Proceedings of the
2007 IEEE Intelligent Vehicles Symposium
Istanbul, Turkey, June 13-15, 2007

ACC with enhanced situation awareness to reduce behavior adaptations in lane change situations

Jörn Freyer, Barbara Deml, Markus Maurer, Berthold Färber

Abstract — **This paper describes a refined lane change support function to enhance current Adaptive Cruise Control (ACC). Its design is based on a field experimental highway study in which experienced participants were asked to drive first without and afterwards with ACC support. The first condition serves as a baseline to identify different driving styles (fluid, moderate, and comfortable) within the sample and to describe the drivers' manual lane change behavior. By contrasting both experimental conditions, it is analyzed how the lane change behavior is altered by ACC and a situation aware ACC system with a lane change support function is described.**

I. INTRODUCTION

ADAPTIVE Cruise Control (ACC) is an advanced automation technology that provides assistance with longitudinal driving control tasks. By relying on frontal radar data, it can automatically adjust speed in order to maintain a safe headway distance between vehicles in the same lane: if the lead vehicle slows down, the system decelerates; when the road is clear again, the system reaccelerates the vehicle back to the set speed. In this context the systems Lane Keeping Assist (LKA) and Lane Change Assist (LCA) need to be considered as well. These assistance systems help the drivers to be aware of vehicles in the blind spot, or warn them in case of an unintended lane departure [1].

As ACC drivers reduce their attention on longitudinal control and focus on lateral control, ACC changes the driving behavior significantly. Several studies confirm that behavioral changes – related to speed, safety margins, or the lateral control of the vehicle – occur while driving with ACC [2, 3]. A comprehensive review of relevant studies is provided by [4, 5]. In these, it is commonly stated that the results obtained are contradictory at times: in some studies for instance, speed or headway distance increases when driving with ACC, while in others this is not the case. To some extent, these differences are due to methodological issues (e.g. simulator vs. real-world studies, type of ACC used). The state of the art of ACC systems has also changed considerably over the last years: especially the applied sensors, the availability in bad weather conditions, and the reaction of the system in borderline situations have been modified. Therefore, not all results of the studies mentioned are comparable.

Besides, the impact of individual characteristics must not be underestimated: as drivers differ in their degree of experience or in their driving style, these parameters will also affect the way in which the vehicle technology is employed. The assumption in [4] that the driving style (e.g. sporting, medium, economical [6]) plays an important role for explaining the behavioral adaptations observed is also considered in this paper. Most of the times, the driving style is assessed by questionnaires [7] or by specific driving parameters (e.g. throttle opening angle, brake circuit, collision time [8]). Whereas the first approach focuses on a long-term *trait*, the second one is more sensitive towards situational context factors and renders a driver's current *state*. To take these various aspects into account, both techniques are applied in this paper.

Another problem of the ACC studies referred to is their lack of detail. For instance, it is insufficient to evaluate only whether the number of lane changes increases or decreases when driving with ACC. A more detailed analysis distinguishing between various maneuvers is necessary. For this reason, not only the *a) overall* amount of lane changes is analyzed, but the following situations are specified in this study: b) *dynamic* lane changes in which a lead vehicle is approached (< 180 m) and immediately overtaken without following it – c) *early* lane changes which are initiated when the lead vehicle is more than 180 m ahead – d) *follow* lane changes which are performed together with a lead vehicle – e) *cooperative* lane changes which are initiated to help other traffic participants in merging situations – f) *navigational* lane changes which are due to route consideration (e.g. having to leave the highway).

II. FIELD EXPERIMENTAL STUDY

15 men and 11 women, holding medium sized or luxury class vehicles, were asked to participate in a field experimental study. All of them were of medium age (∅ 46 ± 9 years) and can be classified as experienced drivers (driver's license for ∅ 27 ± 9 years). Besides, all participants use their cars every day and most of them, 78%, drive on highways at least once a week. In the interaction

Manuscript received January 15, 2007.
Jörn Freyer and Markus Maurer, Audi AG, D-85045 Ingolstadt (e-mail: joern.freyer@audi.de)
Barbara Deml and Berthold Färber, Universität der Bundeswehr, Human Factors Institute, D-85577 Neubiberg (e-mail: barbara.deml@unibw.de).

1-4244-1068-1/07/$25.00

with technical systems, they see themselves as relatively adapted (∅ 2.01 ± .75 on a 6-point locus-of-control questionnaire, in which "1" corresponds to "very high") [9]. Below, the experimental procedure as well as the vehicle is described in more detail.

A. *Experimental Procedure*

To guarantee a sufficient number of lane change maneuvers, a highway with medium traffic density was chosen (see Fig. 1). All participants drove a 100km-track first without and then with the support of ACC. In order to get accustomed to the system, all participants ran through a very intensive ACC training session which was judged to be sufficient by the participants. Besides, a post-test questionnaire revealed that the drivers have a rather high trust in the system and that its reactions are described as being very predictable [see also 10].

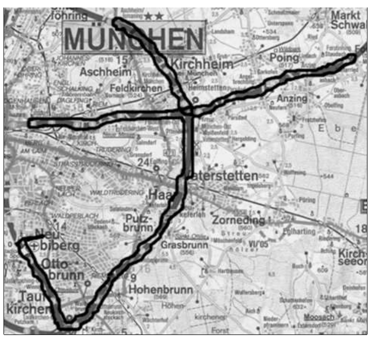

Fig. 1. Test track: Highway intersection in the South-West of Munich (Germany) with two and three lanes, respectively. The distance was covered twice by every participant, first without ACC (∅ 59 ± 5 min) and afterwards with ACC (∅ 58 ± 3 min).

Within the experiment the same ACC settings were chosen for all participants with a minimum time gap of 1.3 seconds. This value refers to a speed-dependent headway distance (e.g. 47 m related to 130 km/h) that the system controls after approaching situations and in follow situations. The subjects were instructed to drive "normally" and thus, they were free to choose a desired speed of up to 150 km/h. Because there is no general speed limit on German highways, this constraint was set to provoke more lane changes and to prevent the participants of driving only on the most left lane.

B. *Experimental Vehicle*

An AUDI A6 Avant (model: C6, YOC: 2005) with a mass produced ACC system was employed as experimental vehicle. Thus, a long range radar (opening angle $\varphi = 16°$, distance $r \approx 180$ m) was already integrated in the middle of the front bumper. In addition, two medium range radars ($\varphi = 35°$, $r \approx 60$ m) were implemented in the right and the left backward bumper. A camera, which was mounted on the bottom of the interior mirror, was used to process various lane parameters (e.g. lane marking, track width, lateral vehicle deviation).

III. Results

Before analyzing whether lane change maneuvers are altered by ACC, a cluster analysis was carried out to distinguish different driving styles within the sample. This procedure as well as further results are described in [11, 12].

A. *Driving Style*

The first experimental condition, driving without ACC, is regarded as a baseline which represents the "normal" manual driving behavior. To identify different driving styles, only this data set is subjected to cluster analysis (k means algorithm). By this statistical procedure, a set of objects (here: participants) is divided into distinct, homogeneous groups (here: driving styles).

The analysis is based on the following three parameters: The participants' *average speed* [v_{Base}], their *average time gap to lead vehicles* [Δt_{Base}] and the lateral "mobility" of the drivers, which is operationalized by the *total amount of lane change maneuvers to the left* [c_{Base}]. When grouping the sample by these variables, three different driving styles can be distinguished (see Table 1):

TABLE I
CLUSTER CENTERS

	① fluid	② moderate	③ comfortable
v_{Base} [km/h]	108.22 (.768)	103.80 (.348)	94.88 (-.1244)
Δt_{Base} [sec]	1.85 (-.899)	1.98 (.003)	2.22 (1.008)
c_{Base} [amount]	42.50 (.989)	33.30 (-.360)	26.40 (-.707)

The z-standardized value is given in brakets.

The driving style of the first group (N = 9) is labeled *fluid:* These participants reveal the highest average speed and the highest amount of lane change maneuvers, while at the same time having the shortest average time gap. The Euclidian distance to the second group ($d^z_{1,2} = 1.674$) is smaller than to the third one ($d^z_{1,3} = 3.244$).

The second group (N = 9) takes a medium position. Thus, this driving style is summarized as *moderate*. The Euclidian distances to the first and the third group ($d^z_{2,3} = 1.915$) are almost the same.

Finally, the participants in the third group (N = 8) are described as *comfortable* drivers, being the slowest while having the largest average time gap and the fewest lane change maneuvers.

In addition to this objective assessment, the driving styles of the participants were also rated by a trained investigator on a 6-point scale ranging from "very fluid" to "very comfortable". The outcome of this subjective procedure and the cluster analysis turned out to be highly correlated ($r_{Spearman} = .731$, $p = .001$).

B. *Lane Change Behavior*

To examine the lane change behavior two-way analyses of variance (ANOVAs) are carried out, with the driving condition (baseline or ACC driving) and the driving style (fluid, moderate or comfortable) as factors. Both the overall amount and the type of lane change maneuvers (dynamic, early, follow, cooperative or navigational) are regarded as criterion variables. Thus, six ANOVAs are calculated (a – f). The descriptive results are summarized in Table 2.

TABLE II
MEAN AMOUNT AND STANDARD DEVIATION OF LANE CHANGE MANEUVERS

	a	b	c	d	e	f
baseline						
fluid	39.7±5.1	22.0±4.7	6.9±2.4	2.6±.7	1.3±1.6	6.9±2.5
moderate	28.9±5.7	13.1±4.8	6.3±2.8	1.7±1.6	1.9±1.5	5.9±1.8
comfortable	24.6±6.2	11.0±5.1	3.1±2.7	1.9±2.1	1.4±1.2	7.3±2.9
with ACC						
fluid	33.1±4.7	10.8±3.5	8.8±.2	4.2±1.8	2.3±1.4	7.6±2.6
moderate	35.9±4.5	10.6±5.1	8.1±3.6	6.0±3.8	3.3±1.7	7.9±2.3
comfortable	32.9±6.1	11.5±3.7	7.6±4.1	5.3±3.0	1.4±1.2	7.1±1.4

a) overall, b) dynamic, c) early, d) follow, e) cooperative, f) navigational

a) Overall amount of lane change: When taking a closer look at the total amount of lane changes (without distinguishing between different types of maneuvers), it becomes apparent that the participants overtook more when driving with ACC. Due to the definition of the driving style, it is to be expected that there are also significant differences between fluid, moderate, and comfortable drivers ($F_{(2;\ 267.24)} = 9.18$; $p = .000$). However, there is another interesting interaction effect worth mentioning ($F_{(2;\ 377)} = 7.13$; $p = .01$): When driving with ACC, fluid drivers reduce their lane changes while both moderate and comfortable drivers increase their lateral mobility (see Fig. 2).

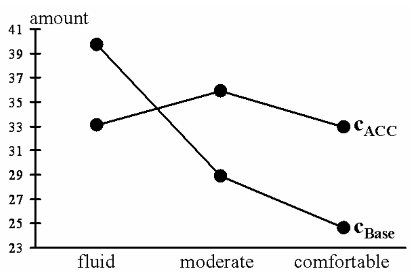

Fig. 2. ANOVA interaction diagram for the overall amount of lane changes with [c_{ACC}] and without ACC [c_{Base}].

For a more specific analysis distinct types of lane change maneuvers are studied in the following (see Fig. 3):

b) Dynamic lane change: Whenever a lead vehicle is approached (< 180 m) and overtaken immediately without following it, this is classified as a “dynamic” lane change. This type of lane change occurs more often in the baseline condition ($F_{(1;\ 253.87)} = 12.42$; $p = .001$) and it is particularly typical for more fluid drivers ($F_{(2;\ 138.73)} = 7.78$; $p = .003$). There is also a significant interaction effect which denotes that fluid drivers reduce this behavior pattern systematically when driving with ACC ($F_{(2;\ 160.09)} = 7.83$; $p = .001$).

c) Early lane change: All maneuvers initiated with the lead vehicle at least 180 meters (maximum range of ACC sensor) ahead are summarized as “early”. Irrespective of the driving style ($F_{(2;\ 27.35)} = 3.02$; $p = .058$), significantly more lane changes of this kind occurred when driving with ACC ($F_{(1;\ 96.04)} = 10.62$; $p = .002$).

This is also indicated by a further parameter: When driving with ACC the average moment of pulling out increased significantly ($F_{(1;\ 10.52)} = 16.32$; $p = .000$; $\varnothing t_{c,ACC} = 2.6 \pm .9$; $\varnothing t_{c,Base} = 1.7 \pm .7$). Here, the moment of pulling out is defined as that point in time when the lane marking is crossed by the front left corner of the vehicle.

c) Follow lane change: This category refers to all situations in which a lead vehicle is followed for a certain time before the overtaking maneuver. As indicated by a significant main effect, this type of change occurs more often when driving with ACC ($F_{(1;\ 126.56)} = 22.21$; $p = .001$). This effect is independent of a participant’s driving style ($F_{(2;\ .90)} = .16$; $p = .854$).

e) Cooperative lane change: On a highway, lane changes are also carried out in order to facilitate merging for other traffic participants. There is a significant main effect which indicates that these cooperative lane changes have increased in the driving-with-ACC condition ($F_{(1;\ 8.60)} = 4.18$; $p = .047$). Besides, this type of maneuver depends also on the driving style ($F_{(2;\ 6.70)} = 3.26$; $p = .048$), but there are no significant interaction effects ($F_{(2;\ 2.29)} = 1.11$; $p = .337$).

f) Navigational lane change: Finally, there are also lane changes which are due to routing. Here, no significant effects concerning the driving style ($F_{(2;\ .60)} = .11$; $p = .894$) or the driving condition ($F_{(1;\ 9.30)} = 1.75$; $p = .193$) could be observed.

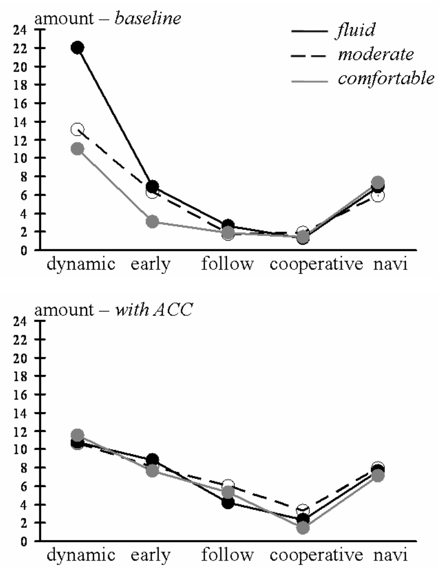

Fig. 3. Ttypes of lane changes within the baseline (top) and the ACC-condition (bottom).

IV. DISCUSSION

The results point out at least two issues. First, ACC compensates for differences which otherwise would be caused by a manual driving style (see Results *a*, *b*): On the one hand, fluid drivers reduce their total amount of lane changes while moderate and comfortable drivers increase their lateral mobility at the same time. On the other hand, the participants also tend to become much more homogenous in their type of maneuvers (e.g. reduction of dynamic lane changes by fluid drivers). The fact that the driving behavior is harmonized by ACC was also observed in other studies [13, 14].

Second, the without-ACC-condition revealed that most of the participants tend to drive relatively close against lead vehicles shortly before overtaking. Therefore, the set time gap of 1.3 seconds is often under-run (even when regarding average values). Thus, it is likely that almost all drivers occasionally got "thwart" by the system when preparing for overtaking. There are mainly two possibilities of reacting to this undesirable effect: either pull out earlier to reduce the effect of the ACC system braking too early in approaching situations (see Results *c*), or increase the number of conjoined lane change maneuvers that are performed together with the lead vehicle (see Results *d*). Both effects could be identified in this study. However, in order to meet the driver's expectations and to accomplish comfort, the ACC system has to resemble as much as possible the "normal" manual driver behavior. To cope with this problem, a human-centered design approach has been taken in this study using the "human operator as template for automation" [15, 16 pp. 325 ff].

V. LANE CHANGE SUPPORT

As illustrated above, current ACC systems do not distinguish between approaching situations with and without a possibility of a lane change like human drivers do. This is due to the fact that they are controlled by speed differential and distance to the vehicle ahead, instead of by the driving situation. Therefore, the application of the approach control in current ACC systems is always a compromise between flexibility in approaching situations with lane change (late start of control) and comfort in normal approaching situations (early start of control). This is inconsistent with normal driving behavior as in approaching situations without a chance for passing, e. g. when the fast lane is blocked, drivers start reducing the speed deliberately at an early point in time.

This anticipatory driving reduces the maximum braking deceleration necessary while approaching. In approaching situations with lane change, the drivers sometimes fall below the safety distance to carry out the lane change without braking.

By combining the driver assistance systems ACC, LKA LCA, a joint consistent situation representation for approaching and lane change situations becomes possible. Below, the idea of an integrated situation aware assistance is illustrated by the function "*lane change support with ACC*".

With the lane change support function, the approach control is changed, depending on the driving situation, in such a way that the approach comfort and the flexibility for a lane change can equally be optimized at the same time. That way the conflict of objectives described above can be solved. To put it simply, the function can be divided into three central processes: the status analysis, the behavior prediction and the actual behavior with several different modules (Fig. 4).

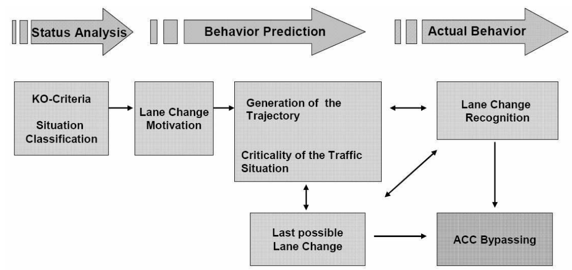

Fig. 4. Lane change support function.

The lane change support function is organized like a cascade, so every successive module is only activated and calculated once it has been released successfully by the preceding module.

A. *KO-Criteria and Situation Classification*

In the status analysis, within the KO-criteria, the availability and the quality as well as the system status are checked for all driver assistance systems used for lane change support.

By using the navigation data and the lane classification of image processing unit, the general road conditions are checked, especially whether the vehicle is driving on a highway and whether a fast lane exists further to the left.

In addition, the traffic situation is determined from the state variables of the surrounding vehicles, especially which traffic scenario *lead*, *lag*, *gap*, *free overtaking* [17] is prevailing.

B. *Lane Change Motivation*

In the module lane change motivation, it is predicted whether the driver wants to change the lane or not. This lane change desire is defined depending on the influencing lead vehicle. Thus the surrounding traffic situation is deliberately not taken into account.

In this paper, only lane change situations because of slower lead vehicles are described. For other motivations like for instance cooperative behavior in merging situations, a similar procedure is applicable.

The lane change desire comes clearly before a driver action starts to initiate a lane change. To determine the lane change motivation, the motivation criteria are established from the state variables v_{ego}, v_{diff}, v_{desire}, d_{egofront}, a_{front}, Tn_{set}, and from their derivatives with respect to time. With v_{ego} representing the vehicle speed, v_{diff} representing the differential speed and d_{egofront} the distance to the target object and a_{front} the acceleration of the target object. v_{desire} is the ACC set speed and Tn_{set} refers to ACC headway setting.

They allow a statement on the dynamics and criticality of the approach. These criteria are filtered and, if necessary, the average is taken. They are then compared to the threshold values determined in the field experimental study, and the performance of each criterion is calculated. Subsequently, the criteria are weighted relatively to one another and combined in one over-all motivation. From this over-all motivation it is derived whether a lane change desire exists, and the following trajectory generating module is calculated accordingly.

C. Generation of trajectories

The trajectory is defined as the predicted path of the ego-vehicle during the whole lane change maneuver.

To describe the trajectory mathematically a derivative of the adapted sine line [18] has been chosen (1). To the path thus obtained, a variable straight piece is added. This piece symbolizes the decision time t_{decision} until the driver initiates the lane change actively.

$$for \quad (0 \le i \le t_{decision}) \qquad y(i) \;=\; y_{deviation} \tag{1}$$

$$for \quad (i \ge t_{decision})$$

$$y(i) \;= (-\frac{1}{2}\; y_{total} \times (\cos((\frac{\pi}{t_{Sine}}) \times (i - t_{decision})) - 1)) + y_{deviation}$$

The geometry of the trajectory on the y-axis (2) is determined by the lateral distance (y_{total}) to be covered: it consists of the lateral deviation in the ego-lane ($y_{\text{deviation}}$), and of half the lane width of the ego-lane ($d_{\text{startlane}}$) and of the target lane ($d_{\text{targetlane}}$) respectively.

$$y_{total} \;=\; -\,y_{deviation} \;+\; \left(\frac{d_{startlane}}{2}\right) \;+\; \left(\frac{d_{t\arg etlane}}{2}\right) \tag{2}$$

In the longitudinal direction, the factors vehicle speed, longitudinal vehicle acceleration, and lane change duration limit the geometry of the trajectory. The speed of the ego-vehicle is controlled by ACC and is thus known throughout the lane change. The longitudinal vehicle acceleration is determined within the normal ACC limits and is dependant proportionally on the difference between the driven speed and the ACC set speed. As a simplification, a constant longitudinal acceleration of the vehicle is assumed during the lane change. It is effective during the period $t_{\text{acceleration}}$ until either the lane change has been finished or the set speed reached (3). Negative differences between v_{desire} and v_{driven} are not taken into account for the calculation assuming that in general the speed is not to be reduced during a lane change.

$$for \quad (0 \le i \le t_{accel}) \qquad v(i) \;=\; (a_{longitudinal}(i-1) \;\times\; \Delta t) \;+\; v(i-1)$$

$$for \quad (i \ge t_{accel}) \qquad v(i) \;=\; v(i-1) \tag{3}$$

A further limiting factor for the geometry of the lane change is the maximum lateral acceleration accepted by the driver.

With higher speed, drivers accept only lower lateral acceleration as convenient as was shown in [19]. The results from the field test [19] about lateral acceleration were verified by an internal remake of the study. This means that the movement in lateral direction at high speed is markedly slower. Based on the identified lateral acceleration values depending on the speed, the predicted lane change duration is calculated by taking into account the longitudinal acceleration (4).

$$t_{total} \;=\; t_{decision} \;+\; t_{Sine} \tag{4}$$

Then the continuous trajectory is sampled and expressed in a (x,y,t) form with all points and times for the ego-vehicle known.

To reduce computing effort for calculating the criticality, the discrete trajectory is minimized to five significant points used for assessing the criticality of the surrounding traffic situation (see Fig.5).

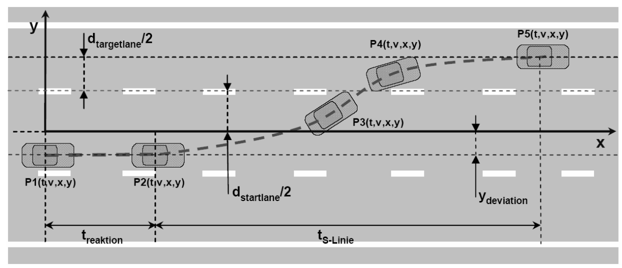

Fig. 5. Sampled Trajectory.

These five points mark the actual point in time (point 1), the point in time when the lane change is initiated (point 2), the point in time when the lane markings are crossed by the front left vehicle corner (point 3), the point in time when the lane markings are crossed by the back right vehicle corner (point 4), and the point in time when the vehicle has reached the middle of the target lane (point 5).

D. Criticality of the Traffic Situation

Based on the traffic situation classification, all relevant vehicles on the side, in front, in front to the left, and behind of the ego-vehicle are taken into account. The longitudinal driving behavior of the relevant vehicles is predicted with a longitudinal acceleration uncertainty (5)**.** The calculation is based on the normal equation of motion with the variables x-position, speed and acceleration for the investigated period of time.

$$x_{object} \;=\; x_0 \;+\; (v_0 \times t) \;+\; (0.5 \times a_0 \times t^2) \tag{5}$$

$$v_{objekt} \;=\; v_0 \;+\; (a_0 \times t)$$

For the five characteristic points in time, the collision times (*TTC*) and time intervals (*Tn*) are predicted relative to the surrounding vehicles (6).

$$Tn \;=\; \frac{x_{ego} \;-\; x_{object}}{v_{ego}} \qquad\qquad TTC \;=\; \frac{x_{ego} \;-\; x_{object}}{v_{ego} \;-\; v_{object}} \tag{6}$$

It is considered as the only valid criterion for release that endangering or pushing a surrounding vehicle can be excluded throughout the lane change at all times.

E. Lane Change Recognition

Below the above described modules of behavior prediction, there is the module for recognizing signs of a lane change being initiated at this moment.

In particular, the lane change is recognized reliably by the criteria of curve adjusted steering angle, turn signal, lateral speed, and time-to-line-crossing (*TLC*). In analogy to the motivation determination, the characteristics are weighted and added to give the over-all probability of a lane change initiation at this moment.

This module is necessary as a reset condition of the lane change prediction. Apart from that, it is used to reduce the impact of the vehicle ahead at an early point in time within the lateral movement of the ego vehicle. Thus the follow control allows for a dynamic lane change.

F. Last possible lane change

If no active initiation of a lane change is detected until a set point in time, the predicted lane change desire is discarded and the system is switched over to the normal approach mode. This mode is necessary as the speed differential still needs to be controlled if the lane change prediction and the driver's action do not fit.

An unjustified lane change support can entail a less comfortable approaching to the lead vehicle but can never cause a critical driving situation like a take over request of the ACC system.

G. Bypassing of the ACC controller

If a lane change is rated as probable by the functions described above, the new situation dependent acceleration requirements of the ACC system are generated. This is implemented using a bypassing system between the Rapid Prototyping ECU and the development ECU of the mass produced ACC system.

Matching the driving situation, the speed differential to the preceding vehicle is reduced as early as possible when approaching without a chance for a lane change. High automatic decelerations can be avoided. In approach situations with a chance of a lane change, the braking is postponed deliberately in order to allow for more flexibility in a lane change. After recognizing a lane change, braking can be avoided altogether.

The bypassing technology also facilitates the use of the ACC control in normal ACC mode, and at the same time changing the internal control parameters online in lane change situations.

VI. Conclusion

Within this work a field experiment was carried out to examine how lane change maneuvers are altered when driving with ACC. In order to achieve a detailed analysis different driving styles were distinguished by a cluster analysis and the lane change behavior is interpreted separately for fluid, moderate, and comfortable drivers.

Based on these results a refined lane change support function is described which improves the performance of current ACC systems in lane change situations. The effectiveness and the acceptance, as well as the impact of this new lane change support function on driving behavior is currently tested in a further field study. This experiment replicates the study that is described in the first part of this paper, with the only difference that this time the new situation aware ACC system is applied.

Acknowledgments

The authors would like to thank Dr. Veronika Krapf for her very valuable comments.

References

[1] R. Bishop, "Intelligent Vehicle Technology and Trends", Artech House, Norwood, 2005.

[2] M. Hoedemaeker, "Driving behavior with ACC and the acceptance by individual drivers", IEEE Intelligent Transportation Systems, Dearborn, MI, October 1-3, pp. 506-509, 2000.

[3] C. M. Rudin-Brown and H. A. Parker, "Behavioural adaptation to adaptive cruise control (ACC): implications for preventive strategies", Transportation Research Part F: Traffic Psychology and Behaviour, 7 (2), pp. 59-76, 2004.

[4] F. Saad, "Behavioural adaptations to new driver support systems: some critical issues," IEEE Systems, Man and Cybernetics, Den Haag, The Netherlands, October 10-13, pp. 288-293, 2004.

[5] N. Dragutinovic, K. A. Brookhuis, M. P. Hagenzieker, and A. W. Marchau, "Behavioural effects of Advanced Cruise Control Use – a meta-analytic approach", European Journal of Transport and Infrastructure Research, 5 (4), pp. 267-280, 2005.

[6] N. Tricot, D. Sonnerat, and J. C. Popieul, "Driving styles and traffic density diagnosis in simulated driving conditions," IEEE Intelligent Vehicle Symposium, Versailles, France, June 18-20, Vol. 1, pp. 298-303, 2002.

[7] O. Taubman-Ben-Ari, M. Mikulincer, and O. Gillath, „The multidimensional driving style inventory – scale construct and validation", Accident Analysis & Prevention, 36 (3), pp. 323-332, 2004.

[8] M. Canale and S. Malan, "Tuning of Stop and Go driving control strategies using driver behaviour analysis," IEEE Intelligent Vehicle Symposium, Versailles, France, June 18-20, Vol. 2, pp. 407-412, 2002.

[9] G. Beier, "Kontrollüberzeugungen im Umgang mit Technik: Ein Persönlichkeitsmerkmal mit Relevanz für die Gestaltung technischer Systeme," Berlin: dissertation.de – Verlag im Internet, 2004.

[10] B. Rajaonah, F. Anceaux, and F. Vienne, "Trust and the use of adaptive cruise control: a study of a cut-in situation," Cognition, Technology & Work, 8 (2), pp. 146-155, 2006.

[11] B. Deml and B. Färber, "Prädiktion des Fahrstils zur adaptiven Auslegung von Assistenzsystemen," M. Grandt (ed.), "Cognitive Systems Engineering in der Fahrzeug- und Prozessführung," Bonn: DGLR (ISBN 3-932182-51-0), pp. 129-143, 2006.

[12] J. Freyer and M. Maurer, „Analyse des Fahrverhaltens unter dem Einfluss von Fahrerassistenzsystemen in Realfahrten", 4. Workshop Fahrerassistenzsysteme, Löwenstein, 4-6. Oktober, pp. 31-41, 2006.

[13] R. Jiang and Q.-S. Wu, "The adaptive cruise control vehicles in the cellular automata model", Physics Letters A, 359 (2), pp. 99-102, 2006.

[14] P. A. Ioannou and M. Stefanovic, "Evaluation of ACC vehicles in Mixed Traffic: Lane Change Effects and Sensitivity Analysis", IEEE Transactions on Intelligent Transportation Systems, 6 (1), pp. 79-89, 2005.

[15] P. Zheng and M. McDonald, "Manual vs. adaptive cruise control – Can driver's expectation be matched?", Transportation Research Part C: Ermerging Technologies, 13 (5), pp. 421-431, 2005.

[16] M. A. Goodrich and E. R. Boer, "Model-based human-centered task automation: a case study in ACC system design", IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, 33 (3), pp. 325-336, 2003.

[17] U. Sparmann, "Spurwechselvorgänge auf zweispurigen BAB-Richtungsfahrbahnen", Karlsruhe: b. t., 1978.

[18] E. Weiss, "Untersuchung und Rekonstruktion von Ausweich- und Fahrspurwechselvorgängen", Düsseldorf: VDI-Verlag (Fortschritt-Berichte VDI: Reihe 12 ; 96), 1988.

[19] K. H. Schimmelpfennig and U. Nackenhorst, "Bedeutung der Querbeschleunigung in der Verkehrsunfallrekonstruktion. Sicherheitsgrenze des Normalfahrers", Verkehrsunfall und Fahrzeugtechnik 23, 1985.