Abstract

The paper introduces a new driver assistance system within the BMW ConnectedDrive concept. Based on the driving dynamics and navigation data, the Dynamic Pass Prediction (DPP) indicates road sections that are not safe for overtaking. By reducing the enormous driver workload before overtaking situations a safer and more comfortable driving is achieved without losing driving pleasure. This example shows how driver assistance systems can take advantage of navigation data especially if it contains curve and sign information. With the quality of navigation data available today the DPP function is feasible. Taking driving parameters into account, a situation adaptive recommendation provides even more benefit for the customer.

Introduction

More comfort, more performance, more safety. Precisely these are the demands BMW Group products consistently meet and fulfill at all times – even where the general conditions for mobility are not always perfect.

Growing traffic density and its consequences such as traffic congestion and longer traveling times, as well as the greater complexity of many traffic situations, are making driver assistance systems increasingly attractive and useful. These systems give the driver helpful information making it easier to make decisions and handle difficult and complex traffic situations. Hence, driver assistance systems serve to ensure superiority at the wheel even under difficult conditions, enhancing both safety in road traffic and sheer driving pleasure at all times.

The fundamental principle applicable to all functions is that the driver retains an active role and responsibility, remaining in control of the car and its functions at all times. And a further point is that generally driver assistance systems only take effect when activated by the driver. The driver naturally retains the final decision in the assessment of traffic situations.

Should ACC Active Cruise Control, for example, start to accelerate the car after a vehicle ahead has moved out of the car’s direct lane, the driver is able to reduce speed again immediately to let another motorist merge into his own lane.

Consistent application and implementation of these principles always pays off. And as a result, driver assistance systems developed and introduced in series production by the BMW Group are acknowledged not only as innovative, but also as attractive and mature, making a practical and, therefore, much appreciated contribution to superior motoring at all times.

About 43% of severe traffic accidents today occur on rural roads. Typically, severe accidents can be assigned to following accident sites: 33% on curved roads, 18% on sloped roads, 20% at or close to intersections, 29% on other places, see [1]. On rural roads, overtaking counts for about 10% of all severe accidents. Even though road traffic in Europe is steadily increasing, the number of fatal accidents was reduced by 40%
within the last decade. This positive effect can be mostly attributed to automotive active and passive safety systems such as improved braking systems, DSC, air-bags, improved car structures, navigation systems as well as traffic regulation, infrastructure design, etc. However, 40,000 casualties per year in Europe is still too high.

The BMW ConnectedDrive concept focuses on the intelligent integration of driver, car and environment concerning driver assistance and communication [2]. For BMW ConnectedDrive, driver assistance systems enhance safety and support drivers actively without interfering: they only make recommendations. Examples of available BMW systems include Active Cruise Control (ACC) using navigation data, Adaptive Light Control (ALC) and BMW Night Vision (NiVi), see [3-5].

Vehicle navigation based on map data will play a major role in future BMW driver assistance systems. The integration of precise navigation in-vehicle control systems enables automatic adaptation of the system (its states as well as its parameters) depending upon the upcoming geometry of the roadway and memorized attributes/events using a GPS positioning system in combination with a digital road database. For the past years, the importance of accurate and up-to-date digital map information has increased dramatically. The digital maps are seen as a new type of sensors for the vehicles and could contribute to detect objects or dangerous curves beyond the horizon of the driver (and sensors). Driver assistance applications relying on map data need to be guaranteed of a certain level of reliability and accuracy in order to provide safe and efficient services.

In order to drive a vehicle well, the driver needs accurate information about the driving environment in addition to well-founded training, experience and the ability to perform routine functions. Ideally, the driver is able to estimate a situation fully and completely and then make the correct decisions. The driving environment is based on the one hand on the position, movement and type of the other vehicles on the road, and on the other hand on the route and the nature of the road, on traffic regulations, weather, visibility etc.

However, because of the limitations of sensors, driver assistance functions at best possess only part of the information needed to describe the whole situation. Consequently, the driver will always experience a deficit in the expectations if the subjectively perceived information does not correspond to the full picture of the driving environment. The map preview as an electronic horizon can act as an additional sensor that will enhance the assessment of the situation of the vehicle.

To travel safely and in relaxed style at all times, it is essential for the motorist not only to maintain superior control of the car, but also precisely assess the road ahead. And it is precisely for this reason that BMW's modern navigation systems support the driver in providing clear orientation and, in future, by offering additional information on the course of the road and for appropriate judgment of current traffic conditions.

In this context navigation systems and their associated databases are used as additional forward-looking environment sensors, which make part of the missing information available. The geometry of the road surface and other information about the road, such as its type, curves and the number of lanes or restrictions, results in an estimation of the driving environment. This gives rise to opportunities for optimizing the driver assistance functions.

The outlined assistance system Dynamic Pass Prediction (DPP) (see figure 1) offers a new function for recommending overtaking related handling strategies. The fundamental algorithms of the overtaking decision taking process, the HMI development as well as results from real drive tests are described.
Map Database

A prototype version of DPP is based on commercial NAVTEQ digital maps that can be found in most of today’s in-car navigation systems.

To find out if a street segment is suitable for overtaking, the DPP system examines a number of standard street attributes such as number of lanes, form-of-way (motorway, single-carriage road, roundabout), speed restrictions, etc.

Another important element in the realization of DPP functionality is availability of street curvatures. While this data is not yet available in commercial digital maps, NAVTEQ pre-calculates the curvatures at shape points using existing street geometry. In general, such calculation can take place on-board. However, to achieve better results, a sophisticated spline-interpolation algorithm is used. This method is calculation intensive and it is not practical to perform in real-time on the navigation computer.

In the digital map database, calculated curvatures for street shape points are stored. In addition, on each crossing, one curvature value for every pair of streets is pre-calculated and stored in the database. Hyperbolic interpolation is used to emulate continuous curvature function over entire street length. During the road tests, it was found out that the curvature data is of good quality. The legal overtaking restrictions are not part of standard NAVTEQ digital map attribute set. NAVTEQ collected and integrated to the database number of street attributes that may affect the overtaking decision process. For instance, positions of pedestrian crossings, traffic lights as well as street markers are inserted in the database of the test area.

Electronic Horizon and Most-Probable-Path

An extract of the digital map containing streets that can be reached by the car in the near future is called an Electronic Horizon (ADAS Horizon, Extended Driver Horizon). The path on the Electronic Horizon that will be followed with highest probability is called most-probable-path. Construction of the Electronic Horizon and Most-Probable-Path is outside of scope of this article, but it can be said that EH is generated using probabilistic algorithms that takes into account the number of street attributes as well as the calculated route (if available).

DPP algorithms examines only street segments along the Most-Probable-Path. While is possible that the Electronic Horizon most-probable-path does not correspond with the driver’s intentions, this situation is very rare in DPP. Typically, DPP will be used on cross-country roads where frequency of crossings is not very high. In addition, on each such crossing the EH algorithm takes the most important road to follow. Drivers only turn to side roads either when they know in advance which path they will follow (i.e., they already are aware of the crossing), or if calculated route follows that way. In the later case, since calculated route is used as parameter in EH algorithm, the side road will be on the most-probable-path and the turn will be taken in account by the DPP algorithm.

DPP Driving Dynamics

Based on road geometry and other attributes in digital navigation maps as well as actual driving dynamic parameters, DPP informs the driver about road sections that are not safe for overtaking. In the sense of the BMW ConnectedDrive concept, the driver gets knowledge about roads ahead even when he is driving in unfamiliar areas. This avoids the continuously increasing willingness of the driver to take an overtaking risk. By using DPP in overtaking situations, safe, relaxed and comfortable driving is achieved.

Since the proposed system does not monitor oncoming traffic, it will not indicate that overtaking is safe. So
the complete maneuver remains the driver’s responsibility. As a matter of course the driver is obliged to obey effective traffic rules.

In order to adapt to the actual situation DPP also makes use of dynamic vehicle information like initial velocity, acceleration, and deceleration. The given geometrical distance values during the overtaking maneuvers are shown in figure 2, where vehicle 1 denotes the vehicle that is overtaken and vehicle 2 the overtaking vehicle.

The parameters for the overtaking distance are given by $S_H$, describing the whole overtaking distance, $S_1$ and $S_2$ the safety distance to the vehicle in front of the overtaking vehicle and after the overtaking maneuvers, respectively. $l_1$ and $l_2$ are length of the vehicles. $S_L$ finally describes the distance that the overtaken vehicle has passed during the overtaking maneuvers. The sum of the whole overtaking distance is than given by

$$S_U = S_H + S_L,$$

SU also depends on:

- $v_0$: the initial speed of the overtaking vehicle, which is assumed to be equal to the speed of the overtaken vehicle
- $v_1$: the assumed velocity of the overtaking vehicle after the overtaking maneuver
- $v_{max}$: speed limit
- $a_a$: acceleration of the overtaking vehicle
- $a_d$: deceleration of the overtaking vehicle
- $a_s$ well as the range of vision and the oncoming traffic

Figures 3 - 5 show speed plots for different situations. In figure 3 the overtaking vehicle accelerates to a turning speed $v_m$ and subsequently decelerates to the desired speed $v_1$. Applying standard motion equations

$$v = v_0 + a \cdot t$$

and

$$S = v_0 \cdot t + \frac{1}{2} a \cdot t^2$$

Eliminating variables $v_m$, $t_a$ and $t_d$ results in the required passing way $(\text{Figure 3} - \text{5})$.

Figure 4 shows the special case of acceleration to the required speed without a deceleration phase. In figure 5 the maximum speed is limited by $v_{max}$. Calculation of the passing way $SU$ is done analogously. The time values $t_a$, $t_c$, and $t_d$ are calculated dynamically.

All road sections are marked as “overtaking not recommended” except those with curvature attributes below a limit continuously for at least the passing way $SU$. The influence of velocity is shown in figure 6 – 8. Map data on a rural road between Königsdorf and Bad-Tölz (South of Bavaria) are illustrated. The orange road sections show sections where overtaking is not recommended for various velocity parameters.

As you can see, figure 6 presents an electronic horizon with high speed and figure 8 with low speed. If the driver is driving with higher speed the overtaking distance is much larger than with low speed as you can nicely see in figure 6. Therefore, the driver has more orange sections with higher speed where overtaking is not recommended. On the other hand, if the driver is driving with low speed, there are less orange sections where overtaking is not recommended and hence the driver has more passing ways.
Hardware and Software used in the BMW vehicle

The GPS receiver module used for our prototype is manufactured by U-Blox and based on the ANTARIS®4 chipset. The U-Blox RCB-4H is an ultra-low power GPS receiver board featuring the ANTARIS®4 positioning engine with SuperSense Indoor GPS. It is the pin-compatible successor product of the RCB-L1j. The RCB-4H is equipped with a MCX/OSX RF connector and a 20-pin connector for power and digital I/O. The supported Assisted GPS (A-GPS) functionality provides fast time to first fix even in difficult signal conditions.

The sensor data necessary to calculate the vehicle position is provided by a self-made acquisition unit, equipped with two Atmel® microprocessors, which combines the data from the vehicle (signals from gyroscope, speed pulses, reverse driving information) with the GPS position acquired by the aforementioned GPS receiver module and sends them via CAN. Figure 9 shows a block diagram demonstrating how the GPS data and vehicle data are integrated into the onboard system with the map database and the presentation in the vehicle via the navigation display and on the head-up display.

In this implementation, DPP is an ADASRP 2006 Plug-In. Advanced Driver Assistance System Research Platform 2006 is Windows-based.
framework application for hosting various ADAS solutions (see Figure 9). The ADASRP platform is developed by NAVTEQ. Vehicle Positioning module map-matches GPS position to the vector map database using additional sensor data like gyroscope and odometer. When the vehicle position is known, the Electronic Horizon module predicts the vehicle’s most-probable-path, up to several kilometres ahead. Using map data such as road geometry and legal speed limits as well as various environmental data, Speed Profile Server calculates the maximum speed along the most-probable-path. The Dynamic Pass Predictor will find out parts of road not suitable for overtaking using the most-probable-path attributes and calculated maximum speed as well as vehicle dynamic data. In the calculation, data about vehicle ahead provided by ACC system will be taken in account as well.

HMI, Visualization and Results from Real Test Drives

Dynamic Pass Prediction is implemented in a 5 series sedan with navigation system and head-up display (HuD). Results from real test drives have shown that the system enhances safety and actively supports drivers without interfering. The calculated distance is matched with map and navigation data where overtaking is not recommended. The resulting information is shown on the head-up display and on the navigation display (shown in Figure 10 and Figure 11). In Figure 10 the orange colored bars indicate road sections that are not safe for overtaking and show the matched vehicle position and the electronic horizon in the navigation display. Figure 10 shows the illustration on the head-up display.

If a road segment is straight and free of crossings but too short for overtaking, it will be marked with light orange color. Since the overtaking distance is a function of speed, it is possible that road segments that are too short become white if the vehicle changes speed.

Segments, which the DPP algorithm finds unsuitable for overtaking, are marked in orange color (see figure 12). most-probable-path (MPP) event signs symbolize the reason for the classification in the DPP engine. The most-probable-path (MPP) is part of the electronic horizon. If multiple reasons recommend not passing, an MPP event sign representing the first reason will be shown. All the colours in visualization are freely configurable. It is possible, for instance, to set the colour of ‘too short’ segments same as colour ‘do not pass’ segments.

As illustrated in the HuD design (Figure 12), the vehicle on the display is orange if the start of an overtaking maneuver is not recommended; otherwise the vehicle is shown in white.
Figure 12 demonstrates the function on the road. The Dynamic Pass Prediction info not only enhances driving comfort and ensures a superior style of motoring, but also help to optimise active safety on the road. It is a fact that one out of every ten severe traffic accidents on country and overland roads in Europe is attributable to overtaking. In many cases this is due to a lack of knowledge of local conditions and the road itself leading to false assessments of traffic and overtaking options. Dynamic Pass Prediction, therefore, makes it much easier for the driver to choose precisely those sections of the road where the driver can overtake at minimum risk. The bottom line, therefore, is that the driver benefits from better knowledge of local conditions and again can relax to an even greater extent at the wheel.

Even so, not even the most sophisticated and advanced assistance system is able to relieve drivers of their responsibility at the wheel. The driver is still required to properly assess traffic conditions and take appropriate decisions. The system does provide very effective and helpful support in this process, reliably telling the driver where it is not advisable to overtake a slower vehicle.

Apart from extra safety, this also helps to avoid pointless and particularly tense attempts at overtaking another vehicle, allowing the driver instead to relax and prepare for another road section where passing a vehicle involves a far smaller risk.

And again, this means extra safety and greater economy. In particular, however, it means enhanced superiority at the wheel, with drivers being able to use the dynamic potential of their BMWs wherever they are able to proceed with maximum efficiency on the road.

**Conclusion**

Driver assistance systems heavily rely on remote sensing for road traffic situation perception. The concept of advanced vehicle navigation extends the driver’s visual horizon to an electronic horizon with a much larger range. The ability to combine dynamic data (such as vehicle data) and map data (such as the roadway
geometry from a vehicle navigation system), provides the means for a driver assistance system to generate a “clear” picture of the current traffic scene.

BMW has proven by series applications, that the integration of advanced vehicle navigation in driver assistance systems, can bring substantial benefits in terms of reliability, robustness, increased functionality, fuel efficiency, active safety and performance. Driver assistance products using map databases as an additional information source will most likely be introduced in phases. The Dynamic Pass Prediction is based on available GPS technologies and common map databases designed for driver assistance systems. Even with the quality of navigation data available today, BMW’s DPP system can be enhanced by dynamics, which adapt to the situation providing even more benefit for the customer. By using DPP in overtaking situations, safer more comfortable and superior driving is achieved.

To travel safely and in relaxed style at all times, it is essential for motorists not only to maintain superior control of their cars, but also precisely assess the road ahead. It is precisely for this reason that BMW’s modern navigation systems support drivers in providing clear orientation and, in future, by offering additional information on the course of the road and for appropriate judgment of current traffic conditions.

Outlook for MAPS & ADAS and ADASIS Forum

Digital maps have large potential to enhance or enable Advanced Driver Assistance Systems (ADAS) by extending driver horizon and therefore contributing to safer, smarter, and cleaner road transport. For a predictive sensor called ADAS Horizon, in-vehicle digital maps are an important source of information providing look-ahead capability for ADAS applications and providing further information for on-board sensors to enhance environment perception. This paper reports on results from the European Commission project MAPS&ADAS, part of PReVENT Integrated Project, dedicated to the development, testing, and validation of a standardized interface (ADAS Interface) between ADAS applications and ADAS map data sources for accessing map data for vehicle position.

MAPS&ADAS (start February 2004, duration 3 years) is a subproject of the Integrated Project (IP) Preventive Safety (PReVENT), funded by the European Commission. The MAPS&ADAS subproject seeks to develop and validate appropriate methods for the collection and maintenance of safety content to be integrated into safety-enhanced in-vehicle digital maps and related changes of the standardized exchange format (GDF) to be used in ADAS and Navigation Applications, as well as a standard interface from navigation systems to general positioning and map systems towards ADAS that make use of map data for track preview purposes. The MAPS&ADAS consortium is composed of leading partners: ERTICO (project coordinator), BMW, DaimlerChrysler, Ford, Volvo Tech, Blaupunkt, Navigon, Siemens VDO, Navteq, Tele Atlas, Lower Saxony, Transver, and Hanover University.

The ADASIS Forum acting as the MAPS&ADAS user forum is a self-funded industry initiative launched in 2002 and coordinated by ERTICO, aiming at supporting and promoting the development and the implementation of a standardized interface between ADAS applications and digital map content. The ADASIS Forum is composed of 30 members from vehicle manufacturers, ADAS suppliers, navigation system suppliers, and map providers.

References