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Collision avoidance systems PRORETA: situation analysis and intervention control

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Abstract: After a discussion of passive and active safety systems for automobiles and accident statistics it follows that a further progress in the reduction of accidents can be especially expected by next generation driver assistance systems with a sequence of warnings and active interventions. PRORETA is an Industry-University research project with the goal to develop steps towards accident free driving. The *first project* considers two vehicles moving in the same direction. The other vehicle is detected by a fusion of LIDAR and camera data providing the system with relative speeds, distance and locations. If the driver does not react to an obstacle on the own lane, the system automatically triggers an emergency braking and/or swerving to avoid a collision. This includes e.g. a fast and precise evasive trajectory control by automatic steering.
The *second project* is dedicated to vehicles in opposite direction performing an overtaking maneuver on rural roads. The own vehicle detects the velocities and distances to the preceding and oncoming vehicle by RADAR and lane markings etc. with a camera. The measured data of the two sensors undergo a sensor fusion with Kalman filters. The overtaking maneuver is predicted by using the measured data of all three vehicles. If an accident free overtaking is in danger, warnings are given to the driver and if the driver does not react a full braking of the own vehicle is fired such that the driver can turn back behind the overtaken vehicle.
The contribution describes the developed strategies and some basic calculated features and control systems. Measured data is shown and some videos give an impression of the driving experiments on the runway of an air field.

Keywords: Collision avoidance, vehicles, road traffic, LIDAR, RADAR, video camera, automatic braking, automatic swerving, trajectory control, overtaking maneuver, driving experiments

1. INTRODUCTION

Automobile safety is one of the high priority issues in the design of vehicles, construction and equipment to minimize the occurrence and consequence of automobile accidents. The improvements in automobile and roadway design have steadily reduced injury and death rates in developed countries. This positive development was reached by measures of passive and active safety systems.

Passive safety systems provide vehicle components in order to protect occupants during a crash respectively to reduce the consequence of accidents. Some examples are:

- *Interior safety systems* for passenger protection
  - Constructive crashworthy systems like crumple zones (front, rear, side), cell strength, survival space, collapsible steering columns, cockpit padding.
  - Passenger restraint systems: seat belt with retractor and tightener, air bags (front, side, window)
- *Exterior safety systems* for protection of external humans:
  - vehicle-related measures to minimize injuries to pedestrians, bicycle- and motorcycle-riders, e.g. hood measures and deformation behavior
  - exterior body shape and structure
- *Active passive safety systems*
  - pre-crash-sensors for early actuating of occupant safety systems
  - pre-safe-systems for preparing passive safety systems for a possible accident (e.g. belt tightening)
  - pre-safe-structure: active chassis systems for passenger protection

Active safety systems have the goal to prevent accidents by assisting the driver. Some examples are

- Safe driving behavior of the vehicle by appropriate design of the chassis, suspensions, steering and braking systems

⋆ The contribution results from the research cooperation PRORETA between Technische Universität Darmstadt and Continental AG. The research project is being carried out in cooperation of the Institutes of Automatic Control, Automotive Engineering Ergonomics (PRORETA1) and Multimodal Interactive Systems (PRORETA2). The participating Institutes thank the Continental AG for the generous support and good cooperation.

- Human conditional safety: acceptable low physiological stress for drivers and occupants
- Driver assistance systems:
  - ABS (anti-lock braking system)
  - TRC (traction control systems)
  - ESC (electronic stability control)
  - ACC (adaptive cruise control)
  - BAS (brake assist system)
  - AFS (active front steering)
  - LDW (lane departure warning)
  - LKS (lane keeping support)

The passive safety systems have reached a well-developed status such that mainly the active passive systems will show further progress. Therefore larger steps in the reduction of accidents are expected by active safety systems.

Accident statistics exist from several sources. The official German statistics DESTATIS distinguishes between the type of fatalities and kind of fatalities. The type of fatalities describe the traffic situation and therefore the origin of the accidents and the kind of fatalities describe the movement of the accident participants relative to each other.

The major types of accidents are for Germany according to Statistisches Bundesamt (2007):

- driving accident, 42 %
- accident between vehicles moving along, 21 %
- turning into a road or crossing it, 12 %
- crossing the road (pedestrian), 10 %

The kind of accidents with fatalities are distinguished as:

- road departure, 34 %
- with oncoming vehicles, 21 %
- with vehicle turning or crossing, 15 %
- with pedestrians, 13 %
- with vehicles moving ahead or waiting stationary, or laterally moving, 11 %

A reduction of driving accidents and accidents with road departure can e.g. be supported by ABS, TRC, ESC, LDW and LKS. However, accidents between vehicles moving along, turning and crossing or with obstacles need newly developed driving assistance systems, so called anticollision systems or collision avoidance systems.

Figure 1 shows a roadmap for driver assistance systems. Basic components are the required mechatronic actuators, ranging from ABS- to AFS-systems and sensors, from wheel speed through acceleration to RADAR and video camera. The development within the last 30 years shows three generations:

1st generation	lateral and longitudinal stabilization and control
2nd generation	warning and careful active actions
3rd generation	warning and full active actions

The last generation is still in the development phase, see also Zittlau and Hoppe [2008]. The scheme in Figure 2 distinguishes some accident situations between vehicles:

(1) *Vehicles move in the same direction*
- other vehicles:
  (a) move ahead or stop
  (b) move laterally, turn or cross (includes objects on road)
- Collision avoidance (CAV) actions: warning, braking, swerving

(2) *Vehicles move in opposite directions*
- own vehicle:
  (a) overtaking maneuver
    - rural road
    - autobahn, freeway
  (b) straight driving
    - vehicles leave correct lane
- CAV actions: warning, braking AND swerving

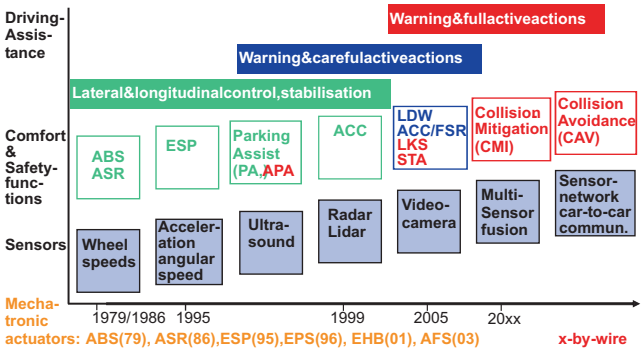

Fig. 1. Roadmap for the development of driver assistance systems: 3 generations

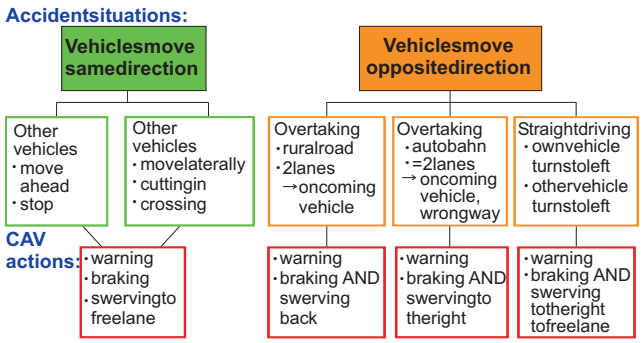

Fig. 2. Organisation chart for collision avoidance systems (longitudinal direction)

The research project PRORETA is an Industry-University project on collision avoidance system between Continental AG and Technische Universität Darmstadt. The project PRORETA 1 (2003-2006) was dedicated to cases 1 (a) and (b), and project PRORETA 2 (2006-2009) to case 2 (a) for rural roads. Both projects were performed by the cooperation of three research institutes: Automatic Control, Automotive Engineering and Ergonomics (1st project) and Multimodal Interactive Systems (2nd project).

An important basis for these collision avoidance systems is the detection of the environment around the vehicle. Table 1 summarizes the present state of sensors like different types of RADAR, LIDAR and cameras. A comprehensive survey of the state of the art is given in the handbook on driver assistance systems, Winner et al. [2009].

In the following the developed collision avoidance systems, the assumed accident situations, the intervention planning and control functions will be summarized and experimental results with driving experiments will be shown.