Opportunities of advanced driver assistance systems towards overtaking

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Advanced driver assistance systems (ADAS) are available on the market whilst the development of existing systems and new systems continues. Improving safety is one of the key purposes of these systems. ADAS would therefore be welcome to support overtaking manoeuvres, since these cause many fatal accidents each year. Before an ADAS could be developed that can assist drivers with overtaking a thorough task analysis of overtaking is necessary and presented in this paper. The overtaking manoeuvre is divided in five phases, in which more than 20 subtasks are distinguished. Next, possibilities of ADAS towards overtaking are verified. Almost all subtasks of an overtaking manoeuvre can be assisted with existing ADAS functionalities, combined in a so-called active overtaking assistant. Unfortunately, for the more complex subtasks such as 'judging the distance with the first opposing vehicle' and 'monitoring the deviations of the lead vehicle' no ADAS functionality is available yet.

Keywords: advanced driver assistance systems, ADAS, overtaking, task analysis, instrumented vehicle, frequency, observations

1. Introduction

For more than a decade, Advanced Driver Assistance Systems (ADAS) are developed. Although not all ADAS have the aim to increase safety, it is an important effect for road authorities, and road users in general. Indeed, ADAS is seen as one of the most promising tools to reach the safety target to halve road fatalities between 2000 and 2010 in the Netherlands (NVVP, 2001).

A substantial part of fatalities is caused by overtaking. Transportation experts estimate that lane change crashes, including overtaking and merging, account for 4 to 10% of all crashes (Barr and Najm, 2001). In the Netherlands about 26 (out of 1000) fatalities are caused by overtaking on an annual basis (SWOV, 2003). The ADAS developments, the safety target and overtaking as a cause of fatal accidents together were the motives to start the PhD project ROADAS: Research on Overtaking and Advanced Driver Assistance systems.

Developments towards an overtaking assistant have already started elsewhere as well. At the moment, a kind of overtaking assistant for motorways is available in Japan (STARDUST, 2003). However, in the Netherlands, most overtaking accidents happen on rural roads. BMW is working on a kind of passive overtaking assistant, the so called 'Überholassistent', especially meant for use on rural roads. It will warn the driver when it is not safe to overtake due to the infrastructure, for example a hill, a sharp curve, etc. For an active overtaking assistant, assisting with the whole overtaking procedure, a thorough analysis of the overtaking manoeuvre is necessary. And, if all the subtasks of an overtaking manoeuvre are known, one should investigate which are the most crucial tasks, that is, when drivers need assistance. In Washington D.C. over 8000 lane changes were observed and analysed, enabling some recommendations towards the design of an overtaking assistant (Lee, Olsen and Wierwille, 2004). They focussed on the monitoring task of a driver, trying to recognise patterns in gazing sequences. Monitoring is not the only task of a driver during overtaking and it is necessary to verify if and how ADAS could assist the other tasks.

The objective of the study presented in this paper to make a thorough task analysis of overtaking on roads with opposing traffic. This analysis is the starting point of the design of an overtaking assistant, for which a first sketch is also made and reported in this paper. The distinguished subtasks of the overtaking task are quantified with the aid of data from two studies on overtaking: an overtaking frequency study and an observation study. These two studies are briefly described in the next chapter and fully reported elsewhere (Hegeman, 2004; Hegeman, Brookhuis and Hoogendoorn, 2005). Next, an attempt is made to verify the feasibility to actively assist the driver with the overtaking task. 'Active' in this case does not mean that the system performs the manoeuvre, but that it is able to indicate to the driver when it is safe to perform it. The paper ends with a summary and discussion of possible effects of ADAS on overtaking.

2. Quantifying the overtaking task

The first data set to quantify the overtaking subtasks includes overtaking frequency data, collected on two roads in the Netherlands (Hegeman, 2004). Three observation sessions were carried out on the N305 Almere-Zeewolde, a two lane rural road with a speed limit of 100 km/h (for trucks and cars with trailers 80 km/h). This road was selected because of its relatively long road sections without intersections, on which maximum overtaking frequency is expected. The first set of observations lasted for three hours, the second and the third both eight hours, all in both driving directions. The overtaking frequency was calculated by a comparison of the order of vehicles at the beginning and at the end of a road section. The overtakings were observed by cameras and observers. On the last observation day, a second road section with an overtaking prohibition was observed simultaneously. Table 1 shows some results of the observations. Important features of the observed road are the unequal split of the traffic in the two directions, for example for some hours the flow in one directions was twice as large as the opposing flow. The trip purpose of drivers on this road was mainly work related. On the other observed road, the N255 in Zeeland, most trip purposes were recreational. This road also has a speed limit of 100 km/h and was observed for six hours on a workday and a holiday. The split of the traffic here was more equal. The busiest direction was observed, while in the other direction the flow was counted. Table 1 shows results of the observations on this road as well.

Another data set used to quantify the tasks of an overtaking manoeuvre came from overtaking behaviour video observations (Hegeman et al., 2005). An instrumented vehicle was used to observe overtaking manoeuvres performed by unaffected drivers. On the N305, where the overtaking frequency observations were carried out as well, respectively 13, 24, 11 and 0 overtaking manoeuvres were observed while driving 70, 80, 90 and 100 km/h. With the camera data of the instrumented vehicle, the overtaking manoeuvres were thoroughly analysed, extracting data as indicator use, duration of the overtaking manoeuvre and time to collisions (TTC) with the first opposing vehicle. These observations led to the classification of four overtaking strategies, of which the first three were already described in (Wilson and Best, 1982):

Normal	The overtaker approaches the lead vehicle. The overtaker has to wait for an overtaking opportunity and therefore adjusts its speed to the speed of the lead vehicle. After some time it is able to overtake the lead vehicle. The overtaker will accelerate during the overtaking manoeuvre
Flying	The overtaker drives with its desired speed. It observes the lead vehicle and is directly able to overtake the lead vehicle, without adjusting its speed
Piggy backing	A vehicle overtakes the lead vehicle and the overtaker follows this vehicle. So the overtaker stays behind the preceding vehicle, while they both overtake the lead vehicle
2^+	The overtaker overtakes one or more vehicles behind the lead vehicle and in the same move, it also overtakes the lead vehicle. So the minimal number of vehicles that are overtaken is 2

An illustration of the four overtaking strategies is given in figure 1.

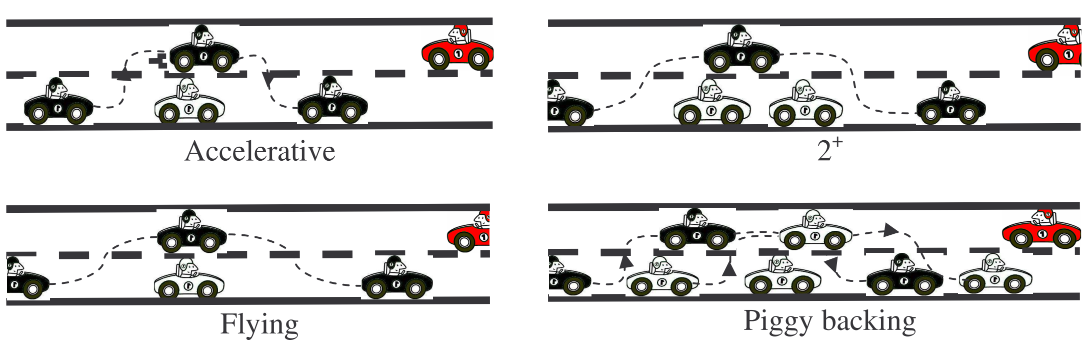

Figure 1. Illustration of the four overtaking strategies

These overtaking strategies affect the subtasks of an overtaking manoeuvre and are therefore important to distinguish before the task analysis is made. For the task analysis of this paper, the normal or accelerative overtaking strategy is taken, which is more or less the basis of the piggy backing and 2$^+$ strategies as well. The flying overtaking strategy is the easiest strategy and somewhat deviating, but by far not always possible to apply on the busy roads of the Netherlands.

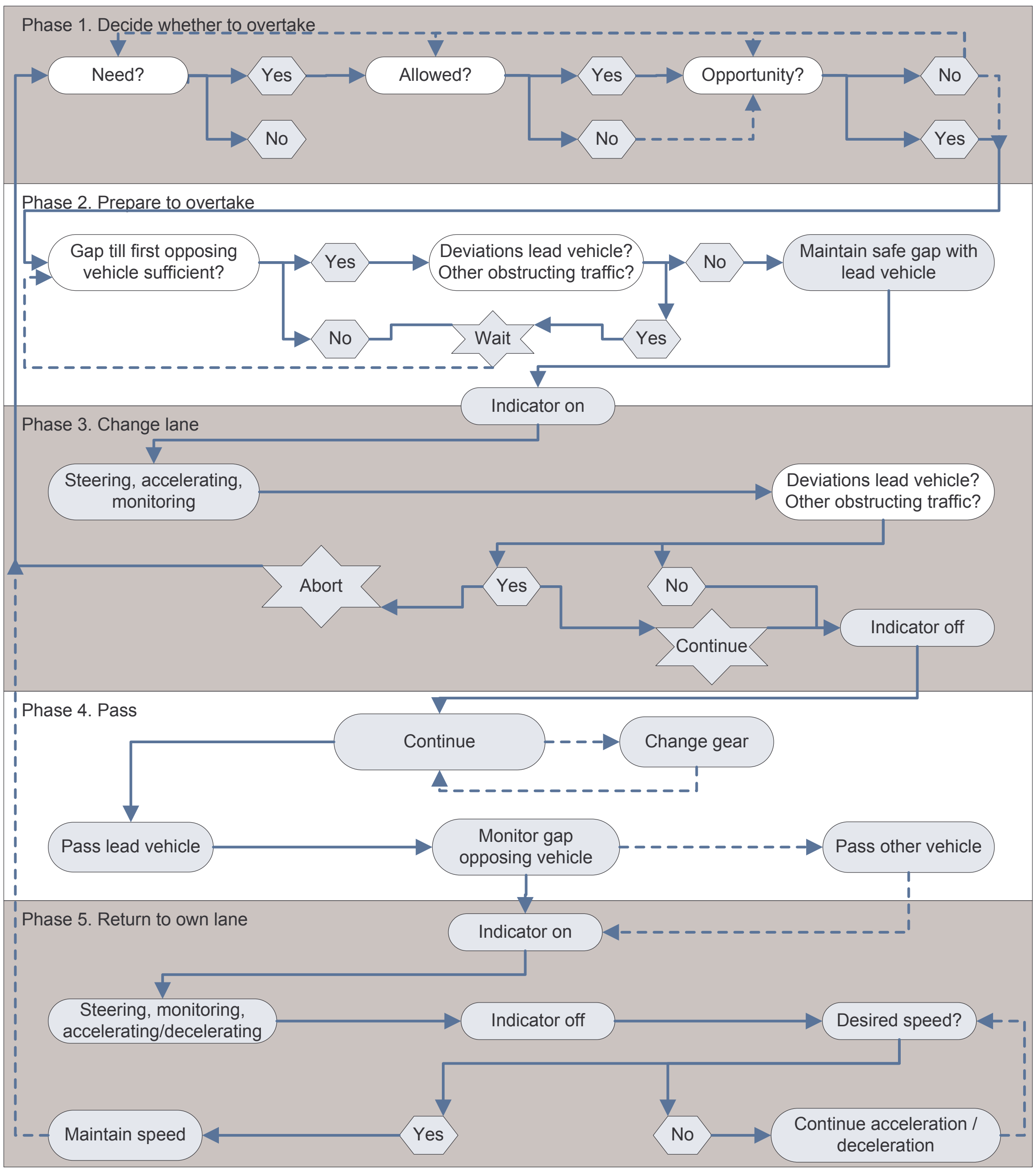

Figure 2. Task analysis of the overtaking task on roads with opposing traffic

3. Task analysis of overtaking on rural roads

Since overtaking involves many activities, for example steering, monitoring, accelerating, at the same time closely watching the vehicle ahead, possible opposing traffic and other traffic all at relatively high speeds, it can be regarded as a complex driving subtask. In ‘Driver Education Task Analysis’, ‘passing’ is included as one of many driving subtasks described (McKnight and Adams, 1970). This description is used as a basis for the overtaking task analysis proposed here. The overtaking task is divided in five phases, each existing of several basic control tasks, general driving tasks and situational behaviours. An overview is given in figure 2. In this flow diagram the overtaker ‘flows’ through the arrows. At each decision point (yes/no) the arrow divides and, depending on the ‘right’ answer, the overtaker can continue or has to wait. The dotted lines show some alternative paths. All elements of figure 2 are described in the next sections and, if possible, quantified by using the empirical overtaking frequency data and the overtaking manoeuvre observations.

3.1 Phase 1: Driver decides whether to overtake or not

The first task of an overtaking manoeuvre is the decision to overtake or not. The first question is whether the driver feels the need to overtake. The need to overtake depends on the desired speed, the speed of the preceding vehicle etc., and behavioural factors, for instance, whether the driver is in a hurry. The need to overtake is difficult to measure at an individual level, but is related to the overtaking demand and overtaking frequency. The macroscopic theoretical overtaking demand can be calculated with the so called catch-up formula (Wardrop, 1952):

$$\rho_p = \frac{k^2\gamma(u)}{2} = \frac{k^2\sigma_s(u)}{\sqrt{\pi}} \approx 0.564\frac{q^2\sigma_s(u)}{\bar{u}_s^2} \qquad (1)$$

where q is the intensity [PCU/h], k is the density [PCU/km], σ_s is the standard deviation of the average speed $\bar{u}_s$ [kph] and mean speed difference is $\gamma(u) = 2\sigma_s\pi^{-1/2}$ (Stuart and Ord, 1987). The overtaking demand of the observed road sections in the overtaking frequency study are calculated and shown in table 1. This table also shows the observed overtaking frequencies.

Table 1. Observed overtaking frequency and theoretical overtaking demand[1]

	F0-dir1	F0-dir2	F1-dir1	F1-dir2	F2-dir1	F2-dir2	F2-d1-X	F2-d2-X	ZW	ZW-X	ZF	ZF-X
Flow [veh/h]	1023	456	692	429	536	334	413	291	258	271	438	470
Opposing flow [veh/h]	456	1023	429	692	334	536	291	413	231	227	320	320
Average speed [km/h]	86	92	92	88	89	89	84	88	89	86	87	83
S.D. speed [km/h]	5.8	7.2	7.9	7.6	6.5	7.8	9.3	8.4	8.0	8.8	8.5	7.6
Theoretic overtak.demand [#/km-h]	533	111	297	124	154	75	148	65	41	53	129	143
Observed overtaking freq. [#/km-h	52	4	25	7	23	7	1	1	7	1	16	2
Frequency / Demand [%]	10	3	9	5	15	9	1	2	16	1	13	1

[1] F0 = 3h observation Flevoland, F1, F2 = 8h observations Flevoland, dir1 = busy direction, X = observations on sections with overtaking prohibition, ZW = Zeeland workday, ZH = Zeeland holiday

Table 1 shows that at most 16% of the overtaking demand was really performed. The overtaking need will lie somewhere between this macroscopic overtaking demand and the observed overtaking frequency. Indeed, the theoretical demand is clearly an overestimation of the need: a driver with a desired speed which is 0.1 km/h higher than the lead vehicle has a theoretical overtaking demand, but will not overtake in practice. And, behavioural factors are not included in the theoretical demand, for example, if a driver has to turn left or right soon, overtaking will not take place either in most cases. The overtaking need will therefore be lower, but not as low as the observed overtaking frequency. For example the big difference between the frequency in the busy direction (e.g. F1-dir1) and the less busy direction (e.g. F1-dir2) shows that more drivers at the less busy direction would have felt a need to overtake, but there were no opportunities. One could argue that there are less drivers in this direction and therefore less drivers with an overtaking need, but the ZH flow is almost similar to the F1-dir2 flow, but with less opposing flow, and here the observed overtaking frequency is higher. This is also due to the lower average speed and the higher standard deviation of speed. More insight in the need to overtake can be derived by further analysis of the video data of the overtaking behaviour observations. For example, by counting the vehicles closing in at the instrumented vehicle, without being able to perform an overtaking manoeuvre, or measuring the following duration of drivers who did perform an overtaking manoeuvre. These analyses are beyond the scope of this paper.

A driver with an overtaking need will watch the roadside for overtaking regulation signs. In the Netherlands, an overtaking prohibition for special vehicle types, for example trucks or vehicles with trailers, is indicated with road signs, at the beginning of each road section. ‘No overtaking zones’ for all traffic are always indicated with at least one continuous line between two driving directions. Some years ago these were only positioned in curves or on hills, where it is difficult to see possible opposing traffic. The “Sustainable safety program”, launched in 1992, however, includes an overtaking prohibition on all rural roads with a speed limit of 80 km/h (distributor road) and 100 km/h (flow road). This program is supposed to be a strong advice for road authorities, but they are not obliged to apply the sustainable safety design to their roads. If they do, there should be at least two continuous lines between the two driving directions to indicate the overtaking prohibition and preferably a physical barrier. For a prohibition without physical barrier, some drivers might decide to overtake anyway. As Table 1 shows, overtaking manoeuvres were observed on sections with an overtaking prohibition. On the road with equal flows in both directions, respectively 11% (busy day) and 13% of the overtakers ignored the overtaking prohibition. On the N305, in the direction with much opposing traffic, over 15% of the overtakers ignored the overtaking prohibition, while in the busy direction this is ‘only’ 5%. This implies that drivers, who get less opportunity to overtake, are more inclined to ignore an overtaking prohibition. Or, on a less busy direction, it makes more sense to overtake, since you will not immediately end up behind another ‘slow’ vehicle. The non-compliance to overtaking prohibition is indicated in figure 2 with a dotted line.

When it is desired and allowed to overtake, the third subtask is to look for an opportunity, which is dependent on possible infrastructural limitations such as hills, curves, intersections, railroad crossings, bridges or tunnels. There should be no overtaking limitations for the whole overtaking distance. McKnight et al. (1970) assumed that this overtaking distance is judged by the driver on the basis of the lead vehicle’s speed. However, analysis of the observed overtakings showed that the duration of an overtaking manoeuvre is independent of the lead vehicle's speed. The overtaking distance depends on the duration of the manoeuvre which is dependent on the acceleration capability of the car, which in turn is dependent on load of the car (passengers, cargo, trailer). Additionally relevant are familiarity with the car and proper operation of the car. Besides the required overtaking distance, the driver also has to allow adequate safety margins for the return to the right lane. And the gap in front of the lead vehicle should be verified as being large enough. At this stage, only more or less static factors influencing the overtaking opportunity are verified. Dynamic opportunity factors, such as potential opposing traffic, are judged in the next phase. The opportunity judgements of this phase lead to a determination whether the overtake manoeuvre can be safely completed within the available overtaking distance. During the reported observations of overtaking manoeuvres, one of the overtakers clearly waited to perform its manoeuvre till after a smooth curve. There were no other infrastructural limitations on the road section used for the observations.

Note that most of the described tasks of the first phase are checked continuously. Indeed, if an overtaking opportunity is present, the driver should use the time optimally. When all the tasks of the decision whether to overtake (Phase 1) are performed and all are positive, that is, there is a need, it is allowed and there is an opportunity to overtake, the driver will start the preparation to overtake. The dotted lines in figure 2 indicate that some drivers will perform a manoeuvre even if it is not allowed or if there is no (safe) opportunity.

3.2 Phase 2: Prepares for overtaking

On a bi-directional road, the opportunity to overtake is highly dependent on oncoming traffic. The distance to the first oncoming vehicle has to be judged. This is a difficult subtask, firstly because it is not included in other tasks of driving (McKnight et al., 1970), implying that drivers will not have the kind of routine in the performance of this task such as with for example steering. Furthermore, human beings are poor judges of distance and speed, let alone the speed of oncoming vehicles. Estimates are influenced by their own car speed and the speed limit (McKnight et al., 1970). For most of the reported observed overtaking manoeuvres there was no opposing vehicle visible at the moment the overtaking manoeuvre started. When the gap with opposing traffic is sufficient, all surrounding traffic will be observed, starting with the deviations of the lead vehicle. If it is signalling to indicate a left turn, changing lanes preparing to overtake, decelerating suddenly or weaving or wandering, the overtaking manoeuvre will not start. Changes in speed of the lead vehicle are hard to detect by the driver. If a driver is following a car ahead at a distance of 30 m, a minimum change of 3.7 m is needed before the driver will become aware that the distance is increasing or decreasing, that is, a change in relative velocity (Mortimer, 1988). Since the instrumented vehicle was the lead vehicle during the reported observations, no activities of the lead vehicle were observed. However, not only the lead vehicle and opposing vehicles are of importance, the driver should also take notice of traffic from behind, possibly also performing an overtaking manoeuvre. Also important during this second phase of the overtaking manoeuvre, is to maintain a proper following distance prior to the lane change. During normal driving, a time headway of two seconds is recommended. Using the speed of the instrumented vehicle, only one driver kept more than two seconds headway (flying overtake). 29 drivers kept a headway shorter than one second. The final task of Phase 2 is the use of the indicator. In the reported observations 32 drivers used their indicator, eight did not and for eight drivers it was not visible on the video.

The time frame in which Phase 2 is performed is measured for the reported observed overtaking manoeuvres, being the time between the last opposing vehicle has passed the vehicle while preparing the overtaking manoeuvre and the moment this vehicle's front left wheel touches the centre line. This time frame is called the perception reaction time, measured for 26 drivers whereas 21 of these had a perception reaction time shorter than one second (see Hegeman et al., 2005).

3.3 Phase 3: Changes lane

Phase 3 starts with steering, accelerating and monitoring to let the vehicle enter the centre of the new lane. In case of a flying overtake, acceleration is not necessary. For six observed overtaking manoeuvres the flying overtake strategy was applied. At the end of the lane change, the indicator should be switched off again. Some drivers leave the indicator also switched on during Phase 4 of the overtaking task. The average duration of the third phase of the overtaking manoeuvre, that is, the time between the left front wheel touching the centre line and the right back crossing the centre line, was 1.5 s ± 0.5 s for all reported observed overtaking manoeuvres (Hegeman et al., 2005).

3.4 Phase 4: Pass

In the fourth phase, the overtaking vehicle is at the left lane and will pass the lead vehicle. During an accelerative overtaking manoeuvre, the pass of the lead vehicle is a continuation of acceleration, and if necessary to change gear. According to McKnight et al. (1970), two extra tasks during the pass of the lead vehicle are to signal the lead vehicle when necessary and flick headlights at night. Both are not commonly used in the Netherlands and are therefore not included in figure 2. Also not very commonly done, but perhaps useful is to sound a horn when the lead vehicle is about to pull out and overtake another vehicle or the lead vehicle is moving laterally towards the car. The overtaking driver will pass the lead vehicle while monitoring the gap with possible opposing vehicles. In theory, acceleration till the desired speed is enough. But most drivers will continue accelerating as long as they are on the overtaking lane and adjust the speed to the desired speed when back on their own lane. If sudden acceleration is needed, the driver should press the accelerator to the floor to finish the manoeuvre quickly. But, if the opportunity to complete the pass is uncertain, the pass will be aborted and the driver will return to the right lane, behind the lead vehicle and the overtaking manoeuvre should start again at Phase 1. This did not happen during the overtaking observations. When the sight distance permits, several vehicles can be passed in one overtaking manoeuvre. This is defined as the 2^+ strategy, which was five times applied during the reported overtaking observations. The average time spent on the left lane, that is, the duration of the fourth phase of the overtaking manoeuvre was reported to be 4.2 s ± 2.3 s (Hegeman et al., 2005).

3.5 Phase 5: Returns to right lane

The fifth and final phase of the overtaking manoeuvre is to return to the right lane. Similar as at the start of the manoeuvre, the indicator should be used to indicate a lane change. During the reported observations, 25 drivers used their indicator in this phase, 17 did not and for 6 it was invisible. The steering action to position the vehicle in the centre of the own driving lane can start if both headlights of the lead vehicle (not leading anymore) are observed in the rearview mirror. But if the gap with the opposing vehicle becomes critical, that is, smaller than 4 seconds (Van der Horst and Hogema, 1993) the driver can decide to move back to the right lane sooner, for example, when both headlights are observed in the right sight mirror. Since the speed of the overtaking vehicle and the lead vehicle is in the same direction and the overtaking vehicle is likely to drive faster, the danger of a collision between these two vehicle is smaller than between the overtaker and the opposing vehicle. In 39 of the 48 observed headways after the overtaking manoeuvre headways were smaller than two seconds, of which seven were even smaller than one second. Back in the right lane, the driver can control the speed again. If the overtaking vehicle enters the right lane behind a new lead vehicle with a lower than desired speed, the speed has to be adjusted to this speed. The average duration of the fifth phase of the observed overtaking manoeuvres, that is, the time between the right front wheel touches the centre line and the left back wheel has crossed the centre line, was found to be 2.7 s ± 0.7 s (Hegeman et al., 2005).

3.6 Summary

The presented task analysis divided the overtaking manoeuvre into five phases, in total existing of more than 20 subtasks. The performance of all these subtasks takes on average 7.8 s ± 2.5s. In the next section, a first sketch of an overtaking assistant on rural roads is given.

4. A first sketch of an overtaking assistant on rural roads

The task analysis of overtaking presented in the previous chapter describes the overtaking manoeuvre in great detail. We argue that such an analysis is a good starting point for the design of an advanced driver assistant system (ADAS) that aims to assist the overtaking task. This chapter will provide a first sketch of an overtaking assistant on rural roads. The system in mind should warn the driver when it is not safe to overtake and will inform the driver when it is safe to overtake, taking into account all aspects affecting overtaking feasibility. At this stage, it remains only an advisory system that gives advice, visual or auditory, similar to, for example, a navigation system. It will not actively support any of the vehicle control tasks, as, for example, a cruise control does. Thus, it will not affect steering, braking, accelerating, etc. For all features necessary for an overtaking assistant, possible technologies to realise them are discussed. For each of the technologies it is verified whether they are already available in existing ADAS or could easily be added to existing systems.

4.1 Functionalities for an overtaking assistant

Since not all drivers will (always) feel the need to be assisted at overtaking, the system should have an ON/OFF switch. Drivers can then choose to have assistance whenever they need it. The ON/OFF switch will be part of the overtaking assistant and will not be integrated with other systems, that is, if a driver switches ON the cruise control, the overtaking assistant is not automatically switched ON as well.

The decision whether to overtake or not is instigated by the felt need to overtake. The presence of other systems might influence the need to overtake. In the case of the cruise control example: if drivers drive with adaptive cruise control and are able to follow a lead vehicle with a slightly lower speed than their desired speed without having to control the speed themselves, the need to overtake might decrease. Contrarily, some drivers may see it as a challenge to keep the cruise control ON as long as possible, which, in turn, increases the overtaking need.

Next, an overtaking assistant should include information about overtaking prohibitions. Both signs and continuous lines should be included to avoid conflicts between positive advice ('it is safe to overtake') and overtaking permission. For the realisations of this overtaking opportunity functionality, existing advanced navigations systems, based on Global Position Systems (GPS) can be used. These systems then have to be provided with prohibition information. This is feasible for the signs, but detecting prohibitions that are indicated with continuous road markings will be more difficult. Perhaps functionalities of a lane departure warning system (LDWA) could help here.

A support function for the last task of the first phase of the overtaking task, verification of the opportunity for an overtaking manoeuvre, should include features for both recognition of environmental limitations as well as infrastructural limitations. Static environmental limitations such as hills and curves could be included in advanced navigation systems, which is being developed by BMW. Ideally, the system should also be able to deal with dynamic environmental limitations such as fog or heavy rain. Possibly sensors could help here (Nishikawa, Imachou and Kamata, 2005). Infrastructural overtaking possibility limitations include the existence of junctions or roundabouts, within the distance required to perform the overtaking manoeuvre. Current navigation systems have information about distance to junctions or roundabouts and this information could therefore be used to avoid a positive overtaking advice while the driver is close to a junction.

The assistance with judgement of the gap with the first opposing vehicle will be an important feature of the overtaking assistant, because this is assumed to be the most difficult part of the overtaking manoeuvre for a human being. For this judgement, the system has to know the speed of the overtaking vehicle, the speed of the first opposing vehicle and the remaining distance between the two. It will then be able to calculate the remaining time to perform the manoeuvre. The observed overtaking durations, with an average of 7.8 seconds, give some information for what a safe time gap will be. To this duration, a safety margin of some four seconds should be added (Van der Horst et al., 1993). Preferably, the threshold setting for positive advice ('it is safe to overtake') will be adjustable by the driver, within some (absolute) safety margins. Such a feature is comparable with current adaptive cruise controls enabling drivers to choose their own following-distance settings. The minimal possible (time) distance setting required for an overtaking manoeuvre can be based on the observed durations of overtaking manoeuvres (Hegeman et al., 2005). Mind that the overtaking assistant should continue the judgement of the distance with the first opposing vehicle during the whole overtaking manoeuvre. It should warn for possible other vehicles approaching the overtaker with a TTC smaller than for example three seconds (Lee et al., 2004). The realisation of a functionality that is able to assist the driver with the judgment of the (time) distance with the first opposing vehicle is very difficult. As yet, no radar, laser, camera or sensor is able to 'look' far enough ahead. The European project PReVENT aims to warn drivers for approaching vehicles with a relative velocity of 120 km/h by using sensors (PReVENT, 2005). Perhaps it is possible in the near future to recognize other vehicle by means of navigations systems. Otherwise, for this functionality, we have to wait until vehicle to vehicle communication is available, which is on its way (Misener, Sengupta and Krishnan, 2005). The feasibility of these systems is demonstrated, but it will take some time before vehicle to vehicle communication is available on the market. Moreover, for overtaking assistance, all vehicles need to be equipped, to be sure that no opposing vehicle is missed.

The task to monitor deviations of the lead vehicle will remain mainly a task of drivers themselves. The eyes of the driver are adequate 'tools' to recognise indicators or brake lights. This also holds for activity of other obstructing traffic, since the driver is the supervisor of the system. But, an overtaking assistant should include a collision warning system (CAS) if other vehicles approach too close (Lee et al., 2004). Developments towards recognition of vehicles in the blind spot are on their way as well. Drivers indeed indicate a need for 'blind spot warning', mostly on motorways, but also on rural roads (Van Driel, 2005). The rear view camera of a Japanese lane change assistant, to monitor possible vehicles approaching from behind, is an example of a development towards blind spot assistance. This system requires the use of the indicator, a task for which no assistance system is available yet, while far from all use their indicator (Lee et al., 2004; Hegeman et al., 2005)

The task to keep a safe distance with the lead vehicle yields some contradictions. On the one hand, drivers should keep the recommended safe following time of two seconds. On the other hand, the longer the distance between the lead vehicle and the overtaker, the more time it will take to perform the overtaking manoeuvre. Some simple calculations show that this additional time is on the order of seconds (depending on the relative speed during the overtaking), and is hence non-negligible. Conflicts with distance keeping assistances systems, for example adaptive cruise control will occur during overtaking manoeuvres. The question is whether these systems should temporarily allow a shorter headway, for example, at those moments the overtaking assistant gives a positive overtaking advice. This will help avoid conflicts between different assistance systems and will not increase the necessary overtaking time.

The use of the indicator remains to be a task of the drivers themselves, since the overtaking assistant discussed here is an advisory system and will not interfere with control tasks. Advice to use the indicator when changing lane could be added to the overtaking assistant, either informative or even automatically switched ON if the driver feels an overtaking need and there is an overtaking opportunity. This will also be useful for blind spot warning systems that only work if the indicator is used.

The subtasks steering and accelerating, which are part of most phases of the overtaking manoeuvre, will remain tasks for drivers. The overtaking assistant will not interfere with these control tasks. The actual pass of the lead vehicle and possibly other vehicles prior to the lead vehicle will also be performed by drivers; no assistance is required to do this. Finally, the subtasks to control the desired speed and to maintain this does not have to be assisted by the overtaking assistant. Of course, existing systems such as cruise control could help drivers with these tasks.

Table 2 shows an overview of what subtasks (as distinguished in figure 2) should be assisted by the overtaking assistant and what is already available with respect to existing ADAS or could be added to existing ADAS. The ADAS in mind are shown between brackets.

Table 2. Which tasks of the overtaking manoeuvre will be assisted and which could be integrated in existing adas? The tasks correspond with the identified tasks in figure 2.

Overtaking subtasks		
Do it yourself	**Assisted** **Integrated with other systems**	**Special for overtaking assistant**
Need? [1]	Allowed (GPS)	*Need?*
Steering, accelerating	*Opportunity (GPS, LDWA)*	*Opportunity*
Other obstructing traffic	*Other obstructing traffic (blind spot warning, CAS)*	*Other obstructing traffic?*
Deviations lead vehicle	*Deviations lead vehicle? (side warning)*	Gap with first opposing vehicle
Indicator on (2x) Indicator off (2x)	*Safe distance with lead vehicle (CAS, ACC)*	*Safe distance with lead vehicle*
Change gear		
Monitoring	*Monitoring (CAS)*	*Monitoring*
Pass lead vehicle Pass other vehicles		
Desired speed?	*Desired speed? (ACC)*	

[1] Italic means that the subtask is partly in one column and partly in another, for example could be integrated with another system or will be specially developed for the overtaking assistant

5. Summary and discussion

5.1 Summary

To improve traffic safety, Advanced Driver Assistance Systems (ADAS) are considered promising tools (Brookhuis, 2005). Overtaking causes too many fatal accidents each year. To study the opportunities of ADAS towards overtaking, a thorough task analysis of the overtaking manoeuvre has been carried out. In this task analysis the overtaking manoeuvre is divided in five phases, each including several subtasks of the overtaking manoeuvre. Some of these subtasks, for example steering, accelerating, monitoring, keeping proper distance, are also performed during normal driving, but are especially demanding during an overtaking manoeuvre. In the meantime, extra subtasks such as judging speed and distance to opposing vehicles, judging the space in front of the lead vehicle, judging the overtaking distance and overtaking time are performed too. Observed overtakers were able to perform overtaking manoeuvres in an average period of 7.8 seconds, with a standard deviation of 1.9 seconds.

The paper presents a description of an overtaking assistant for rural roads based on the task analysis, that is, it describes how the system could assist the driving when deciding to overtake, during preparation for overtaking, lane changing, passing, and returning to its lane. Contributing elements of existing ADAS should be integrated in an active informative overtaking assistant. On a technical level, this overtaking assistant should include GPS functionality, with maps including overtaking prohibitions and infrastructural overtaking restrictions ahead. Prohibitions indicated with a continuous line between the driving directions, can only be assisted by lane departure warning assistance (LDWA) which should therefore also be integrated in the overtaking assistant. For this, it is necessary that the LDWA looks (far) ahead of the vehicle (on the digital map), which is not possible yet. Additional ACC features help with headway keeping prior to the overtaking manoeuvre, under the conditions that it still functions if the driver accelerates. Perhaps temporarily allowance of headways shorter than two seconds will avoid an increase of current overtake time. ACC will also assist with the speed regulation after the manoeuvre is completed. Finally, collision avoidance systems will assist the overtaker with the task to monitor activities of the lead vehicle and possible other surrounding traffic. A CAS will warn if the distance with any vehicle becomes smaller than three seconds (Lee et al., 2004).

Although most tasks of an overtaking manoeuvre will be supported by the proposed overtaking assistant existing of features of many ADAS, not all subtasks can be supported yet. Judging the distance with the first opposing vehicle, monitoring the deviations of the lead vehicle and other surrounding traffic and judging the gap in front of the lead vehicle will remain unsupported for the time being.

5.2 Discussion

The task analysis of the overtaking manoeuvre shows that there are many subtasks, but does not show which the most difficult ones are. In other words, failure of which subtask causes accidents? In theory, this could be determined from accident reports, but in practice this turns out to be very difficult. In most accident reports, only one cause of the accident is given. ‘Overtaking’ is most likely to be given as accident causation in case of a frontal collision of two opposing vehicles. The overtaking driver highly likely failed to judge the gap with the opposing vehicle correctly. For other subtasks, for example ‘keep proper headway with lead vehicle’ an other accident cause than overtaking might be reported by the police, for example, inattention. This not only leads to an overestimation of gap judgment with opposing vehicle as overtaking accident causation, but also to an underestimation of overtaking as accident cause. Another question is, if drivers get assistance with the subtask that they failed to perform correctly, will they not fail to perform another subtask correctly? In other words, will it help to assistant one task out of a chain of many tasks? Perhaps only an overtaking assistant being able to assist all subtasks of an overtaking manoeuvre will be able to eliminate overtaking as an accident causation.

A second point of discussion is the size of a safe headway prior to and after the overtaking manoeuvre. In the Netherlands two seconds headway is recommended as a minimal safe headway. Since perception reaction time is at least one second (Van der Horst et al., 1993), this seems reasonable. But during overtaking, the driver is alert and expects something to happen. For expected happenings, perception reaction times of around half a second are observed (Koppa, 1995) and thus a shorter headway could be safe enough. Moreover, in case of an overtaking manoeuvre, longer headways result in a longer distance to travel on the left lane and therefore a longer duration of the overtaking manoeuvre. The headway keeping functionality of an ACC was suggested to be integrated in an overtaking assistant, under the condition that it also functions during acceleration. Some currently available ACC's give the driver the opportunity to manually choose the minimal headway. For a BMW, the absolute minimum is 0.9 s. (www.bmw.com). This seems to be a safe minimum headway for a driver who wants to overtake and secure extra overtaking time. The question what is a safe headway also accounts for the headway after the manoeuvre. In this case, the shorter overtaking distance is not an argument for a shorter headway, but, since the speed of the overtaker is higher than the lead vehicle's speed, the danger of a collision is smaller and the headway is likely to increase after the manoeuvre is completed. Therefore, a shorter headway, for example one second, should be allowed, especially when the distance with an opposing vehicle is small. Already in 1963, it was recommended to 'cut in' in front of the lead vehicle, if the distance with an opposing vehicle becomes critical (Crawford, 1963).

Finally, we would like to discuss the observed short time between the pass of the last opposing vehicle after which the overtaking manoeuvre will be performed and the start of the overtaking manoeuvre. For 21 of the observed 26 drivers, this time was found to be shorter than one second (Hegeman et al., 2005). It seems that the 'prepare to overtake' phase is performed before the overtaking gap is available. A driver with a need to overtake, continuously performs all the subtasks of Phase 1 and Phase 2 in order to optimally use a possible overtaking opportunity. A consequence for the overtaking assistant is that it should inform the driver of an oncoming overtaking gap before it is present. The realisations of this feature depends on the design of the human machine interface (HMI) which is outside the scope of this paper.

The next step for the development of an overtaking assistant, is a driving simulator experiment in which the effects of the suggested overtaking assistant in this paper will be tested to functionality, usefulness and acceptance by the driver. Participants will drive with an overtaking assistant, assisting with finding an overtaking gap, indicator use, and headway keeping. Objectives of the study will be the functional design of an acceptable and useful system.

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