interactIVe - High precision maps for sustainable accident reduction with the enhanced Dynamic Pass Predictor

Kees Wevers
NAVTEQ, De Run 1115, 5503 LB Veldhoven, The Netherlands
phone: +31.40.298.1585; email: kees.wevers@navteq.com; web: www.navteq.com
Jan Loewenau
BMW Group Forschung und Technik, Hanauer Str. 46, 80992 Munich, Germany.
phone: +49.89.38244993; email: jan.loewenau@bmw.de; web: www.bmwgroup.com
Sinisa Durekovic
NAVTEQ, Otto-Volger-Str. 1, 65843 Sulzbach, Germany
phone: +49.6196.589313; email: sinisa.durekovic@navteq.com; web: www.navteq.com
Meng Lu
National Laboratory for Automotive Safety and Energy, Tsinghua University,
Beijing 100084, P.R. China; phone: +86.10.62771667; email: m.lu@tsinghua.edu.cn

Abstract

The paper presents the preliminary result of the development of the eDPP (enhanced Dynamic Path Predictor) during overtaking situations. The eDPP application offers a higher degree of accident prevention through: advanced driver-information and driver-warning strategies; improved actuation using the new and enhanced ADASIS v2 (Advanced Driver Assistance Systems Interface Specifications, version 2) protocol and high precision maps; an advanced visibility range sensing system (using camera based traffic sign recognition); vehicle-to-infrastructure communication for acquiring information on the local traffic situation (traffic, dynamic hazards), vehicle-to-vehicle communication for overtaking warnings; and integration of the independent ACC (Adaptive Cruise Control) system including other vehicle parameters, as well as its interaction with the driver. The eDPP increases vehicle intelligence, and substantially contributes to safer and more efficient driving experience for the whole range of vehicles, in conjunction with the EfficientDynamics strategy of the BMW Group.

Introduction

The work is carried out for a large part in the framework of the EU-funded project interactIVe (Accident avoidance by active intervention for Intelligent Vehicles) [1], which offers the car manufacture and the digital map provider the opportunity to share views, requirements and concepts regarding the field of safe driving and accident reduction, especially with the objective to save lives. In addition, it provides the opportunity to support map database suppliers in developing new methods of dynamic data capturing and dynamic data format extension, while providing valuable feedback through real-life experience with the BMW prototype application eDPP (enhanced Dynamic Path Predictor). The eDPP is an example of a new generation advanced driver assistance systems (ADAS) [2]. Based on road geometry and relevant attributes from the digital map for navigation and driving assistance applications, as well as actual dynamic driving parameters, the previously in a similar cooperation effort developed Dynamic Path Predictor (DPP) system informs the driver about road sections that are not safe for overtaking [3]. The next step in this approach is the eDPP concept, which will provide the driver with knowledge about the roads ahead, even when he is driving in an unfamiliar area. This substantially reduces the overtaking risk by keeping the driver from starting an overtaking maneuver when it is not safe to do so. Using the eDPP system in overtaking situations will contribute to the optimization of an overtaking maneuver by controlling the speed based on road environment and visibility range. In this way the system will help to achieve a safe, relaxed and comfortable driving experience for the driver.

Digital map and positioning

Digital Map

A digital road map for in-vehicle applications consists of geometry and related attributes. The core geometry provides a connected node/link representation of the road centrelines of the road network. Connectivity is important for enabling routing in the network. The shape of a link, if it is not a straight line, may be represented by one or more shape points (intermediates). Attributes are referenced to links, nodes and shape points. Additional geometry may be present for cartographic representation. Nodes and shape points are represented in World Geodetic System 1984 (WGS84 [4]) global coordinates (latitude/longitude pairs), which provide absolute positions. Coordinate resolution of current digital road maps is 10 microdegrees, which roughly corresponds to 1.1 m in latitude and 0.7 m in longitude at 50° latitude. This sets a limit to the accuracy of both information retrieved from the digital map, and information that is stored in geometrical relation to the digital map. For instance, lane information can be provided as a digital map attribute (number of lanes, width per lane, position with respect to road centreline), but if positioning within a lane is required, and lane width is 2.5 m, then the resolution should be in the order of 0.25 m.

The Geographic Data Files (GDF) standard provides both a data model and an exchange format for map databases for in-vehicle applications. Currently the original European standard version 3.0 of 1995 [5] is still used as the basis (with extensions), even though version 4.0 is since 2004 available as an international standard [6].

Absolute Versus Relative Positioning

Standard vehicle positioning as used in a navigation system and other ADAS applications provides absolute positioning. Inertial sensors, like an inertial measurement unit (IMU), or the more simple combination of the vehicle odometer output and a gyroscope, provide relative positioning, which is fused with GPS (Global Positioning System) positioning to provide an estimated absolute position, which in turn is fused in a process named map matching with map information to provide the projection of the estimated absolute position on the map road centreline (as well as correction of the longitudinal position at turns). This implies that the resulting absolute position is accurate in longitudinal direction (within the limit set by the coordinate resolution of the map), but not necessarily in lateral direction.

All other sensors provide relative positions of observed objects, i.e. positions relative to the location of the sensor, and expressed, for instance, as a bearing and a distance (polar coordinates). Examples are radar, lidar, camera and communication based triangulation using a wireless local are network (WLAN) or a wireless sensor network (WSN). If the absolute position of the sensor is known, the absolute position of the observed object may be calculated, either in global coordinates, or, for instance, in a local meter grid with its centre fixed to the object that maintains the local dynamic map. On the other hand, if absolute positions of objects are known, their relative positions can be calculated.

Exchange of Position Information

It is likely that exchange of position information of moving objects between different local dynamic maps will be based on WGS84 coordinates, and that AGORA-C location referencing [7,8] will be used to increase robustness, especially for map differences. This method has been developed for traffic information messages, much as a dynamic map-based alternative for static TMC (Traffic Message Channel) location coding. In TMC location coding is based on pre-coding of locations and storage of location codes and additional information in location tables. The location codes en-able encoding of the location in a traffic information message. Although developed for providing text or spoken messages by use of dedicated radio receivers, it became only a success after its adoption in navigation systems. Disadvantages of TMC coding are the need for creation, maintenance and dissemination of location tables, the need for inclusion of location codes in map databases, and the limited addressability of the road network due to limited table size and the effort involved.

In AGORA-C the digital map acts as the location table. A code is created from the map when needed, used in a message, and discarded after interpretation and use in the receiving system. Any part of the network can be addressed. The coding is based on points on the location in WGS84 coordinates, which may have different point types, and several attributes as present in GDF type map databases. The additional attributes provide robustness against map differences, while still keeping the code size within an acceptable limit [9].

Enhanced dynamic path predictor

Development of the eDPP

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 eDPP concept the driver will get knowledge about roads ahead even when he is driving in unfamiliar areas. Furthermore, with the visibility sensing system, the driver will be continuously informed about the visibility range which depends of the traffic signs, weather conditions and lighting environment. This avoids the continuously increasing willingness of the driver to take an overtaking risk. By using eDPP in overtaking situations a safe, relaxed and comfortable driving will be achieved. Such DPP system will contribute to the optimization of overtaking maneuver by controlling the speed based on road environment and visibility range leading to a safe and comfortable driving.

To highlight the innovative aspects of this new application the enhanced DPP will combine the data from the digital map (e.g. curves, crossings, relevant traffic signs and slopes) with integrated vehicle parameters using the ADASIS v2 (Advanced Driver Assistance Systems Interface Specifications, version 2) protocol and the visibility sensor data (e.g. visibility distance, weather, fog, wipers, and turn signal, given by the vehicle sensors via CAN - Controlled Area Network), and ACC (Adaptive Cruise Control) functionalities (e.g., distance and speed of vehicle in front) to support the driver while driving with a improved electronic horizon. The ADASIS has been developed, by the ADASIS Forum (founded in 2002 on the initiative of NAVTEQ and now coordinated by ERTICO) and in the EU funded MAPS&ADAS project (2004-2007) [10,11]. In addition, overtaking with better knowledge of the environment, i.e., including local traffic situations via Car2Car (Car to Car) and Car2I (Car to infrastructure) communication (vehicle in front or oncoming traffic) or long range visibility provided by the map data and visibility range provided by the visibility sensor will lead to reduce the heavy fuel consumption of overtaking.

As one can see in Fig. 1, e.g., the vehicle is driving with eDPP on road sections that are not safe for overtaking (orange sections). Therefore, the eDPP will via ACC adapt the speed to vehicles ahead that the driver is supported with a safe speed on the stretch of the road the driver is currently driving. To provide this helpful support, the eDPP application with a given graphic in the instrument cluster in the cockpit (Head-Up Display and navigation display) presenting the sections of not safe for overtaking. The driver will be further supported by given different traffic signs and that's support the driver on road sections at his current location and situation.

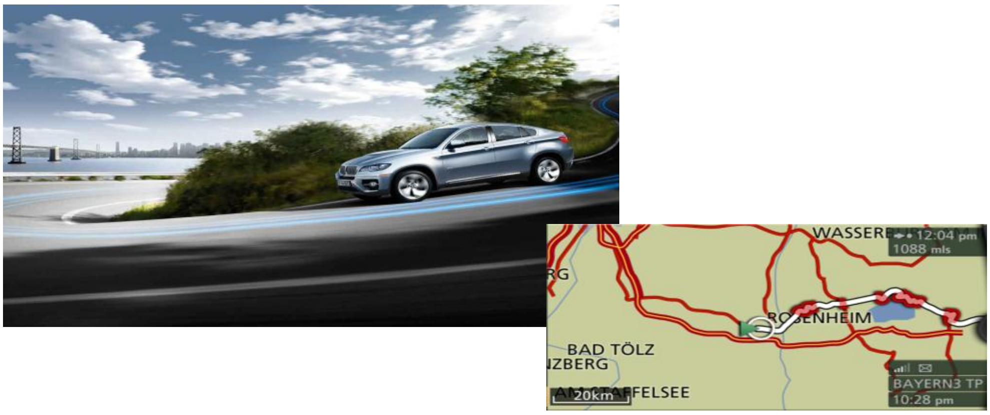

Fig. 1. BMW test vehicle with the eDPP and navigation display

The driver activates the eDPP application and the signal will be also transmitted to the Head-Up Display and navigation display. Based on the driving dynamics and navigation data, the eDPP indicates road sections that are not safe for overtaking. For valid overtaking sections, the use of actual visibility range depending on driving conditions, e.g., weather and lighting, will enable safe and optimal overtaking maneuver with less fuel consumptions, as well as an optimal visual communication to the driver.

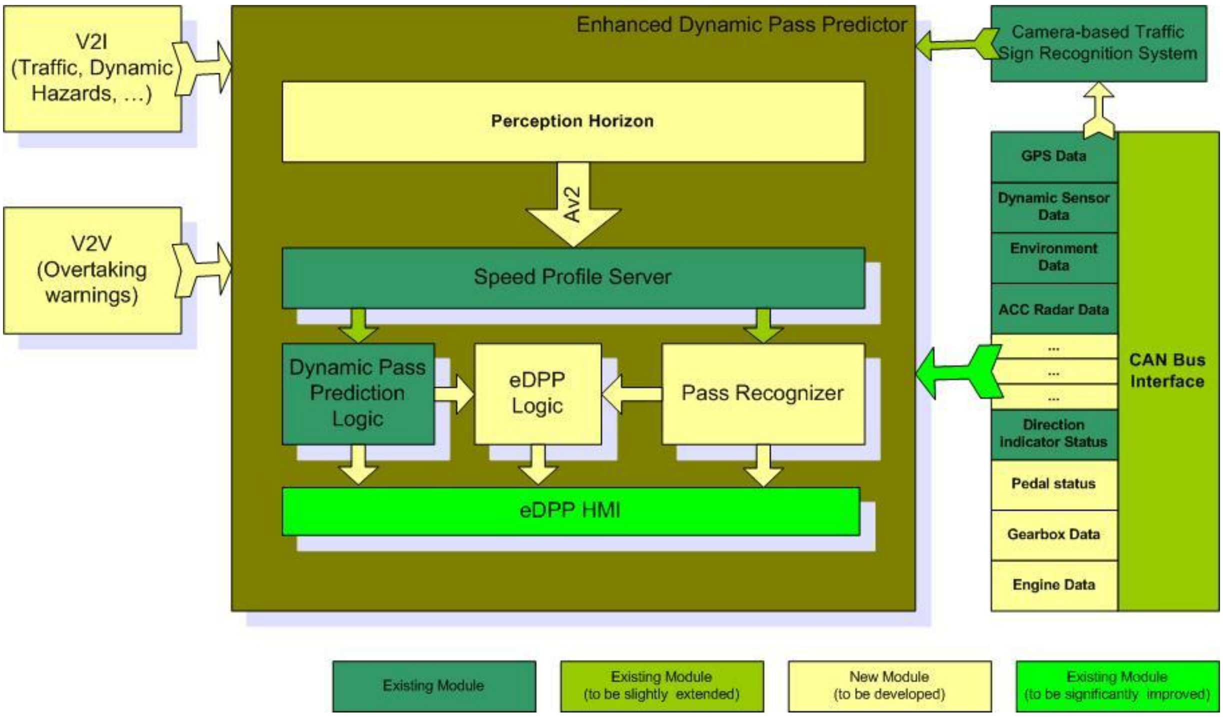

Fig. 2. Architecture of eDPP

By reducing the enormous driver workload before overtaking situations a safer and more comfortable driving will be achieved without losing driving pleasure. The system will show further how driver assistance systems can take advantage of navigation data especially if it contains curve, sign information and the new parameters from the ADASIS v2 protocol.

With the quality of navigation data available today the eDPP function is feasible. Taking driving parameters and Car2X (Car to x) communication into account, a situation adaptive recommendation supports and provides more safety and even more benefit for the customer (see Fig. 2). The requirements of the Perception Horizon for the eDPP have to be defined during further discussion with the partners in the project.

This function will help the driver above all on roads where it is not safe for overtaking especially with oncoming cars, crossings, and unknown road works and on rural and curvy roads, local traffic situations, thus ensuring that the driver is supported in such cases. The eDPP function will receive its information on the route from the navigation system and Car2X communication, which also comprises information about an improved electronic horizon as well as a modern prediction to support safe driving (see Fig. 3).

Fig. 3. BMW test vehicle with an improved electronic horizon

Different HMI output devices for the eDPP are evaluated regarding their potential to convey information on efficient and anticipative driving to the driver (e.g., acceleration, deceleration, and gear-shift). The HMI should act as a overtaking-driving coach for the driver. Output devices exploiting different modalities are compared standalone and in combinations. Examples include displays (cluster, TFT, head-up display) haptic feedback, e.g., through the seat, pedals (Actives Gas Pedal) as well as sound. Premises are to integrate information and avoid information overflow but to provide the driver with intuitive ambient information on the most safe and efficient driving style in the given situation. The selection will be based on rapid prototyping and evaluation in the driving simulator or test track. The information under presentation concepts will be designed following the current human-factors requirements for in-vehicle systems. The final in-car system will be fully functional with the eDPP on-board application.

Components

The following comments are used and installed in the BMW vehicle:
1) Instrument cluster in the cockpit, with Head-Up Display and navigation display;
2) Vehicle computer display;
3) Visibility sensor (front camera);

4) Navigation platform (ADASRP [12]) based on protocol with the Perception Horizon;
5) Vehicle sensors via CAN and ACC functionalities;
6) eDPP HMI (Human Machine Interface) concept.

Scenarios

To guide the design and development of the system, and to help testing the eventual result of the implementation, a set of target scenarios has been developed, based on discussion and brain storming sessions, which all concern potential conflicts in overtaking situations. Beside a large list of overtaking examples two important scenarios are shown to explain how overtaking situations are handled and evaluated. Further will be shown how it will be possible to avoid accidents on dangerous crossings and unknown road works given by means of modern controlling modules and via Car2X communication.

Scenario 1

The outline of Scenario 1 is summarized in Table 1, and illustrated in Fig. 4. These tables are taking directly from the interactIVe project documents.

	Scenario Outline
Scenario short description	Conflict between an overtaking vehicle and a vehicle from oncoming and turning traffic with unknown curves.
Level 1 typical scenario	Dangerous situations during an overtaking situation behind a track which is turning and an oncoming vehicle in a unclear and an unknown curve (Type 10+66), e.g., curves and turning vehicles. When entering the overtaking area the vehicle overtakes but during the overtaking situation the track is turning and at the same time there is coming a curve and an oncoming vehicle. The driver brakes, reduces the speed and is driving again behind the track before the track is turning the curve starts and the oncoming vehicle is nearby. The driver avoids a possible accident.
Accident type	Dangerous Situations during an overtaking situation behind a track which is turning and an oncoming vehicle in a unclear and an unknown curve.
Level 2 narrative	The driver is driving a vehicle on a rural road with speed limit of 100 km/h and a vehicle in front is driving at a speed of about 60 km/h during he is approaching an overtaking area. The driver is willing to overtake and during the overtaking situation the track is turning and there is a unknown curve and an oncoming vehicle in front of the overtaking vehicle, and as a result- not to have an accident - the driver brakes, reduces the speed and is driving again behind vehicle and he not taking an overtaking manoeuvre.
Sketch	1) Vehicle starts overtaking (FV) 2) Vehicle is overtaking (FV→ LV) 3) LV is turning, there is a oncoming vehicle (OV) and an unknown curve in front of the overtaking vehicle and the overtaking vehicle brakes, reduces speed and driving behind vehicle again (FV behind LV)

Table 1. Scenario 1: Overtaking on Roads with Unknown Curves and Oncoming and Turning Traffic

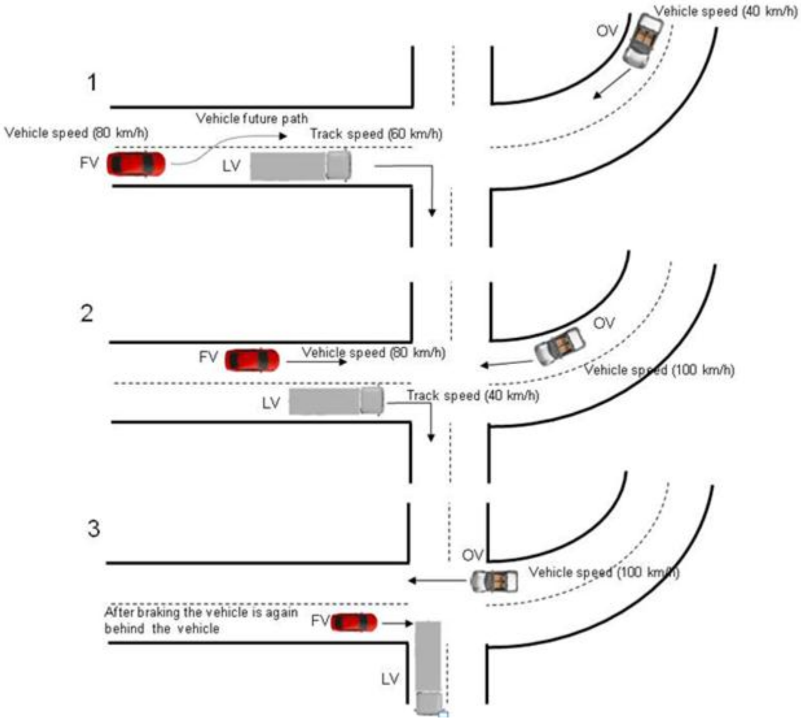

Fig. 4. Illustration of Scenario 1: overtaking on roads with unknown curves and oncoming and turning traffic

Scenario 2

The outline of Scenario 2 is summarized in Table 2, and illustrated in Fig. 5.

	Scenario Outline
Scenario short description	Conflict between an overtaking vehicle and unknown road works.
Level 1 typical scenario	The host vehicle is driving on a rural road whilst attempting to overtake a lead vehicle. Whilst overtaking, road work obstructions are encountered in the overtaking path or lead vehicle path that lead to a collision between the vehicles.
Accident type	Driving accident whilst overtaking.
Level 2 narrative	The host vehicle is driving on a rural road whilst following a slower lead vehicle and waiting for a suitable position to overtake. The driver is impatient and continually monitors his existing Pass Predictor system for when a suitable overtaking opportunity will present itself, thereby missing road signs for upcoming road works. When the overtaking opportunity presents itself, the driver pulls out and accelerates to overtake the lead vehicle, but is suddenly made aware of upcoming road works in the overtaking path or lead vehicle path. The driver attempts to slow down, but so does the lead vehicle once the danger is made know. Both vehicles attempt to avoid the road works, but end up colliding with one another.
Sketch	1) Vehicle starts overtaking (FV) 2) Vehicle is overtaking (FV→ LV), but road works in the overtaking path suddenly become visible. 3) Overtaking vehicle brakes, but so does lead vehicle 4) They both try to avoid road works and collide with one another.

Table 2. Scenario 2: Overtaking on Roads with Unknown Road Works

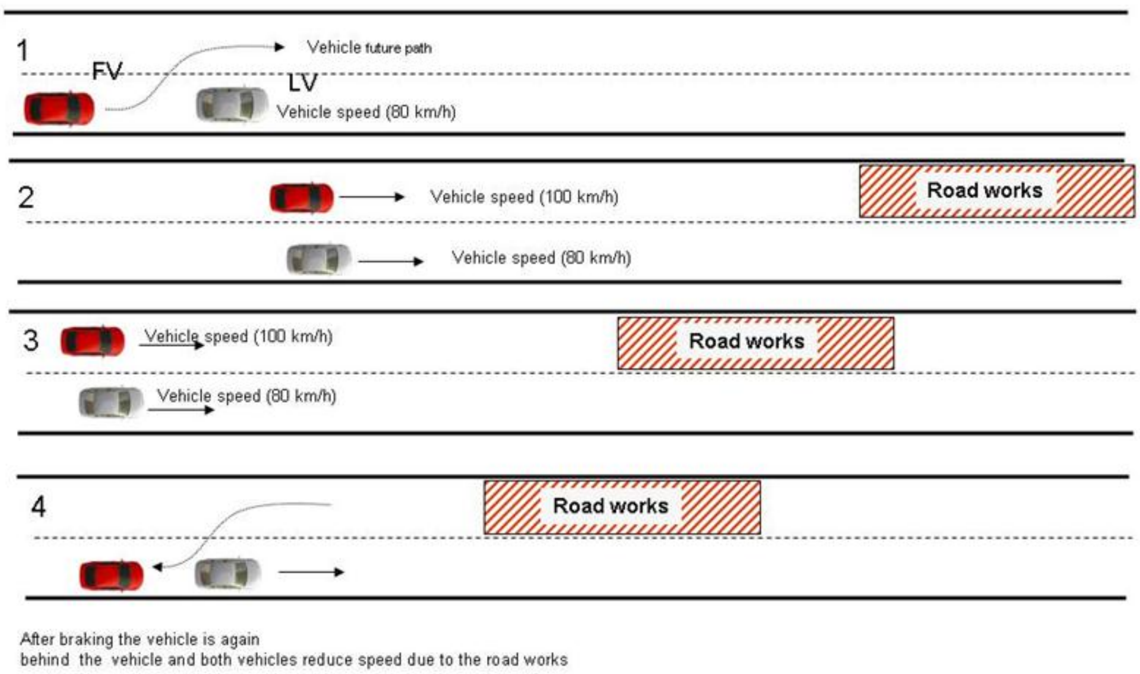

Fig. 5. Illustration of Scenario 2: overtaking on roads with unknown road works

Conclusion

The realized eDPP (enhanced Dynamic Path Predictor) based on high precision maps will enhance road traffic safety especially focuses on overtaking situations. Examples of overtaking scenarios are explored and will be demonstrated. The digital map database plays an important role in cooperative driving assistance systems. Progressive developments of these systems create increasingly stringent requirements concerning completeness and updatedness of in-vehicle digital map databases.

The eDPP applications will contribute to road traffic safety. The further research by means of using the Perception Horizon will improve the eDPP, and the eDPP application will be demonstrated and evaluated.

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