Pass/No Pass
Dynamic Road Prediction for Safe Overtaking

A new driver assistance system indicates road sections that are unsafe for passing. Combining digital map data with position, velocity, and acceleration from both the car’s system and from GPS, the advanced navigation system extends the visual horizon to an electronic horizon with a much larger range. Reducing driver workload, the system creates a safer, more comfortable driving experience.

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Vehicle navigation based on map data will play a key role in future driver assistance systems. A GPS system used in combination with a digital road database providing road geometry and memorized attributes or events can enhance precise navigation and automatic adaptation within the vehicle control system.

In recent years, the importance of accurate and up-to-date digital map information has increased dramatically. Digital maps constitute a new type of sensor for the vehicles and could contribute to detection of objects or dangerous curves beyond the horizon of the driver, and of other onboard sensors. Driver assistance applications relying on map data require a certain level of reliability and accuracy in order to provide safe and efficient services.

About 43 percent of severe traffic accidents today occur on rural roads. Typically, severe accidents occur in these accident sites: 33 percent on curved roads, 18 percent on sloped roads, 20 percent at or close to intersections, 29 percent in other places.

On rural roads, passing, or overtaking, accounts for about 10 percent of all severe...
Driver Assistance Systems

Growing traffic density and its consequences such as traffic congestion and longer traveling times, as well as the greater complexity of many traffic situations, make driver assistance systems increasingly attractive and useful. These systems give the driver helpful information, make it easier for him or her to make the necessary decisions, and support the driver in handling both 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.

The fundamental principle applicable to all functions is that the driver retains an active role, responsibility, and the final decision at all junctures, remaining in control of the car and its functions at all times. Generally, driver assistance systems only take effect when activated by the driver. Should 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.

During the road tests, we found that the curvature data is of good quality, although full functioning of the prediction system requires improved and extended map data.

The legal overtaking restrictions are not part of the provider’s standard digital map attribute set. The provider 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, and street markers are inserted in the database of the test area.

Electronic Horizon

An extract of the digital map containing road areas that may be reached by the car in the near future — a driver-adjustable environment that may extend as far as 10 kilometers — is called the electronic horizon (EH) or extended driver horizon. The path on the electronic horizon that will be followed with highest probability is called the most probable path (MPP). Construction of the EH and MPP is outside the scope of this article, but we can state that the EH is generated using probabilistic algorithms that take into account a number of street attributes as well as the calculated route (if available).

The DPP algorithm examines only street segments along the MPP. While it is possible that the EH MPP 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 will usually prefer the most important road to follow; the driver will turn to side roads either when he know in advance which path he will follow (that is, he is already aware of the crossing), or if the calculated route follows that way. In the latter case, since the calculated route is used as a parameter in the EH algorithm, the side road will be on the MPP, and the DPP algorithm will take the turn into account.

FIGURE 1 shows the how the vehicle positioning module map-matches the car’s 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 (MPP), up to several kilometers ahead. Using map data such as road geometry and legal speed limits, as well as various environmental data, the Speed Profile Server calculates the maximum speed along the MPP. The Dynamic Pass Predictor will find out parts of road not suitable for overtaking using the MPP attributes and calculates maximum speed, as well as vehicle dynamic data. In the calculation, data about the vehicle ahead, provided by the ACC system, will be taken into account as well.

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 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 a safe, relaxed, and comfortable drive 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 traffic rules in effect.

To adapt to the actual situation, DPP also makes use of dynamic vehicle information such as initial velocity, acceleration, and deceleration.

FIGURE 2 shows the given geometrical distance values during the overtaking maneuver, where vehicle 1 denotes the vehicle that is overtaken and vehicle 2 the overtaking vehicle.

The parameters for the overtaking distance are given by $S_o$, 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 vehicle lengths. $S_f$ finally describes the distance that the overtaken vehicle has passed during the overtaking maneuvers. The sum of the whole overtaking distance is then given by $S_U = S_H + S_f$, where $S_H$ is given by $S_H = S_1 + S_2 + l_1 + l_2$.

$S_U$ depends further on:

- $v_0$: the initial speed of the overtaking vehicle, which is assumed to be equal to the speed of the overtaken vehicle,
- $v_f$: the assumed velocity of the overtaking vehicle after the overtaking maneuver,
- $v_{max}$: speed limit,
- $a_a$: acceleration of the overtaking vehicle and
- $a_d$: deceleration of the overtaking vehicle.
as 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 $v_o$ and subsequently decelerates to the desired speed $v_d$. Applying standard motion equations

$v = v_0 + a \times t$

and

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

Solving for variables $v_0$, $t$, and $t_2$ produces the required passing distance.

Figure 4 shows the special case of acceleration to the desired speed without a deceleration phase. In Figure 5 the maximum speed is limited by $v_{\text{max}}$. Calculation of the passing distance $S_u$ is done analogously. The time values $t_a$, $t_c$, and $t_d$ will be 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 $S_u$. Figures 6–8 show the influence of velocity, using map data on a rural road between Königsdorf and Bad-Tölz in the south of Bavaria. 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. Although this may seem counterintuitive at first, at higher speeds the overtaking distance is much larger than with low speed. Therefore, the driver has more orange sections with higher speed where overtaking is not recommended. On the other hand, if the driver is driving at low speed, there are fewer orange sections where overtaking is not recommended, and hence he has more passing opportunities.
**Test Drives**

We have implemented the dynamic pass prediction system in a 5er series sedan with navigation system and head-up display (HuD). Results from real test drives have shown that the system enhances safety and supports drivers actively without interfering. The calculated distance is matched with map and navigation data where overtaking is not recommended. The resulting information is shown on the HuD and on the navigation display (shown in Figure 9 and Figure 10). In Figure 9 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 HuD.

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 (see Figure 11). Most Probable Path (MPP) event signs symbolize the reason for the classification in the DPP engine. The 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 colors in visualization are freely configurable. It is possible, for instance, to set the color of “too short” segments the same color as “do not pass” segments.

As illustrated in the HuD design, the vehicle on the display is orange if the start of an overtaking maneuver is not recommended at the moment, and white otherwise.

The DPP data not only enhances driving comfort and ensures a superior style of motoring, but also helps optimize active safety on the road. One out of every 10 severe traffic accidents on country and overland roads in Europe is attributable to overtaking. And in many cases this is due to a lack of knowledge of local conditions.
and the road itself, leading to false assessment 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 he is able to overtake at minimum risk. The bottom line 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 the driver of his responsibility at the wheel, meaning that he is still required to properly assess traffic conditions and make 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 ve-

### Advanced Driver Assistance Projects

Digital maps have a great potential to enhance or enable advanced driver assistance systems (ADAS) by extending the driver horizon and thus contributing to safer, smarter, and cleaner road transport. As a predictive sensor called ADAS Horizon, in-vehicle digital maps are an important source of information providing look-ahead capability for ADAS applications, and further information for on-board sensors to enhance environment perception.

The MAPS&ADAS project (2004–2007) is a sub-project of the Integrated Project (IP) Preventive Safety (PReVENT), funded by the European Commission. MAPS&ADAS seeks to develop and validate appropriate methods for 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, and a standard interface from navigation systems or general positioning and map systems.

The new version of PReVENT is InteractIVe. Map activities within InteractIVe will fully integrate the electronic horizon concept as a part of the perception layer together with in-vehicle sensors and other information coming through the communication channels. This includes the definition, implementation and validation of the novel concept of Rich Electronic Horizon (REH), improving the reliability and usability of the electronic horizon.

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 including vehicle manufacturers, ADAS suppliers, navigation system suppliers, and map providers.
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 the driver being able to use the dynamic potential of his BMW wherever he is able to proceed with maximum efficiency on the road.

**Conclusion**

Driver assistance systems rely heavily 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 source of information 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 the motorist not only to maintain superior control of his car, but also precisely assess the road ahead. And it is precisely for this reason that BMW’s modern navigation systems support the driver, providing clear orientation and, in future, by offering additional information on the course of the road and for appropriate judgment of current traffic conditions.

**Manufacturers**

The GPS receiver module used for the BMW prototype is the RCB-4H manufactured by u-Blox (www.u-blox.com) and based on the Antaris 4 chipset from Atmel (www.atmel.com). Navteq (www.navteq.com) provided the digital maps for the DPP project.

The sensor data necessary to calculate the vehicle position is provided by a BMW proprietary 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.

In this implementation, DPP is an ADASRP 2006 Plug-In. Advanced Driver Assistance System Research Platform 2006 is a Windows-based framework application for hosting various ADAS solutions. The ADASRP platform is developed by Navteq.