume, speed and queue length, are derived and used to calibrate the simulation. The roads, the traffic signals and the traffic flows are defined as the basic inputs, while the travel time, the velocities entering the tunnel and the queue length before intersections are the desired outputs from the simulation. The travel time exported from the simulation is then regarded as the time to guide a glider to reach the exit of the tunnel in the research.

7.3 Inputs of Simulation

In the simulation the basic inputs of the simulation are networks and routes. In networks nodes, edges, types and connections of the edges are defined. A file of routes includes all possible paths of vehicles and traffic flow in these paths. Traffic management equipment, such as induction loops and signals are included in the simulation by way of additional files.

7.3.1 Model of Roads

In SUMO networks can be imported from various sources of maps, such as NAVTEQ and Open Street Map (OSM) [1]. However, in this work only a few roads were studied and the roads are with different numbers of lanes. Thus the roads are built in SUMO according to the UTM coordinates of junctions near the Altstadtringtunnel in the orthogonal images, which are processed from photos taken by 3K cameras in gliders [5].

The Altstadtringtunnel, which is studied for the simulation in the paper, is located in the centre of Munich, to the north of the metro-station Odeonsplatz. The nodes in the simulation contain intersections, starting points of roads, points of forks, position of the entrances and exits of the tunnel, points within curves and so on.

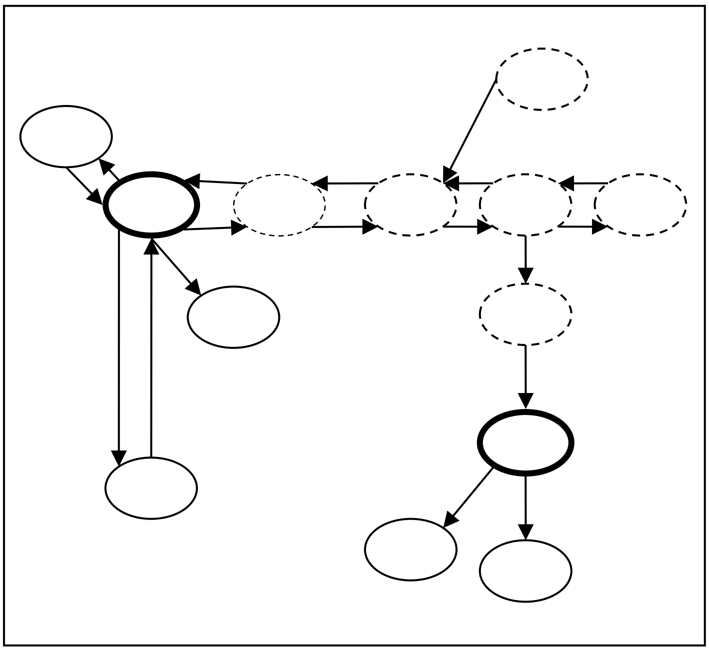

Figure 7-1: Network model of Altstadtringtunnel in Munich

The nodes and edges of the Altstadtringtunnel are illustrated in Figure 7-1, the dotted ellipses are the nodes in the tunnel and the bold ellipses are the signalized intersections. T1, T2, T3 and T4 are the ends of tunnels. T2 is an entrance only and T3 is an exit only. T0 and T33 are the signal-controlled intersections near the tunnel. M5 is the fork point, while M4 is the merging point. It should be highlighted that there is no traffic flow within nodes and U-turns are not allowed. The speed in roads with more than one lane in one direction is 75km/h, since velocity of most running vehicles in these road parts detected from aerial images is beyond

60km/h but below 70km/h. The speed limit of edges of one-lane, such as edges t0-s4, m5-t3 and t33-t34, is 50km/h or 60km/h. Except for the entrance of T2 with one lane and T4 with two lanes, the exits of T3 with one lane and T4 with two lanes, the road consists of three lanes per direction in the tunnel.

7.3.2 Routes and Traffic Flows

First of all, the vehicles are categorized into two types with the length of 5m and 10m. The short vehicle can run with a max speed of 250km/h, while the long with 200km/h. The minimum gaps of the short and long vehicle are 0.5m and 1.2m for safety in the traffic. The ratio of the two types in flows shall be 60:1 based on the observation from the aerial image sequences ON0204-14 at the Altstadtringtunnel.

One flow and a few routes are created based on a departing edge. A route is defined with a sequence of edges and an assigned weight. Then vehicles of one flow will choose a route from the departing edge randomly based on the weights of the route. Figure 7-2 shows the starting and ending points of roads around the Altstadtringtunnel. Zones A, B, C, D are the entrances and A, B, D, E, F, G are the exits of the network.

It should be noted that there was a bus near junction T33, which moved slowly for a few seconds and led to a long queue before the stop line. The bus shall be specially defined with a length of 12 meter. It moved slowly, and nearly stopped while approaching the intersection T33. The bus was inserted at the simulation time 1300s on the edge before T33. Then it stopped at the position of 15m before T33 with the duration of 135s. Some vehicles would overtake it but few might stop behind.

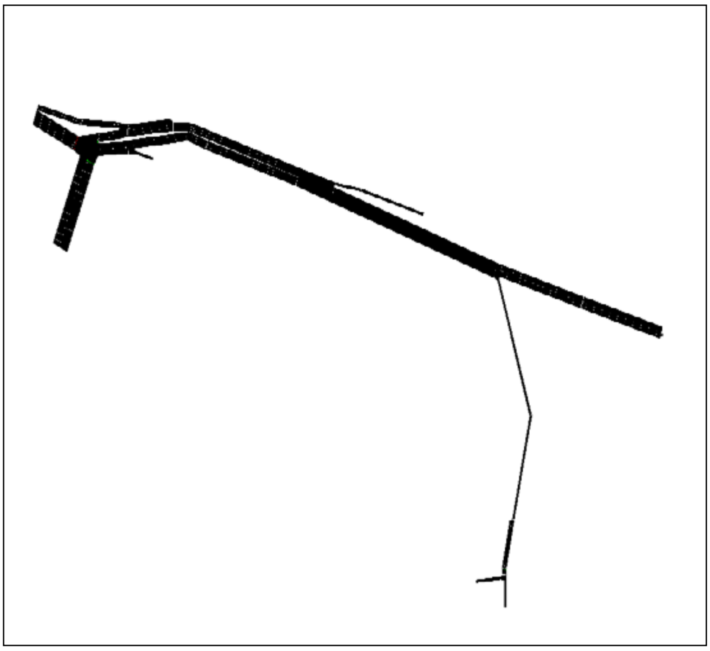

Figure 7-2: Road model of the Altstadtringtunnel in Munich

Table 7-1 shows the routes, flows and assigned weights in the simulation. The flows are calibrated according to the maximum queue length before the intersection. The lanes, in which vehicles depart to enter the roads, are defined as ‘best’, since there would be chaos, if one vehicle turns right but departs from the leftmost lane and another would go straight but depart from the rightmost lane.

Table 7-1: Routes and traffic flows in the study area.

From	To	Flow (veh/h)	Assigned Weights
A	B	900	0.03
	D		1.1
	E		0.05
	F		0.45
	G		0.03
B	D	1100	1.1
	E		0.05
	F		0.45
	G		0.3
C	A	800	0.4
	B		0.75
D	A	1400	0.4
	B		0.75

7.3.3 Signal Groups and Programs

The signal groups are the means of traffic control in the study. Here signal programs are fixed-time. Thus the duration and the phases shall be predefined to run the simulation.

In the junction T0 there are three phases of the signal programs. The phase I is the flow from east to south, the phase II serves the flow from south to east and the phase III serves the flow between east and west. In the simulation non-motorized traffic is not considered, since there is little effect on the traffic flow. The cycle time in the intersection is 100 seconds. The duration of each phase was measured at the intersection at 11:00 on 28th July. The Figure 7-3 illustrates the signal program in the junction T0. The cycle time is 98s in the intersection.

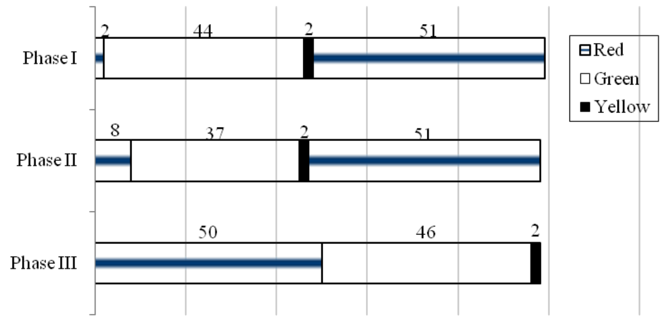

Figure 7-3: Signal Program at the intersection T0 (time unit: s)

The second intersection in the research is T33. It is the intersection after the exit of the tunnel T3 with one lane and extends to two lanes before the stop line. In the junction T33, the cycle time is 90 seconds. The Figure 7-4 shows signal program of T33.

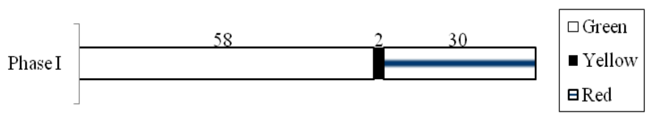

Figure 7-4: Signal Program at the intersection T33 (time unit: s)

7.3.4 Detectors

In order to export the traffic information to files, detectors are set in SUMO. Here three kinds of detectors are installed in the simulation. One is induction loops that record information of traffic flow, such as arriving time, number of vehicles detected. Another is instantaneous induction loops, which are used to get individual ID, speed, arriving, leaving and dwelling time of the vehicles. The instantaneous induction loops are set at the ends of the tunnel to calculate the travel time of vehicles in the tunnel. The last kind of detectors is lane area detection namely E2 detection. They receive information of jams, such as halting time, length of the jam with vehicles and meters and the total number of vehicles influenced in the jam. The lane area detectors cover 40m distance before the stop lines to get the information on the queue.

7.4 Error Checking and Calibration

Before processing the simulation outputs, the simulation clock should match the time series of the aerial images along the Altstadtringtunnel in the center of Munich. The matching base is the offset between the starting time of the first phase in two intersections T0 and T33. The collection and aggregation of traffic data from simulation are done from simulation clock 1431s to 1488s, accordingly aerial images from OF0175 to OF0232 above Munich on 26th April 2012.

Error checking is needed to guarantee that the calibrating process will not be affected by major errors in network and demand. Error checking focuses on three basic stages: software error-checking, input coding error checking and animation review to point out slight input errors [4]. In the research about Altstadtringtunnel the network generated in the simulation matches to the UTM-coordinates [5]. The demand is based on the observation from the aerial images, and then the flows assigned on each path and components of normal and long vehicles are written in the route-file. The inductive loops are set to confirm that the number of the generated vehicles fits the written flows in the route file.

Then the simulation needs to be calibrated to produce a reliable result. Calibration data are composed of measures of capacity, traffic counts and measures of system performance, such as speed and queue [4].

Calibrating factors in the simulation of the Altstadtringtunnel are the max queue length at the exits of the intersections T0 and T33, the velocity of vehicles entering and exiting the tunnel and the right-turning ratio in the intersection. Variables to be revised in the simulation are path choice percentages, the traffic flow and the standing time of the slow-moving bus at the exit T3 of tunnel. The comparison is according to preprocessed data from aerial images. The purpose of simulation is to get travel time in tunnels.

The first targeted calibration data of traffic performance is the queue length at a signalized intersection. The considered period of simulation is from 1430s to 1490s. The queue length of a multi-lane edge is the sum of the number of jammed vehicles on all lanes, since the number of jammed vehicles in the images is counted based on edges and the result will not be influenced by the lane-changing behavior. Table 7-2 shows the result of the calibration considering the measure of the queue length.

Table7-2: Maximum simulating and actual queue length with vehicles.

Queue length with vehicles	Max queue vehicles (simulation)	Max queue vehicles (images)

South of T0	20	21
West of T0	11	-
East of T0	17	17
Straight at T33	12	12
Right turning at T33	4	3

Besides, the speed of vehicles entering and exiting the tunnel needs to be calibrated, since the velocity is decisive for prediction of travel time. The distribution of the velocity during the period of 1430s to 1490s is analyzed statistically. Table 7-3 compares the distribution of the velocities observed in images and through simulation at the entrance T0 and the exit T4 of the tunnel. The variances of velocity entering the tunnel in images are much bigger than in simulation, while the means differ slightly. The speed distribution of the simulation at the exit T4 are displayed almost the same as in reality. However, since we are primarily interested in a general estimate of travel time through the tunnel, a close match with mean is more important than an accurate variance.

Table 7-3: Distribution of velocity entering and exiting the tunnel.

	Velocity (km/h)	Images	Simulation
Entrance T0	Max (km/h)	57.320	52.776
	Min (km/h)	42.264	48.096
	Mean (km/h)	50.028	50.583
	Standard Deviation (km/h)	6.019	1.235
Exit T4	Max (km/h)	69.732	69.948
	Min (km/h)	67.932	68.688
	Mean (km/h)	69.021	69.232
	Standard Deviation (km/h)	0.850	0.432

7.5 Estimation for Performance of Simulation

The travel time is the important result from the simulation. Instantaneous induction loops will be used to calculate the travel time within the tunnel. The time, when one vehicle passes the instantaneous detectors at the entrances and the exits of the tunnel, is recorded in the file ‘travleTime.xml’.

The distributions of the travel time of both paths are shown in Figure 7-5 and Figure 7-6. The result of travel time from T0 to T3 varies greatly, since it is influenced by the congestion at the intersection T33, when the slow-moving bus increases the queue length and the vehicles slow down while approaching the jam. The estimation of travel time of the tracked vehicle is regarded as the same as the vehicle in the simulation with the most similar velocity entering the tunnel. As the result, the glider shall be guided to reach one exit of the tunnel to track the vehicle continuously.

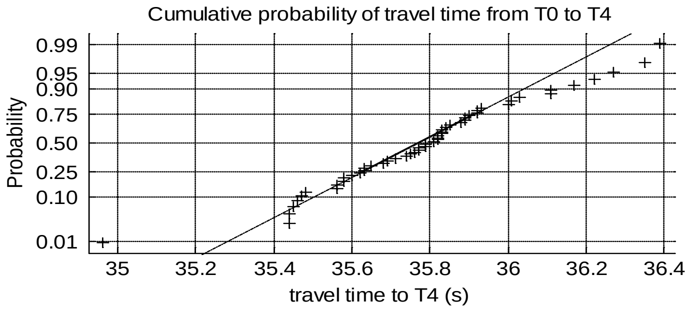

Figure 7-5: Normal probability of travel time from T1 to T4

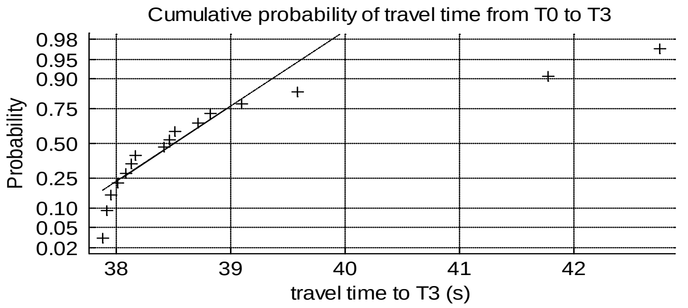

Figure 7-6: Normal probability of travel time from T1 to T4

7.6 Conclusions and Outlooks

The study has shown that microsimulation in general and SUMO in particular can be used to estimate travel times when no data from the aerial images is available. The traffic simulation solves the problem under complex situations, such as an accident in the signalized intersections. However, the database of network and the traffic-control mode, such as signal program of traffic light, are required for applying microsimulation to navigate an airplane to track the vehicle continuously.

Future work could include incorporating SUMO as an online simulation to be used directly with tracking algorithms with aerial images, so that continuous, live results can be obtained.

7.7 References

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