Relation Between Longitudinal and Lateral Action Points

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Abstract Delay on the motorways can be reduced by traffic management measures changing driving behaviour, which need to be tested before implementation. Microscopic traffic simulation is well suited for this, if sufficiently accurate. Recent studies show that drivers do not continuously change their acceleration, but rather at specific moments in time. These moments are called longitudinal action points. Also for lane changing, moments in time can be identified when drivers start and end changing lanes, so called lateral action points. This paper develops a methodology to find these action points. Data of individual driving behavior, collected from a helicopter, show that the approach with action points is plausible. Moreover, the longitudinal and lateral action points are correlated. Current models not incorporating this discontinuous behaviour correctly, might produce incorrect predictions.

1 Introduction

Delay on the motorways can be reduced by traffic management measures changing driving behaviour, which need to be tested before implementation. Microscopic traffic simulation is well suited for this, if sufficiently accurate.

Recent studies show that drivers do not continuously change their acceleration, but rather at specific moments in time [2]. These moments are called longitudinal action points. Also for lane changing, moments in time can be identified when drivers start and end changing lanes, so called lateral action points. Up to now, most traffic simulation models consider longitudinal behaviour separately from lane change be-

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haviour, where in fact, the two are closely coupled. A lateral action (lane change), is generally is triggered by a lack of longitudinal space. But also a longitudinal action can be triggered by a (planned) lane change. This raises the idea that these two processes might hence be intertwined. In particular, in this paper we test whether the action points on the longitudinal an lateral processes perhaps are the same.

The idea that the two are related is not new. For instance, the Mobil lane change model [3] makes a lane change decision based on the possible accelerations, which are calculated using a longitudinal model. The integrated model [7] chooses a path over different lanes, and hence makes the decision to accelerate dependent on the lane change model. It also is useful to mention an earlier approach, the LMRS (lane change model with relaxation and synchronisation [6]) which accounts for accelerations related to a lane change, both for the lane changer as for the putative follower. However, none of these models consider joint action points which are the only points at which acceleration changes.

If accelerations indeed only change at action points, and these are related to the action points of lane changing, this changes the way we should consider microscopic traffic simulators. The idea of not continuously changing acceleration might seriously impact the traffic streams.

2 Methodology

It can be hypothesised that drivers accelerate or decelerate in order to perform a lane change. In fact, we we developed a methodology to fit piecewise linear functions in speed-time and lateral position as function of time, revealing the longitudinal and lateral action points. We calculated these best fits for longitudinal and lateral behaviour separately first, and then do the same if we require the action points to be the same.

2.1 Fitting action points separately

Fitting the action points separately means that we find the longitudinal and the lateral action points jointly. For the longitudinal action points we follow [2]. In summary, we do as follows. We fit a piecewise linear function on the speed-time $(\dot{x},t)$. The quality of the fit is expressed as root mean squared error between the fitted speed and the observed speed. Obviously, the higher the number of intermittent points, the better the fit becomes. For each intermediate point a cost of 2 m/s is added, so any new point should improve the RMSE of the fit by 2 m/s.

For the lateral positions as function of time also a piecewise linear fit is made. There are, however, more restrictions than in the speed profile. We consider that the vehicle needs to drive in a lane unless it is changing lanes, so at a constant y value. For one lane change, we consider two action points: one for the start and one for the end of a lane change. Further constrains are that a lane change cannot start within two seconds of the end of the previous lane change, and all lane changes should have a duration of at least two seconds. Opposed to the piecewise linear fit, adding extra intermediate points cannot improve the fit since it is required that the lane change is finished. However, at the beginning and the end of the trajectory a slight offset of the middle of the lane can be “corrected” by the model by initiating a lane change just before the beginning or the end of the trajectory. Therefore, it is also required that more than half of the lane change is within the observed trajectory.

2.2 Fitting action points jointly

If we consider joint action points, we restrict action points of the start of the lane change is coupled with the longitudinal action point. The error is combined where 1 m/s error has an equal weight as begin a lane off in the lateral direction. Using *Matlab*’s build in function *fmincon* we search the action points which minimize the error. Moreover, the number of longitudinal action points is fixed at the same number as found in the separate fit method. Also the speed at the start and the end of the trajectory is fixed at the values found for the separate fit of speed over time. Similarly, the number of lane changes, as well as the lanes, are the same as found for the separate fits.

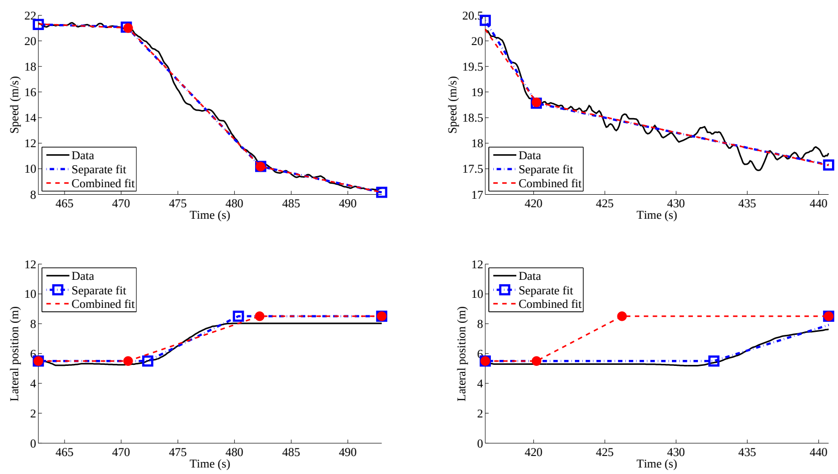
3 Data collection

The ideas have been applied on trajectory data collected at a Dutch motorway. We used a high resolution video camera attached to a helicopter to collect images of the traffic stream. Later, the trajectories of the vehicles were extracted from the video footage using the procedure described in [1].

We collected data at a freeway in the Netherlands, near Everdingen. The data is the same as used by Ossen [5]. It is a three lane freeway with no gradient. Traffic conditions were changing, with speeds from complete standstill up to freeway speeds 32 m/s. The video recorded a road stretch of approximately 300 meters. Due to unavoidable movement of the helicopter the exact location of the road which was in sight moves forward and backward by approximately 100 meter. For this paper, we use video footage of a little over 5.5 minutes, in which time 301 are in view for a sufficiently long time to have a useful trajectory. 23 of these vehicles change lane in the captured scene.

4 Results

Figure 1 shows the trajectories and the fits for different vehicles. It shows that if fitted separately both the longitudinal fit as well as the lateral fit follow the real data quite closely. On average, the mean of the root mean square error in the speed over all vehicles is 0.6 m/s (standard deviation: 0.27 m/s). This supports the idea that drivers do not change their speed continuously, but instead have lateral and longitudinal action points.



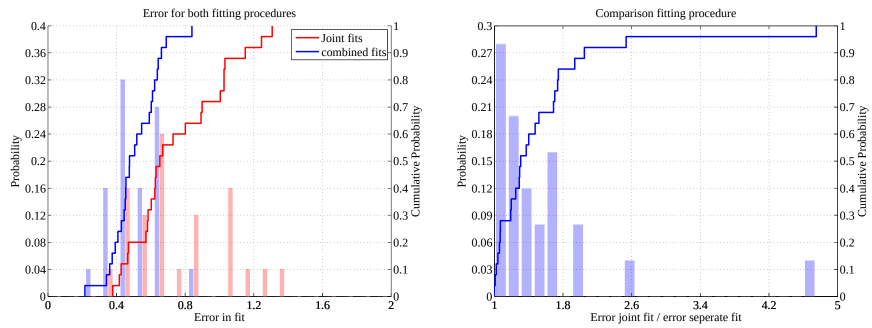
(a) Good fit (b) Bad fit

Fig. 1 Examples of the speed and lateral position over time for 2 vehicles

Table 1 Overview of the typical errors for the fits of 25 vehicles performing a lane change

fit	RMSE speed, [m/s]		RMSE lateral position, [m]		Weighted error, [-]	
	mean	stdev	mean	stdev	mean	stdev
Separate	0.40	0.13	0.56	0.22	0.51	0.13
Joint	0.51	0.26	1.42	0.99	0.75	0.26

The effect of combining fits is only relevant for the 23 vehicles which make a lane change during the observation period. These vehicles have an average error of 0.52 m/s in the fitted speed (standard deviation 0.22 m/s). The distribution of the errors (combining error in lateral and longitudinal direction) is shown in figure 2(a). This shows that indeed the separate fits do better than the combined fit. In fact, this is theoretically required since for each vehicle we impose a restriction during the fitting process. Therefore, the joint fit can never get a lower error than the separate fits. For each vehicle we can calculate how much larger the error in the fit is for



(a) The errors for the joint and for the separate fitting procedure

(b) Comparison of the errors for the joint and for the separate fitting procedure

Fig. 2 The resulting errors

the joint fit. The distribution of these ratios can be found in figure 2(b). The line shows for instance that for approximately 85% of the vehicles the error in the joint fit is less than 80% more than in case of the separate fit. The tendency is for a large part of the vehicles the increase in the error is limited. However, for some vehicles the restriction cause a considerably worse fit. An example of a particularly bad fit is given in figure 1(b). The description of joint behaviour does not match the behaviour of drivers of these vehicles. In fact, that might imply that some drivers do drive according to a different driving scheme than others, which is in line with [4].

5 Conclusions

This paper shows that longitudinally and laterally the movement of vehicles is well captured in a description of action points. Longitudinal action points are moments drivers change their speed, and lateral action points are moment drivers start or end changing lanes.

For many drivers, it is reasonable to assume that the start of a lane change manoeuvre was at the same moment as a change in acceleration. That might imply that for these drivers, performing the lane change might be linked to changing the acceleration. It should also be noted that some other drivers show a completely different behaviour.

This is an important behavioural finding for microscopic traffic flow models. Usually a car-following model is implemented separately from a lane change model, whereas this research suggest drivers might make the decision jointly. Considering these actions jointly can fundamentally change the dynamics of traffic flow. The differences become especially relevant when active traffic management measures are being tested in a traffic simulator.

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