Simulation of Multilane Freeway Traffic with Detailed Rules Deduced from the Microscopic Driving Behavior

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Abstract

A simulation to model traffic on a multilane freeway is introduced starting from microscopic driving rules. The model takes each individual car into account with its individual features and actual situations so that a distribution of parameters as well as different behavior can easily be analyzed. Therefore, a detailed study of certain situations, driving tactics, vehicle properties, and their influence on the global traffic flow can be performed. The model and first results are discussed like influence of the driver behavior on the fundamental diagram and, in addition, the dynamics of microscopic quantities like separation and difference in speed between successive cars. It turns out, that a hysteresis in the reaction of the driver for speeding up and slowing down plays an important role and effects the macroscopic quantities like the shape of the fundamental diagram, e.g. the metastable behavior around the maximum flow and on the speed of observed jams running backward. Furthermore, microscopic time resolved characteristics are strongly influenced, e.g. oscillations in the distance and relative speed between successive cars.

The Model:

- fully deterministic with floating point representation
- working on the microscopic level, i.e. each car is individual with its own features
- complex rules are involving many features (for approaching other cars, passing, breaking, lane changes, ...)
- opens the possibility to model complex behavior and features of the street as well as of the cars
- still significant faster than real time

tool during the planning of streets
usable for prediction and control of traffic flow

Each car (i) is represented by the following state variables:

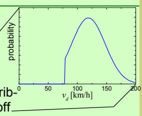
actual position	$x^{(i)}$
actual lane	$L^{(i)}$
actual speed	$v^{(i)}$
actual acceleration	$a^{(i)}$

and the following features:

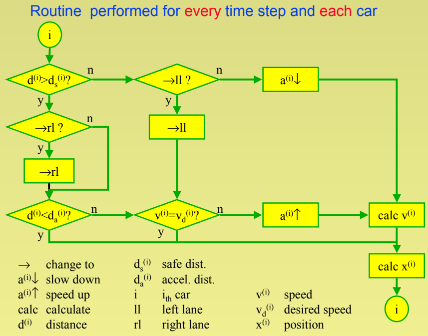
desired traveling speed	$v_d^{(i)}$
maximum deceleration	$a_{min}^{(i)}$
maximum acceleration	$a_{max}^{(i)}$
no reaction factor	$f_n^{(i)}$

The no-reaction factor describes a hysteresis in the driver behavior. If a driver approaches a car from behind he reduces his speed at a certain distance. But he will not accelerate at the same distance if the car in front is accelerating. Instead the separation will get larger until the driver in the back will accelerate. The no-reaction factor describes the ratio between these two distances.

Simulation Parameter	
acceleration a_{max}	1 m/s^2
deceleration a_{max}	-15 m/s^2
space needed for one car s	5 m
safety factor f_s	1.8 s
no-reaction factor f_n	1 - 2
desired traveling speed v_d	Gaussion distribution with cutoff
number of cars	5000
initial local density	100 veh/km
street configuration	freeway with 3 lanes
time step Δt	0.05 s

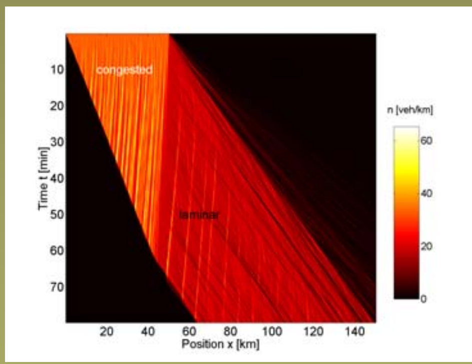


Routine performed for every time step and each car

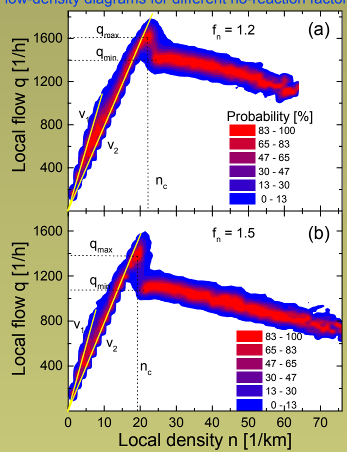


Development of the local density

Starting from highly congested initial condition we study the relaxation in time. The simulation passes through situations of different local densities. The backward running jams can be seen.

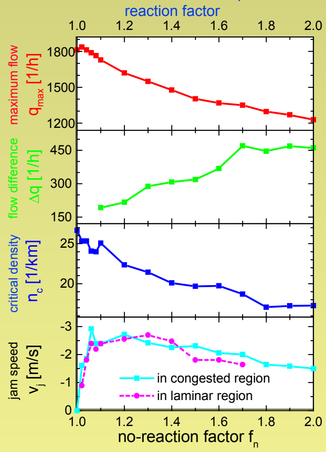


Flow-density diagrams for different no-reaction factors

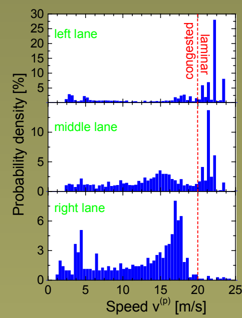


At low values of local density the traffic is freely flowing. The averaged velocity is equal to the mean of the desired traveling speed v_1. With increasing local densities the flow will be reduced and the corresponding velocity is determined by the lowest desired traveling speed v_2. By increasing the local density further the flow collapses and stop-go traffic can be observed. The main influence of the no-reaction factor can be seen in the region of the hysteresis.

Dependence of different characteristic quantities on the no-reaction factor

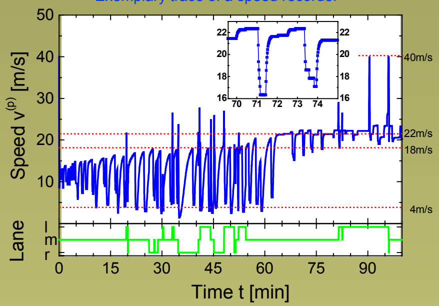


Usage of the three lanes dependent on the speed



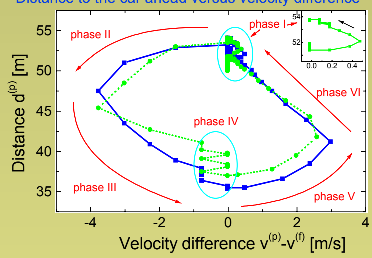
Individual behavior of one car

Exemplary trace of a speed recorder



A car with the desired traveling speed of 40.8 m/s has been chosen as the probe car. Its actual speed is plotted versus the time. At the beginning the car is driving in a congested region. The averaged speed is low but the fluctuations are low as well. By approaching the hysteretic region the fluctuations are increasing. After about 65min the car is moving in interacting traffic with a speed maximum of 22 m/s which corresponds to the lowest desired traveling speed. There are two peaks reaching up to 40.8m/s the desired traveling speed of the probe car.

Distance to the car ahead versus velocity difference



The oscillatory behavior due to the no-reaction factor can be clearly seen.

Comparison between simulation and measurement

	Simulation	Measurement
jam speed	10 km/h	15 km/h
in-/outflow of a jam	1400 veh/h	1100 – 1800 veh/h
average speed in the outflow	80 km/h	79 – 89 km/h
local density in the outflow	16.7 veh/km	17.7 veh/km

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Outlook

- variation of the street properties, like local in- and out-flow, change in the number of lanes (obstacles), local speed limit, etc.
- nonlocal terms in the rules for lane change and passing
- distribution in the length of the vehicles and their ability to accelerate to incorporate trucks

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