DRIVER ASSISTANT FOR WARNING OF HIGH VELOCITY (FIELD OPERATION TEST)

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Abstract: A driver assistance system, which supports drivers by using a special strategy taking the road geometry in front of the vehicle into account, was developed and realized at the University of Siegen. Here, the velocity is exclusively controlled depending on road parameters. So, in front of a bend, the speed will be reduced in time. Behind the bend, the car can be accelerated again. Here, it is described, how a new driver assistant, which warns the driver when the speed of the vehicle is too high in front of a bend, is realized.

Keywords: automotive control, automobile industry, intelligent cruise control, velocity control, vehicles

1. INTRODUCTION

The world‘s car population is increasing every year. In 1970, there were more then 200 million cars. In 1990, there were almost 500 million in the world. It is estimated, that there are nowadays approximately more than 600 million motor vehicles, driving on the streets of earth. This general trend leads to overloads of the roads, requires high concentration from drivers and leads in the end to the endangering of road safety. In order to reduce the risk of accidents and to support drivers in difficult traffic situations, diverse research projects were set up. Large projects were PROMETHEUS and DRIVE in Europe and ITS and PATH in the United States. Within these projects various driver assistant systems, which support the driver by providing with additional information about the vehicle environment, were developed.

According to US statistic information, one in five crashes is reported as a single-vehicle roadway departure. To face this problem University of Siegen has developed and tested a driver assistance system described in this contribution.

In section 2, first the Velocity Profile Planning Module is described, while in section 3, the architecture of the driver assistance system, which uses the Velocity Profile Planning Module for generating the reference velocity, is pointed out. Based on the descriptions in the sections 2 and 3 a driver assistance system was translated into action. The field operation test of section 4 presents these results.

2. VELOCITY PROFILE PLANNING MODULE

2.1 Road Structure

Here, the structure of the road will be explained, as this is of main significance for the understanding of the control strategy and database structure described below. The geometry of a road is three-dimensional and, thus, it must be regarded spatially. Therefore, the street has to be split in layout and levelling construction. Since the altitude difference is mainly influencing only the resistance force in longitudinal direction, it can be handled as a simple disturbance by the vehicle control system. Here, the focus is exclusively set on the road layout construction.

In order to model the layout of a road, there is the necessity for a subdivision of the road into some basic geometric elements. Until the middle of the thirties, exclusively

- the straight line and
- the circular arc

the basic elements used in road construction (Bauer and Mayr, 2003). Since the straight line is the shortest way between two points, it is used for simple connections. However, if there are obstacles on the way, the direction has to be changed. This problem formerly was solved by using the arc of circle. Unfortunately, between a straight line and a circular arc the steering angle must be changed in extremely short time. This causes a big jerk in the lateral force resulting in a risk of instability.

In order to avoid this phenomenon, additionally parts of clothoids must be included. The curvature of a clothoid χ is proportional to the length s

$$\chi = \frac{s}{A^2}, \tag{1}$$

where A is a coefficient that characterizes the clothoid.

2.2 Forces Acting on the Vehicle During the Ride on the Bend

The determination of the time for the braking or the acceleration of the vehicle requires the analysis of all forces acting on the vehicle caused by the road curvature and by the braking maneuver. One task for the control routines is to initialize the brake maneuver in time so that the maximum total force F_{ttl} acting on the vehicle will not be bigger than its maximum recommended force F_{prm}. Generally, the maximum recommended force is not only depending on the vehicle parameters, but also on comfort requirements for the passengers.

With the known maximum recommended force F_{prm} for the part of the bend with maximum curvature χ_{max}, the maximum recommended velocity v_1 can be calculated by

$$v_1 = \sqrt{\frac{F_{prm}}{m \cdot \chi_{\max}}}, \tag{2}$$

where m is the mass of the vehicle. Here F_{prm} is equal to the centrifugal force F_{ltr} (Bauer and Mayr, 2001).

The resulting deceleration of the current velocity to v_1 could be performed only with a brake maneuver, which must be initiated in time. This causes the longitudinal force F_{lng} acting in opposite direction to the vehicle motion, which is perpendicular to the centrifugal force F_{ltr}, as shown in Fig. 1. Thus, the absolute value for F_{ttl} of the vector sum is calculated as follows:

$$|F_{ttl}| = \sqrt{F_{lng}^2 + F_{ltr}^2}. \tag{3}$$

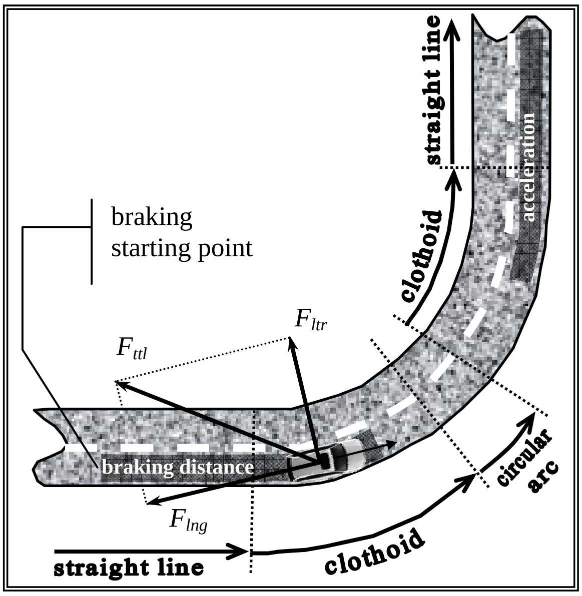

Fig. 1: Velocity strategy depending on road layout

2.3 The Overall Strategy

In order to include the road parameters into the control strategy, first the current position of the vehicle must be found out by a GPS-receiver. On the other hand, in order to find out, on which road segment the vehicle is currently located, the Velocity Profile Module must have access to a database, where all road parameters are stored (Bauer and Mayr, 2003) as shown in Fig. 2.

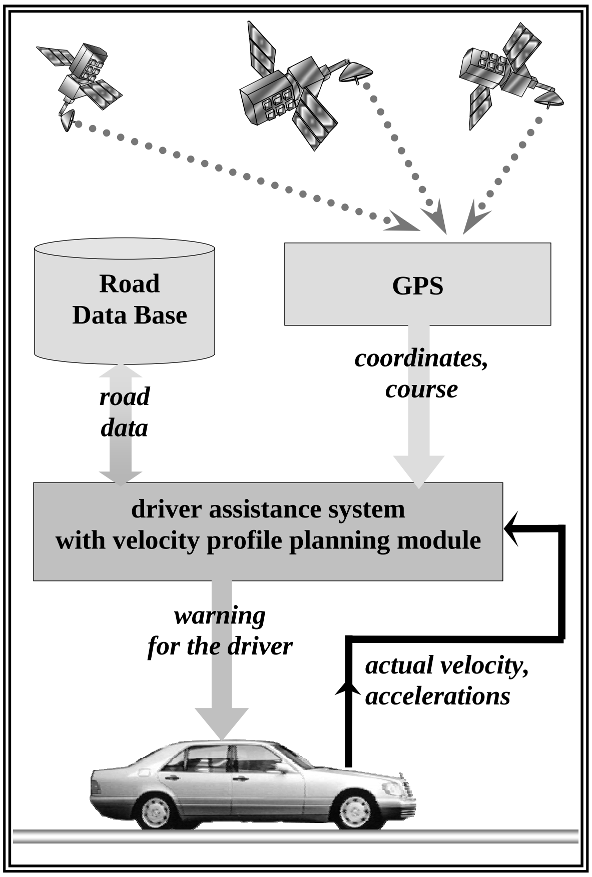

Fig. 2: Overall strategy

An important task of the program is to determine the best moment for initiating the braking maneuver. This maneuver is to start in good time, when a bend appears in front of the automated vehicle.

The Velocity Profile Module is permanently working online, in other words, the program is continually called within short time intervals. Based on the current position and on the road geometry in front of the vehicle as well as on the actual velocity, the module takes the decision, whether the current moment is the best one to initialize the braking maneuver. This decision can be made only if all trajectories of forces acting on the vehicle can be estimated for the following maneuver. Since during the braking maneuver the vehicle drives into the bend, there are not only lateral forces acting on the car, but also longitudinal forces as mentioned.

In order to calculate the maximum force during the braking maneuver, first the predicted force trajectory must be computed. Based on the equations (1), (2) and (3) as well as on the known kinematics equations (Gerthesen et al., 1982)

$$v_{0,cl}(t) = \sqrt{\Delta + 2 \cdot v_{cur}^2(t) \cdot a_{br,cmfr}} \qquad (4)$$

$$v(t) = v_{0,cl} + a_{br,cmfr} \cdot t \, , \qquad (5)$$

$$s(t) = v_{0,cl} \cdot t + \frac{a_{br,cmfr} \cdot t^2}{2} \, , \qquad (6)$$

$$\vec{F}_{lng} = m \cdot \vec{a}_{br,cmfr} \, , \qquad (7)$$

where

- $v_{cur}(t)$ is the current velocity of the vehicle,
- $v_{0,cl}$ is the velocity at the beginning of the clothoid,
- Δ is the current distance between the vehicle and the bend,
- $v(t)$ is the future velocity during the braking on the clothoid,
- $s(t)$ is the current covered way from the beginning of the clothoid,
- $a_{br,cmfr}$ is the comfort brake acceleration,
- t is the current time,
- m is the mass of the vehicle,
- F_{lng} is the longitudinal force,

the total force $F_{ttl}(t)$ trajectory can be computed as follows

$$|F_{ttl}(t)| = m \cdot \sqrt{(v_{0,cl} + a_{br,cmfr} \cdot t)^4 \cdot \left(\frac{v_{0,cl} \cdot t}{A^2} + \frac{a_{br,cmfr} \cdot t^2}{2 \cdot A^2} \right)^2 + a_{br,cmfr}^2} \, . \qquad (8)$$

The maximum of the upcoming total force $F_{ttl,max}$ in case of a braking or acceleration maneuver can be found from equation (8).

The Velocity Profile Module works as follows: If in front of a bend the velocity is too high, the vehicle is slowed down in time, as shown in Fig. 1. Then it passes with a constant appropriate speed the segment of the bend with the highest curvature. Subsequently, the velocity will be increased again on the end of the bend; see also (Bauer and Mayr, 2001).

3. DRIVER ASSISTENCE SYSTEM

Before the system will be accomplished by a driver assistant, which will compute the speed profile depending on the bends in the front of the vehicle and which will warn the driver in case of too high speed, interactions between the driver and the vehicle must be analyzed.

Fig. 3 gives an overview of the connections between the components of the vehicle and the automatic system for velocity planning. By the driver's visual perception of the bend and by the knowledge of his own velocity, the driver can hold the speed of the vehicle or brake down. These actions of the driver influence the current position of the vehicle in relation to the bend and lead to the fact that the driver will probably react by applying the brake pedal. Therefore, the control loop is closed with the driver as controller in the system. Nevertheless, the weak spot in this control loop is still the lack of driver's information regarding the approaching bend, because only the longitudinal perspective of the bend can lead often to a relatively inadequate estimation of what is coming up.

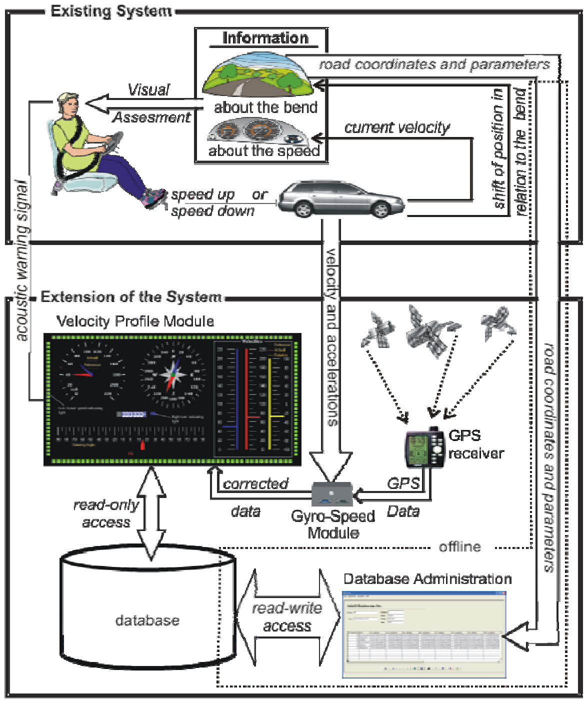

Fig. 3: Extension of the real system

In order to support the driver, an assistance system was developed, which warns in front of the bend in case of a speed being too high. The driver assistance system calculates the desired velocity of the vehicle based on the prediction of the maximum total force, which will act on the vehicle in case that the braking maneuver would be immediately initialized. This prediction of the total force is based on equation (8).

The practical procedure is explained in the following: The architecture of the system extension shown in Fig. 3 can be subdivided in principle into three main components (Bauer, 2005):

1. position determination module (GPS receiver and Gyro-Speed module),
2. database module (database and database administration),
3. velocity profile module (VPM).

Furthermore, the VPM has a higher level position in the hierarchical structure of the driver assistance system than the database and position determination modules. The VPM uses the other modules as external information sources about the vehicle environment in order to take a sensible decision concerning the vehicle's reference value of the velocity.

For this purpose a special Gyro-Speed Module was connected to the serial port of the laptop, where the application was implemented. Moreover, the Gyro-Speed module has two inputs: a RS 232 interface for the data from the GPS receiver and a BNC (bayonet nut connector) for the speed signal from vehicle's speedometer. After the correction of the GPS data by the Gyro-Speed module, where also small movements of the vehicle are considered, the data is forwarded to a special separate thread of the VPM application. This thread makes an additional correction by a special algorithm considering the worst case (Bauer, et al., 2003). Finally, the corrected signal is sent to the VPM. According to the read-only access to the database, the VPM retrieves relevant data about the environment in front of the vehicle. With the information of the current position of the vehicle and of the road in front of the vehicle, the basis for the implementation of the algorithm, which calculates the reference speed, was established. This algorithm estimates the trajectory of the total force acting on the vehicle in future in case that the braking maneuver would be started immediately. Subsequently, the reference value of the current speed can be calculated.

4. FIELD OPERATION TEST

The principle of the procedure described above was confirmed by a field operation test with the real vehicle. Fig. 4 shows the test bed which was necessary in order to perform the field operation test.

The VPM application is running permanently on the laptop, where also the database with road information, especially the data of a nearby existing street, was saved. The plan of the street layout is shown in Fig. 5. Here, the bend consists of an arc of a circle with a radius R=35 meters and two clothoids with the clothoid parameters A=35 meters. These clothoids are the transition curves between the straight lines of the road ($R\rightarrow\infty$) and the arc of a circle (R=35 meters). For experimental purposes this road was driven several times. During the rides many different kinds of information were recorded. Thus, the positions of the vehicle regarding all corrections described in the previous section are visualized graphically in Fig. 6.

During the field operation tests, the velocity of the vehicle was influenced only by the driver of the vehicle. Therefore, the velocity in Fig. 7 has an arbitrary trajectory. As shown here, the driver accelerates the vehicle in the first 13 sec from 4 km/h up to 56 km/h. Since the force is directly proportional to the acceleration Fig. 8 shows only the accelerations.

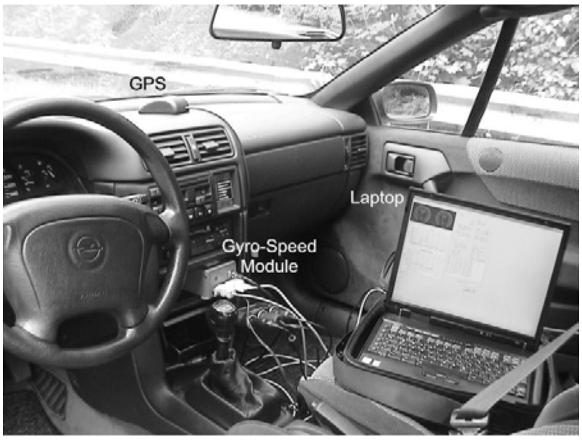

Fig. 4: Test Setup

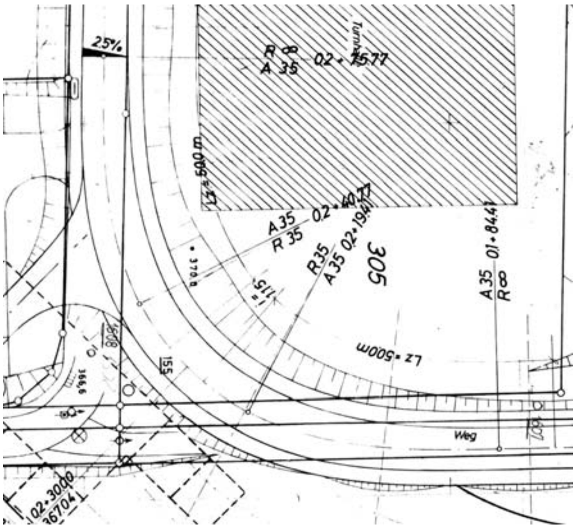

Fig. 5: Map of the road layout

Within the entire test the VPM application predicts always the maximum total force, which will act on the vehicle. Subsequently, it suggests its reference speed. Here, the reference value of the speed may never be higher than the current speed value, i. e. if the calculated reference velocity is higher than the current speed, the application will reduce the reference value to the current value. Therefore, the reference and the current velocities are equal in the first 8 sec. The bend is still too far away. At the time t=9 sec the car is on the position point x=-28.0 m y=74.3 m (see Fig. 6) and the driver assistance system predicts that the maximum total force will be bigger than its maximum recommended value. Therefore, the application suggests a new smaller reference speed. However, since the driver still speeds up the vehicle and the bend is always coming closer, the difference between the current velocity and its reference value grows. This causes that the pulse frequency of the acoustical warning signal increases correspondingly. As soon as the vehicle reaches at the time t=14 sec the position with the coordinates x=-36.0 m y=147.0 m, where the value of the current speed is equal to 56.5 km/h and the predicted maximum total acceleration is 5.28 m/sec², the driver starts the braking maneuver. Since this initialization was too late, the deceleration must be bigger than the usual comfort braking deceleration.

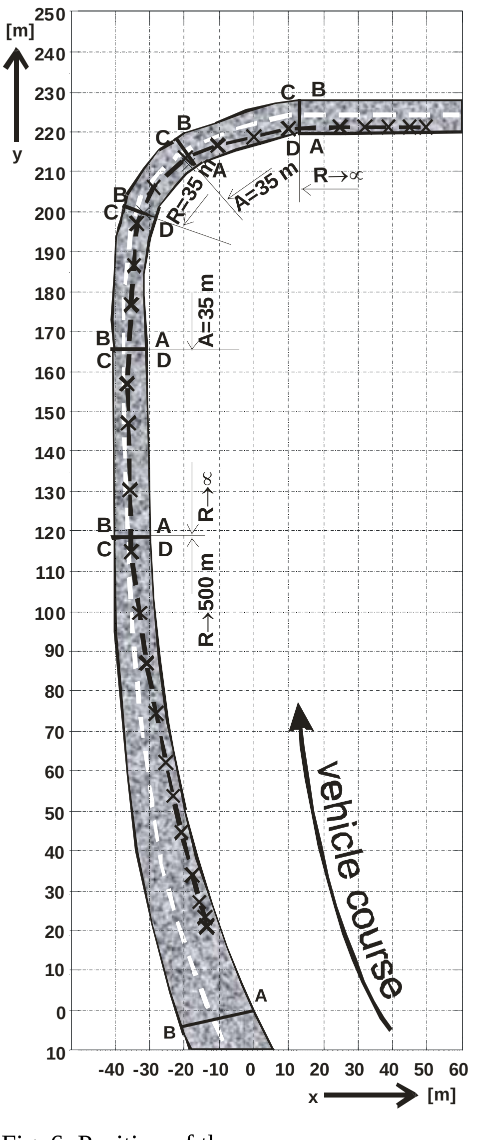

Fig. 6: Position of the car

At the time t=18 sec the vehicle is on the position with the coordinates x=-33.4 m y=197.0 m, what is in front of the arc of a circle on the bend. Since the vehicle is at the 19th, 20th and 21st seconds on the most critical section of the bend, where the curvature is relatively high, the driver assistance system suggests here a constant reference value for the velocity. At the time t=22 sec the vehicle has the position x=-0.2 m y=218.9 m. It is on the clothoid concluding the bend. Here, the driver can accelerate the vehicle again. As shown in Fig. 7 the conformance of the current and reference speed occurs at the 23rd sec.

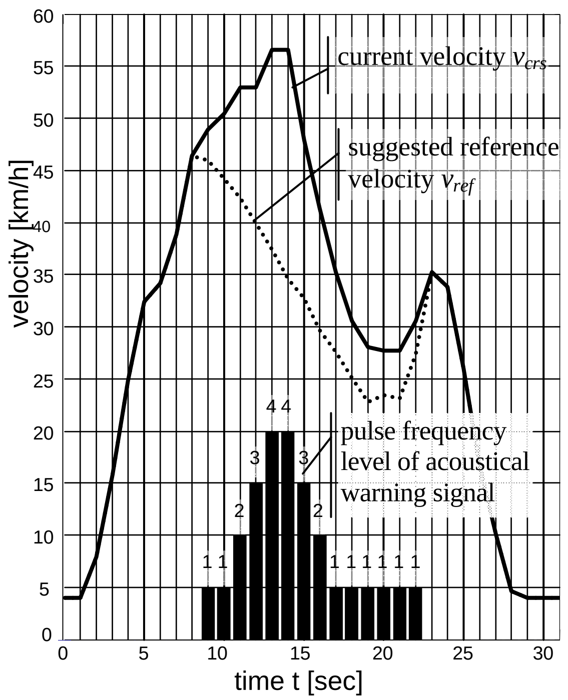

Fig. 7: Velocity during the drive

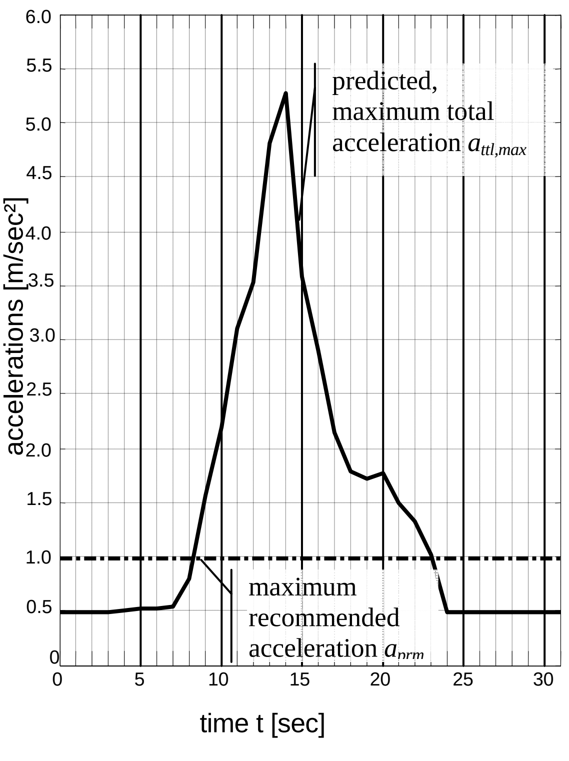

Fig. 8: Predicted and recommended acceleration during the drive

5. CONCLUSION

A driver assistance system, which warns the driver in case that the velocity of the vehicle is too high, is presented here. The driver assistant uses a special algorithm for automated velocity profile planning dependent on the road parameters. The calculated reference velocity depends on the road parameters of the street in front of the vehicle. These parameters reflect especially the curvature of the street and, thus, they are constant and are stored permanently in a database. In order to use these parameters in the algorithms generating the reference value of the velocity, the current position of the vehicle has to be found out by a GPS-receiver. The position delivered by GPS will be corrected first by a Gyro-Speed Module and afterwards for a second time, using a special algorithm, where the worst case is considered. Then, the system estimates the maximum total force which will act on the vehicle in case that the braking maneuver will be initiated right now. Based on a comparison of this value with the maximum recommended force, the driver assistance system suggests a reference value for the actual velocity. A pulsating acoustical signal with a pulse frequency depending on the difference between the reference velocity and the current velocity indicates the driver to slow down his car as soon as possible. The new technology described here provides drivers with additional information about the vehicle environment. Therefore, the ride will be more comfortable and safety in vehicular traffic will be enhanced.

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