Electronic Horizon - Providing Digital Map Data for ADAS Applications

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Abstract. The number of vehicle navigation devices has increased tremendously during the last years. The digital maps of these systems contain a lot of valuable information that provides benefit for other features besides route guidance as well. The area of potential applications reaches from driver information and warning up-to comfort and active safety applications, so-called ADAS[1]. Since built-in sensors are limited to a relatively short range, digital map data can be used to "look" much further into the direction of the vehicle's path. The map data, e.g. road geometry, number of lanes, speed limits, etc. is provided on a vehicle bus system as the so-called Electronic Horizon. European automotive industry has teamed up in the ADASIS Forum to develop a common standardized interface to access the Electronic Horizon. Ford Research & Advanced Engineering Europe has developed a prototype system for Lane Keeping Assistance as one application example.

1 Introduction

Nowadays, modern vehicles are equipped with a variety of sensors to enable safety and comfort features. However, these on-board sensors are limited to a relatively short range of a few hundred meters. On the other hand, digital maps of a navigation system contain valuable information about the road segments lying ahead, such as road geometry, functional road class, number of lanes, speed limits, traffic signs, etc. This data can be extracted and provided to applications as the so-called *Electronic Horizon*. This virtual sensor is now able to provide information within an extended range, see Figure 1. Thus it enables the vehicle to prepare earlier for an up-coming situation.

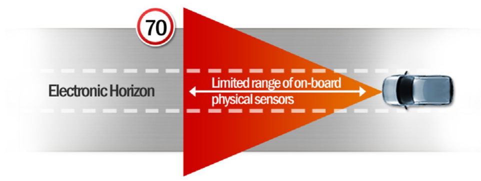

Fig. 1. Range of vehicle sensors.

[1] Advanced Driver Assistance Systems

2 Overview

The support of ADAS requires an accurate knowledge about the road ahead of the vehicle. Since the last years, map vendors already have significantly improved the level of detail and accuracy of digitised data. Up-to-date digital navigation maps contain detailed information about road geometry, topology, and typical attributes such as functional road class, number of lanes, speed limits, traffic signs, etc. Future maps will support even more details depending on the requirements demanded by the automotive industry to support ADAS.

The so-called Electronic Horizon contains road attributes from the digital map as well as vehicle position data. Fig. 2 gives an overview about the principle. The Navigation system, or more generally the *Electronic Horizon Provider*, extracts map data in the vicinity of the vehicle position. All relevant attributes required by applications are extracted and stored locally. The prediction of the *Most Likely Path*, which the vehicle is expected to take, has a significant influence on the quality and reliability of the Electronic Horizon. Ford Research and Advanced Engineering has developed algorithms for calculating the Most Likely Path based on historic information and current vehicle status [2]. The Electronic Horizon is provided to applications on the vehicle's bus system, most likely the CAN bus. The specification of the interface between Electronic Horizon Provider and applications is of special interest for the vehicle manufacturer. In order to reduce development cost and risk, a standardized interface is highly appreciated. As a result of this need, the European ADASIS Forum was launched in the year 2001. Section 4 outlines the interface specification and ADASIS Forum activities.

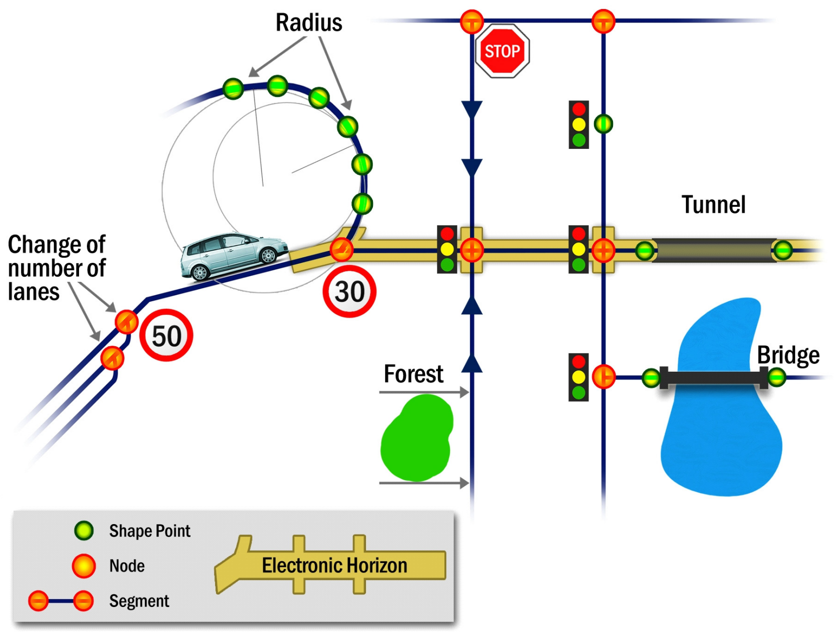

Fig. 2. Electronic Horizon.

3 Electronic Horizon Provider

Ford Research & Advanced Engineering has developed a prototype system to provide an Electronic Horizon, the so-called *Information Manager* [1] [3]. The system has been implemented as a prototype and integrated into test vehicles. The system does not only provide vehicle position and digital map data, but also predicts the Most Likely Path of the vehicle [2]. Fig. 3 gives an overview about the systems architecture. The entire system is designed in a modular way, allowing a maximum of flexibility and providing the opportunity to enhance and modify due to future requirements.

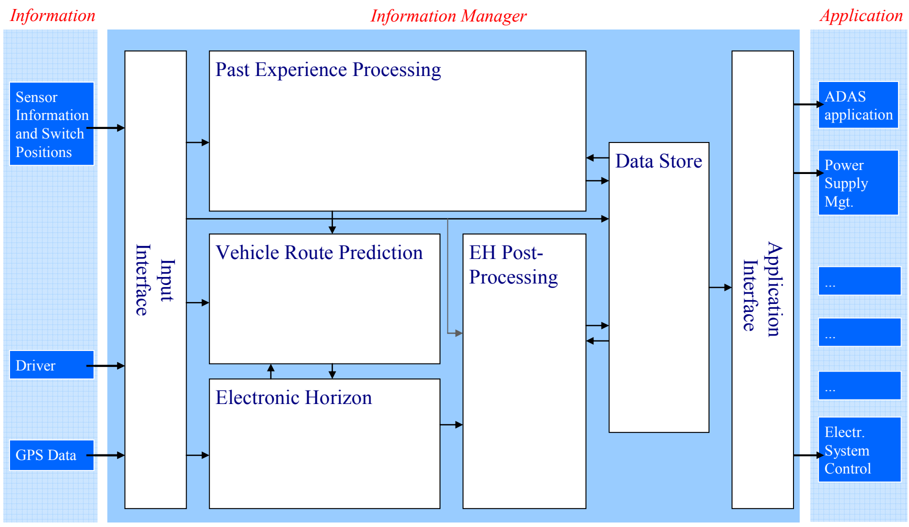

Fig. 3. Systems architecture of Ford's Electronic Horizon Provider (Information Manager).

The following paragraphs introduce the Information Manager in more detail.

3.1 Electronic Horizon & EH Post Processing

The "heart" of the system is a module that retrieves a configurable number of attributes from the digital map in the vicinity of the vehicle (the so-called *Electronic Horizon* module, *EH*). In a first step, the road segments for all possible paths are extracted from the map in the vicinity of the vehicle. Therefore the current vehicle position is estimated by a GPS receiver, and then matched on a road segment. The quality of the Electronic Horizon obviously depends on the correct estimation of the vehicle's path. If the road attributes would be provided for a path the vehicle does not take, the information will be worthless for the application and will cause a re-calculation of the Electronic Horizon. That would consume processing power and time leading to a gap of input data on the application side. In order to avoid re-calculations and to ensure proper operation of the system, the module receives information about the *Most*

Likely Path of the vehicle from *Vehicle Route Prediction* [2]. The EH module then extracts all relevant attributes attached to the road segments only for this single path.

The pre-processed Electronic Horizon is filtered in a second step, the *EH Post Processing,* due to the requirements of the supported applications. The EH Post Processing includes also demonstration software to visualize the Electronic Horizon as shown in Fig. 4. The module can be enhanced with additional sub-modules, e.g. a speed estimator that is calculating a predicted speed profile for the road segments ahead of the vehicle.

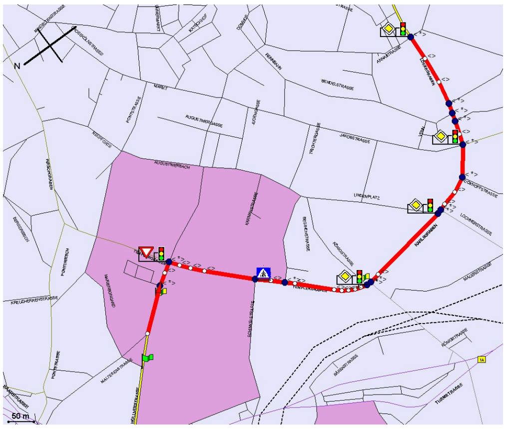

Fig. 4. Visualization of Electronic Horizon.

The calculated Electronic Horizon is then transferred to the *Data Store*.

3.2 Data Store

The *Data Store* is the common database of the system, which stores all data required by the applications as well as needed internally for the *Past Experience Processing*. Incoming data is received from the EH Post Processing as well as vehicle sensor data from the Input Interface. Data is then provided to the *Application Interface* as well as to the Past Experience Processing modules.

3.3 Input/ Output Interfaces

The *Application Interface* provides all data for any connected application in a specified format. The Application Interface supports the ADASIS protocol as described in section 4.2. At the moment, the Application Interface is implemented for the CAN bus only. However, other bus systems can be integrated easily by adding the adequate software.

The *Input Interface* manages all input data for the Information Manager. This includes vehicle sensor data, switch positions and other data available on the vehicle bus system as well as GPS position data. In addition, a driver identification mechanism is used, allowing the system to behave differently depending on the current driver. This information is needed by the *Past Experience Processing* and the *Route Prediction* modules.

3.4 Past Experience Processing

The Past Experience Processing stores the route currently driven by the vehicle, which is subsequently used by the Route Prediction module.

The Past Experience Processing contains a database for storing the collected information, building the basic step for a learning system. This database stores all trip data on segment by segment basis. That is while driving, all road geometry data is broken up into road segments as stored in the digital map. Along with coordinates or keys that allow identifying the segments later, additionally time, date and other data is stored as needed by other supported applications. Fig. 5 illustrates how the map database stores geometry information by splitting up the road network into segments and nodes. When driving to a destination the Past Experience Database receives the sequence of segments. For convenience, the system can either store the whole trip as that sequence or store only the transitions, which are consecutive segment pairs, where the second is always a successor to the first along with the time and date. These segment pairs are also called *decision points*.

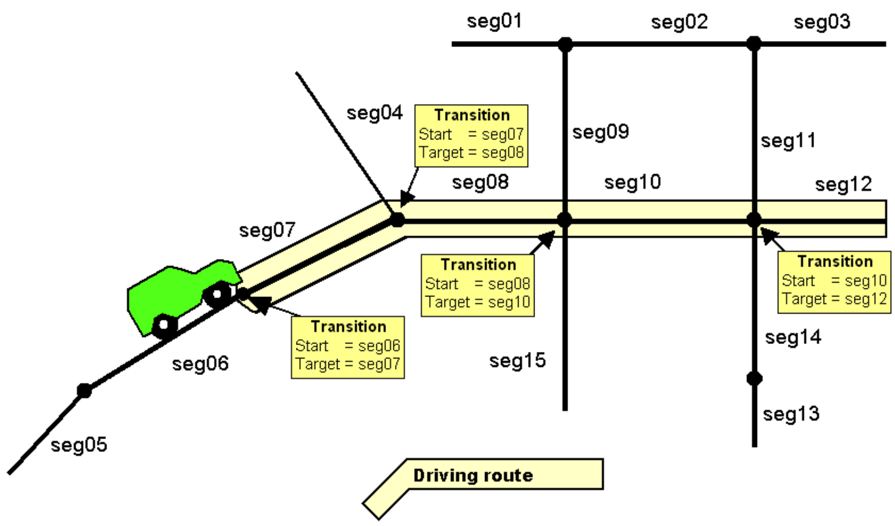

Fig. 5. Storing transitions while driving.

In order to optimize the memory usage, data is stored with an expiration timestamp. Once the past experience data reaches a specified age, the affected records are deleted. The memory management can further be improved by limiting the amount of stored data. Instead of keeping track of complete routes, only the segments that build a so-called decision point are considered (see above). During testing, it has been estimated that 3 -5 Mbytes of storage capacity will be sufficient for achieving a high prediction quality. This amount of memory would allow storing all routes driven by a typical driver during a period of three years.

Additionally, other data might be stored as well, in order to generate profiles and history of vehicle data. For instance, individual travel times can be recorded per each link. This information is then taken into account for future route calculations allowing to calculate an optimum route based on real-world travel times. Nowadays navigation systems only use static values based on the functional road class not matching reality e.g. in terms of traffic jams during rush hours.

3.5 Vehicle Route Prediction

The Vehicle Route Prediction module is responsible for determining the most probable route the vehicle is likely to go. Therefore, a two-way approach is used [2]. First, data from the vehicle's bus system is analyzed to determine a categorized driving situation. For instance, if the vehicle approaches a crossing, the system has to decide which way the driver intends to go. Taking into account turn signal information in combination with the current vehicle speed and distance to the decision point, an intelligent algorithm proposes the way of the vehicle at this crossing.

In a second step, a complete route can be proposed by taking into account the currently driven road segments and comparing these to the stored routes in the Past Experience Processing database. Particular patterns, which occur in a defined accumulation, are compared and used as a decision criterion for determining which route the driver intends to take. In order to optimize processing effort and memory usage no complete routes are compared. Instead only decision points are taken into account, as described in section 3.4, containing the succeeding segment for the one currently driving on. For each successor segment a specific probability is calculated based on the amount of occurrences, day-of-week and time-of-day when driven before. The algorithm chooses the segment with the highest probability as the Most Likely Path.

The estimated Most Likely Path of the vehicle is then provided to the Electronic Horizon module, which uses this information for retrieving a single-path Electronic Horizon, as described above.

4 Interface Specification

A well-defined interface between navigation system providing Electronic Horizon and applications is required. Vehicle manufacturers have a strong interest in using a standard interface specification. In order to develop such a standard interface the *ADASIS Forum* was founded. The following paragraphs introduce the forum itself and its technical approach.

4.1 ADASIS Forum

In 2001 the ADASIS Forum has been launched in Europe in order to specify an industry standard interface for providing Electronic Horizon. Ford Motor Company is playing an active role within that forum and contributing to the interface specification. Since December 2007, Ford has taken over the chairmanship of the forum (C. Ress).

The ADASIS Forum is hosted and coordinated by ERTICO[2] and constitutes to date of more than 30 members including car manufacturers, navigation systems and ADAS suppliers, as well as digital map vendors. The forum's purpose is to:

• Define an open standardised data model and structure to represent map data in the vicinity of the vehicle position (i.e. the Electronic Horizon), in which map data is delivered by a navigation system or a general map data server.

• Define an open standardised API to enable ADAS applications to access the Electronic Horizon and position-related data of the vehicle.

The final specification is currently worked out in the ADASIS Forum and will be transmitted as a next step to ISO for becoming an international industry standard. The first version of the interface specification is already available for forum's members.

During the period from 2004 to beginning of 2008, the successful work of the ADASIS Forum has been supported within the PReVENT project, i.e. MAPS&ADAS sub-project. The objectives for MAPS&ADAS project were to specify, implement, test, and validate the first version of ADASIS specification. Additionally, the development of new digital maps including safety aspects was also a goal of the project.

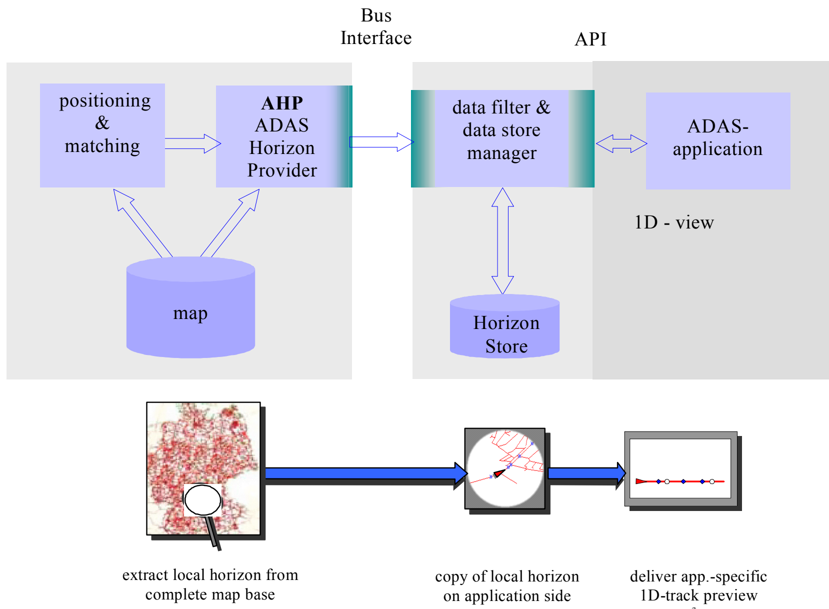

Fig. 6. ADASIS systems architecture.

[2] European ITS organization

4.2 ADASIS Functional Architecture

The systems architecture defined by ADASIS Forum is shown in Figure 6. It consists of the ADAS Horizon Provider (AHP) on the one side. That retrieves digital map data around the estimated position of the vehicle using GPS and map matching. In the first release of ADASIS only a single path in front of the vehicle is supported. Future versions will also be capable of multiple paths where the ADAS Horizon is provided. The data is then compressed and coded for transmission on the vehicle's bus system. On the application side, an ADAS Horizon Reconstructor (AHR) re-builds the ADAS Horizon from the received messages and provides it to the ADAS application. More than one application is supported but depending on the implementation, each one requires its own Horizon Reconstructor.

ADASIS addresses two interfaces on different levels:

(i) A "low level" interface describing the messages to be transferred on the vehicle bus system. The ADASIS specification is generic for any bus system, the so-called *AGMP (ADASIS Generic Message Protocol)*. Since the CAN bus is the most used bus system in vehicles nowadays, a specific implementation for CAN has been derived, the so-called *ASCP (ADASIS Specific CAN Protocol)*.

(ii) A "high level" interface allowing the applications to access the Electronic Horizon data after being re-built by the Horizon Reconstructor. This is a C code style API.

The developed systems architecture and interface specifications have been implemented as prototypes within the scope of PReVENT MAPS&ADAS by the project partners. Data transmission has been realized on a CAN bus. Tests and validation have been successfully been performed. The results look very promising: the average additional bus load caused by the Electronic Horizon is relatively low on the CAN bus (below 1 percent), and no latency issues or other negative effects for the CAN bus messages have been detected. Different ADAS Horizon Providers and Reconstructors have been developed by the project partners. These have been connected via the CAN bus and their interoperability was also demonstrated successfully.

More information about the ADASIS Forum is available on the internet: http://www.ertico.com/en/subprojects/adasis_forum.

5 Example Application: Lane Keeping Assistance

One of the applications, which have successfully been enhanced by the Information Manager, is *Lane Keeping Assistance*. A prototype system has been implemented and validated within the scope of the European PReVENT project. PReVENT is an industry research project, co-funded by European Commission within the 6th Framework, and has been successfully finalized in March 2008. More information about the PReVENT project is available on the PReVENT web site: http://www.prevent-ip.org .

For Lane Keeping Assistance a camera system is used as the primary sensor to detect if the vehicle is still within the lane. In order to support the image processing in difficult situations, e.g. approaching a curve, driving in bad weather, or low light conditions, Electronic Horizon data is taken into account as an additional virtual sensor. This provides information about lane attributes and geometry of the road ahead. In consequence this enables the lane tracker to evaluate more reliably if the vehicle is still within the lane, or whether an action needs to be taken. This could then be done in the form of a warning or by performing an active steering manoeuvre.

Fig. 7 shows an example of the benefit: ambiguous lane markings by shadows of guardrails are not recognized correctly by the camera itself, see left picture. Using lane width information from a digital map can help the lane tracker to exclude wrong information and to detect the lane markings correctly, see right picture.

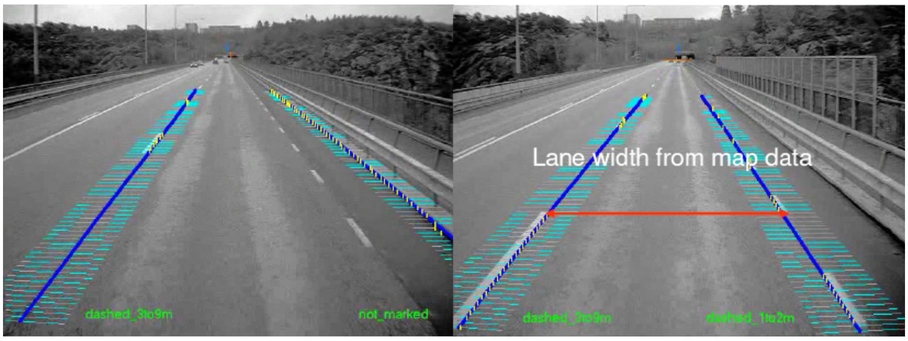

Fig. 7. Lane marking detection with camera only (left) and enhanced with Electronic Horizon (right).

6 Summary and Perspectives

Nowadays navigation systems have the potential to offer much more than solely route calculation and guidance. The digital map provides a lot of information about the route lying ahead of the vehicle that can successfully be used to enable new or enhance existing applications, the so-called Electronic Horizon.

Ford Research & Advanced Engineering has successfully designed and implemented a prototype system providing Electronic Horizon. It provides digital map data as well as the vehicle's position and sensor data to ADAS applications. Special attention has been paid on the calculation of the Most Likely Path the vehicle is expected to take. That allows a high quality of Electronic Horizon data and improves reliability of applications.

As one example how an application can benefit of Electronic Horizon "Lane Keeping Assistance" has been presented. Within the PREVENT project the lane tracker algorithms have significantly been improved with the use of digital map data as an additional "virtual sensor".

However for a series implementation of the system, some restrictions have to overcome in the near future. For instance, the ADASIS specification has to be refined with regard to the test experiences from PReVENT project. Also the Ford prototype system is implemented on a PC with a relatively huge amount of memory and processing power, which has to be replaced by an Embedded Platform for future use in a vehicle or to be integrated into the navigation system.

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