

Cost-Efficient Provision of Accurate Foresight Route Information

Anne Carlsson and Hans-Christian Reuss

Automotive Mechatronic and Software, IVK, University of Stuttgart

Pfaffenwaldring 12

70569 Stuttgart, Germany

anne.carlsson@ivk.uni-stuttgart.de, hans-christian.reuss@ivk.uni-stuttgart.de

Abstract: This paper contributes with a system capable of supplying various assistance and vehicle control systems with the foresight information required for predictive driving strategies. The approach bases on the fact that many vehicles are repeatedly driven the same routes, e.g. every day to and from work. The system automatically identifies relevant driving situations along the road, describes these with a small number of attributes, and stores them in a vehicle internal database. The situation identification algorithms only require information from standard sensors fitted for the basic engine and drive train control and the vehicle stability system. By comparing newly identified events with events from earlier drives already existing in the database, the database is continuously extended and updated during each drive. To correctly predict upcoming road properties, the desired route must be known. To assure a reliable functionality of the preview system, the desired route must be automatically predicted. This can be achieved by introducing a situation-route matching procedure, related to the map matching procedure used in conventional navigation systems.

Key Words: Predictive driving, foresight information, assistance system, situation identification, route prediction

1 Introduction

An efficient and flexible transport system has become crucial for our economic system and way of life, and as a result the number of vehicles sharing our roads is increasing. Consequently we're experiencing higher total exhaust emissions and more stressful driving conditions. Especially the emission of CO₂ from the transport sector is worldwide currently one of the main themes in many political debates, in automotive magazines, and on automotive conferences. Both the reduction of CO₂-emissions and the improvement of road safety are main targets addressed in the European and the North American transport policies.

A great number of assistance and vehicle control systems have been developed to help meeting these targets [1][2][3][4]. In several research projects around the world it has been shown that not only the fuel efficiency but also the comfort functions and some safety systems can be greatly improved with information about the road ahead [5][6][7]. The extended functionality typically bases on the assumption that the required foresight information will be available either from enhanced digital maps or through some communication system, i.e. car-2-car or car-2-infrastructure [8][9]. This

foresight information, however, is not yet available at a reasonable cost and accuracy [10].

In this paper an alternative approach for the provision of the necessary preview information will be presented. This approach bases on the fact that a large number of vehicles are repeatedly driven the same route, e.g. every day to work, for bringing the children to school, or for visiting relatives. Additionally, a lot of the required sensor information necessary for the situation identification is already available in most vehicles in form of sensors for the basic engine and drive train control and the vehicle stability system. The proposed system is hence independent of digital maps, imaging techniques, and communication systems. The only additional system required to realize such a system is a positioning system such as GPS. These facts allow the introduction of a cheap and reliable system for the provision of relevant preview information [11].

2 Self-learning Route Memory

The self-learning route memory is a method for the automatic generation and continuous updating of a vehicle internal database containing information about road characteristics of a frequently driven route. The relations between the system's key processes are shown in Figure 1 which shows the system setup.

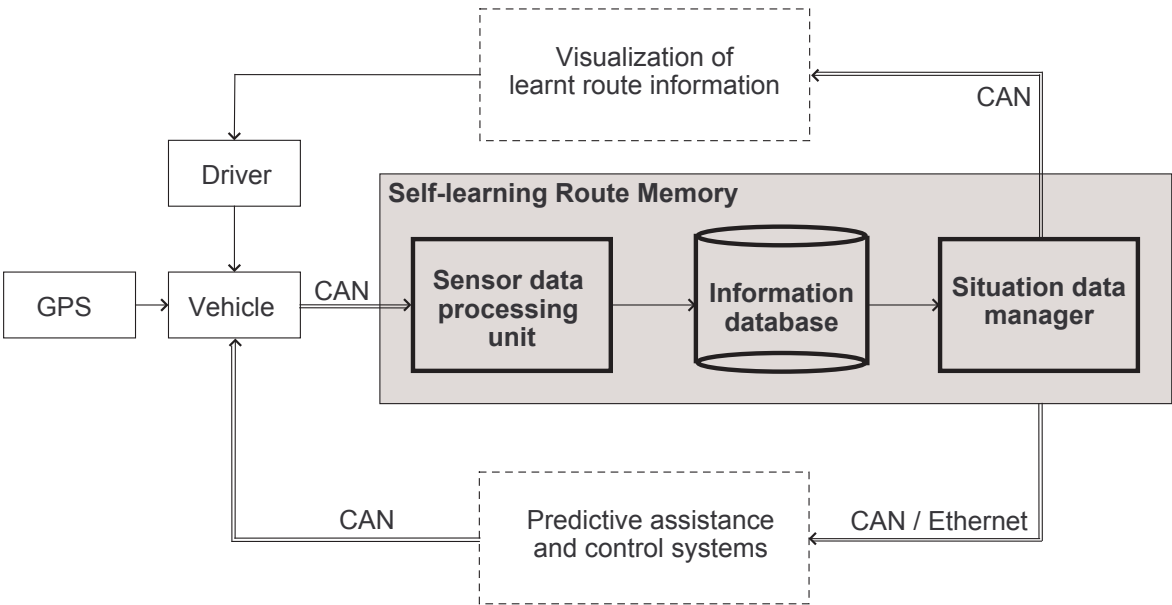


Figure 1: System setup for the self-learning route memory

The route memory system is connected to the vehicle via the CAN bus (or busses, in case of multiple) and has the ability to both receive and send data. During the drive data from e.g. yaw rate, acceleration, and various drive train sensors provide information about the vehicle state and vehicle movements; this data indirectly provide information about the properties of the driven road, such as curves, slopes, etc. The

sensor data are analysed directly in the vehicle during the drive, and features in the data indicating relevant situations are extracted. The situation identification algorithms only make use of the information delivered from standard sensors fitted in the vehicle for the basic engine and drive train control and the vehicle stability system. With information from the vehicle positioning system, each identified situation is associated with a geographical position along the driven route. The identified situations are described through the extracted data features and the position information. This description is simplified and intelligently compressed to reduce the amount of data before the situation description is stored in the vehicle internal database. The target is to describe each identified situation with a sufficient precision using only a fixed number of parameters to be able to store the information in a memory efficient way. For example, the shape of a curve or a slope is described with a simple mathematical function, which is determined by means of curve fitting methods.

Each recognised road property, i.e. each identified situation, is used to update and improve the descriptions of corresponding road properties identified during previous trips along the same road and already stored in the database. The activation of this update process is based on the geographical position and situation type of each event. All situation descriptions stored in the database are associated with an individual counter value. This counter is incremented each time an event is re-identified. A similar system keeps track of the number of times a certain route is driven. Together these two counter values give information about the reliability and plausibility of a stored event description. Only plausible and correctly identified situation data are selected from the database to provide various assistance, control, or information systems in the vehicle with up-to-date predictive route information.

3 Preview Information

Depending on the intended use of the foresight data, the amount and format of the selected route information must be customised. The amount of data can be divided into three levels: a simple event description (level 1), a single event description (level 2), and multiple event descriptions (level 3). A system for optimised gear selection or for energy management in a hybrid-electric vehicle requires precise information about all upcoming slopes, speed limits, curves, halting positions, etc, for the next 2 - 5 km to be able to make the necessary decisions (level 3). A curve light system only needs precise information about the next upcoming curve (level 2). The event description for a driver information system must be reduced to an absolute minimum to prevent a driver information overload (level 1). A general situation description contains information about situation type, geographical position, relative position, situation length, and situation description, i.e. curvature, speed limit, etc. The relative position is in this application defined as the driven distance between the starting position of the trip/route and the identified situation, i.e. the actual vehicle position. This measure is required to order a number of situations with regard to their appearance along the driven route and to determine the remaining distance to an upcoming situation. In the absence of a digital map defining the route trace, solely the information about the geographical position is not sufficient for this specification.

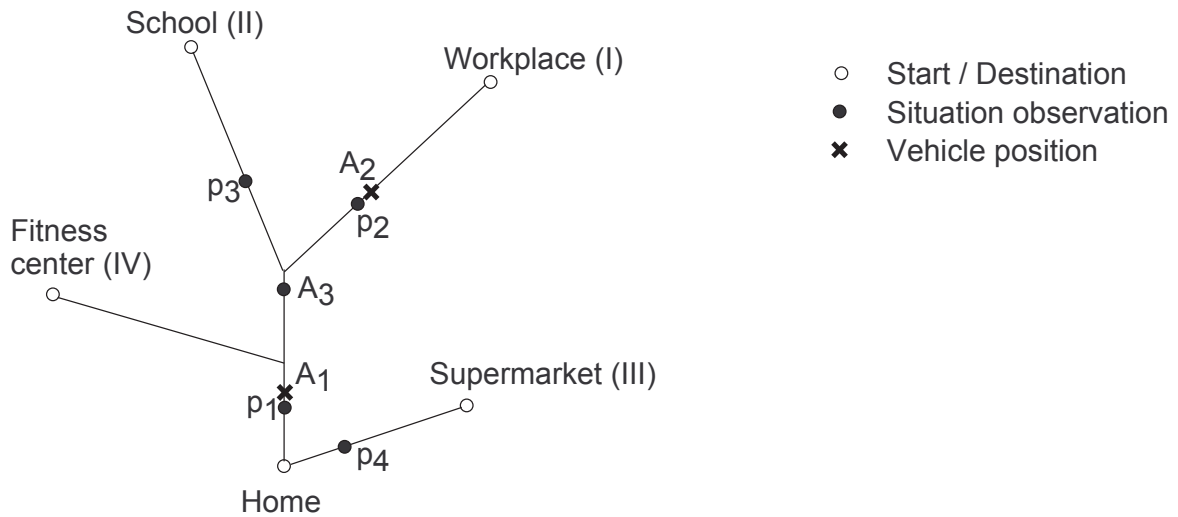
4 Route Identification

To be able to correctly predict upcoming situations and events, it is necessary for the route memory system functionality to have information about what route is currently driven. Additionally also the absolute and the relative position of the host vehicle along the selected route are required. The desired route can be specified by the driver at the beginning of each trip – similarly to the specification of a destination and optionally one or more stopovers for a conventional navigation system for route guidance. However, as the route memory system delivers preview information for frequently driven routes, it can be assumed that the route is familiar to the driver. According to experience, a navigation system will (due to convenience) not be activated along a familiar route as no route guidance is desired. Hence, the system for the provision of preview information must be able of automatically identifying the selected or currently driven route.

For this application, and under the assumption that the GPS is working reliably, the geographical position of the vehicle is known at all times. Hence, in the ideal case, the trip's starting position, i.e. the geographical coordinates of the starting position, can be used to select the corresponding route based on the information found in the database. However, the database contains information about frequently driven routes, i.e. routes common for a certain driver/vehicle combination. This means that a number of different routes – with different destinations – are likely to have the same starting position, e.g. for the driver common stopover places such as home or workplace. Hence, it is not always possible to definitely predict the planned route by using only the starting position as selection criterion. Information about the time of the day and/or weekday can assist the decision-making through a statistical validation in line with “the trip from home to the workplace is mostly conducted between 7 and 9 am”, or “the trip from home to the supermarket is mostly conducted between 6 and 8 pm”.

However, in case this additional information is still not enough to make a definite decision about the planned route, the problem can be solved by the introduction of a “situation-route matching” procedure. The functionality of the situation-route matching algorithm is related to the procedure of map matching used in conventional navigation systems. The situation-route matching procedure is exemplified through the fictitious case illustrated in Figure 2 and listed in Table 1 and Table 2.

Each time a situation is identified during a trip, the current vehicle position is compared with the geographical position of situations of the same type identified during previous trips and already stored in the database. If a corresponding situation, regarding situation type and geographical position, is found in the database, at least one candidate route can be specified according to the selected situation description. If exactly one candidate route is specified by the description of the corresponding situation (see position A_2 in Figure 2), the currently driven route is assumed to be exactly this route. In case the result of the comparison is ambiguous (see position A_1 in Figure 2), the next event along the driven road is awaited and a new situation comparison is performed. If the end of the trip is reached without having found any matching situations, i.e. if no corresponding situations exist in the database, it is assumed that the route is new. Hence, a new route is defined and this information is accordingly added to the database.



@ A₁: Search DB for routes with "curve" @ p₁ = (x₁, y₁)
 ==> Route ID = I
 ==> Route ID = II
 ==> Route ID = IV

@ A₂: Search DB for routes with "slope" @ p₂ = (x₂, y₂)
 ==> Route ID = I

Figure 2: Illustration of the principles for the situation-route matching procedure

Table 1: Reduced route descriptions for the fictitious case illustrated in Figure 2

Route ID	Description	Start position	End position	Counter
I	Home – Workplace	X ₁ , Y ₁	X ₂ , Y ₂	2
II	Home – School	X ₁ , Y ₁	X ₃ , Y ₃	1
III	Home – Supermarket	X ₁ , Y ₁	X ₄ , Y ₄	2
IV	Home – Fitness studio	X ₁ , Y ₁	X ₅ , Y ₅	2

Table 2: Reduced event type descriptions for the fictitious case illustrated in Figure 2

Abs. Position	Position code	Event type	Counter	Route ID
x ₁ ,y ₁	p ₁	Curve	2	I
x ₂ ,y ₂	p ₂	Slope	2	I
x ₁ ,y ₁	p ₁	Curve	1	II
x ₃ ,y ₃	p ₃	Curve	1	II
x ₄ ,y ₄	p ₄	Traffic light	2	III
x ₁ ,y ₁	p ₁	Curve	1	IV

As long as at least one candidate route is specified, a prediction of upcoming events can be carried out. However, before a forking situation of the road, as indicated with position A_3 in Figure 2, an unambiguous prediction of the next situation is not possible as long as multiple candidate routes are identified. Only a statistical analysis of e.g. travel behaviour, i.e. “at what time and on which days is a certain trip/route more likely”, can facilitate this route prediction. In this case the decision-making can be supported by selection algorithms for route prediction based on driving statistics as already proposed in other investigations, e.g. in the patent applications [12][13].

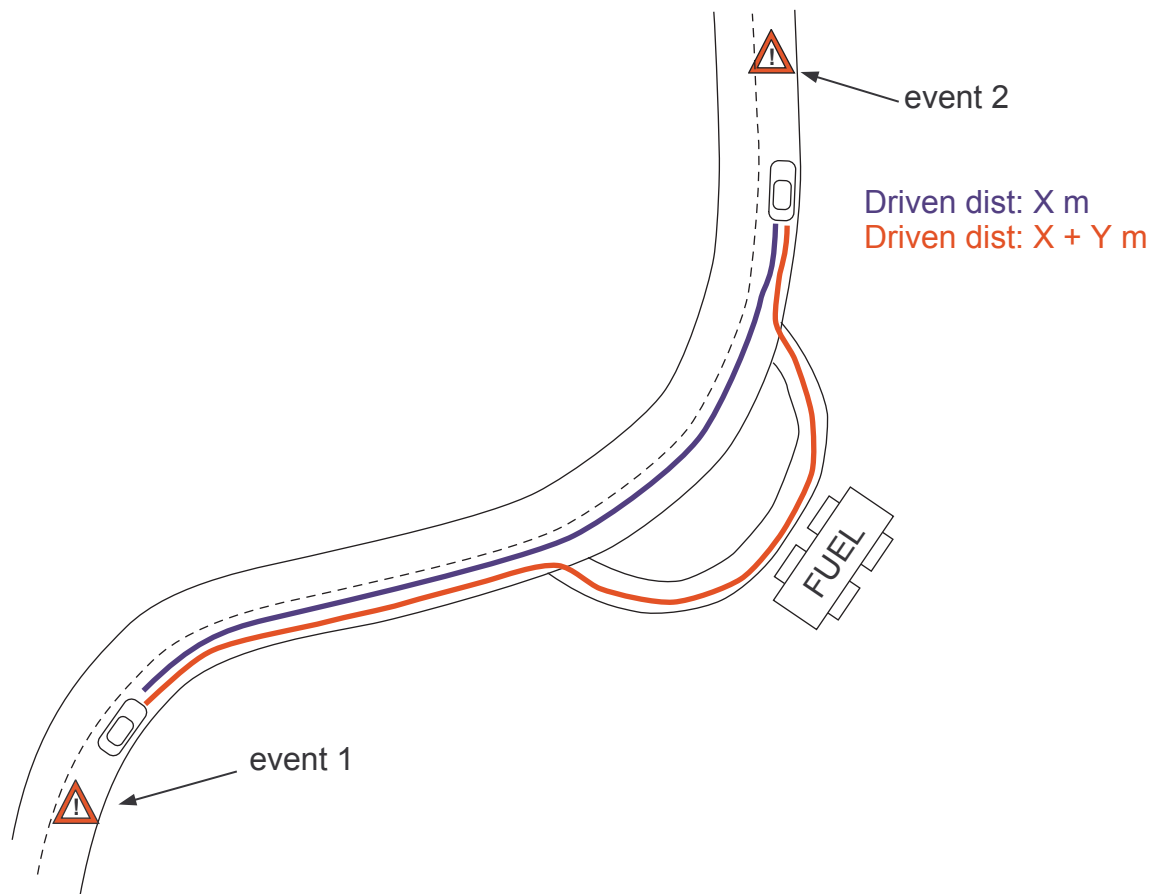


Figure 3: Situation matching procedure for correction of event positioning

The method of situation matching can also be used when the driven route is already known, but the driver selects to shortly abandon the intended route, e.g. for filling up the car at the petrol station as illustrated in Figure 3. In this case, the situation-route matching procedure is used to correct the relative distance for the positioning (see section 3) of upcoming events along the road. Without this correction, the driven distance would indicate that the vehicle is approaching an event earlier than in reality. In this case the situation-route matching procedure can calculate the accumulated offset and hence prevents the relative distance to mismatch for the rest of the drive.

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