Activating safety technologies
The rising traffic density poses a steadily increasing challenge to drivers of cars and trucks, as well as pedestrians and cyclists, who are continually confronted with new traffic situations requiring full concentration. However, driver attention and alertness are subject to variations and lapses.

To this end, assistance systems are being developed in the project *Active Safety* that will be capable of interpreting traffic flow in the vehicle environment while taking into account driver behavior. Using sensor data and algorithms, they will not only measure the current driving situation, but also provide a hazard risk prediction. Should an intervention in a driving maneuver be required, the aim is to tailor the form of assistance optimally to the traffic state and driver behavior.

Thirteen partners including automobile manufacturers and automotive suppliers are working closely together in the project *Active Safety* to develop and coordinate these novel functionalities so that they will be available to a spectrum of diverse vehicle types and a wide range of users. Technical support is being provided by accident analysts from the insurance industry, experts from the federal road authority, and scientists from universities and other public research institutions.

A budget of about 37 million Euros is available to the project *Active Safety* for these activities, almost half supplied by the Federal Ministry of Economics and Technology. By 2010 the engineers and researchers expect to complete construction and optimization of prototypes as well as evaluation on test sites and in real traffic.

**Active Safety – AS in the context of Aktiv**

**Sensibility for more safety**

Mobility represents perhaps the single most important and fundamental economic factor in modern society. Efficient transportation seeks to reduce commuting times; forward-looking traffic management systems add flexibility to business life, enabling better organization of freight transport. Mobility brings family and friends together. The challenge to traffic systems is to meet these demands while maintaining not only efficiency and comfort, but above all safety.

**Aktiv up to 2010**

In 2007 there were 336,002 injury accidents on German roads.
Efficient support - preventing accidents

Driving requires complete concentration – 4,812 seconds per day, and about 488 hours per year. That is the time spent by the average German in traffic. The task is particularly demanding for car and truck drivers, who must remain completely attentive not only to their own vehicles, but also to other participants in traffic, while remaining alert to the roadway, signs, signals, and variable messages.

Up to now, drivers have not always been equal to this task. The yearly statistics on victims of traffic accidents attest to this sad fact: in 2006, 427,428 persons suffered injuries on Germany’s streets and highways, 5,091 of them fatal. In the future, an ensemble of reliable and continually alert assistance systems will support the driver. The goal is to achieve a sustained reduction in traffic accidents and improved safety for all road users while maintaining traveling comfort, in spite of increase traffic density.

Thus, four assistance systems are being developed in the project Active Safety to “nip accidents in the bud”, i.e., to detect hazardous traffic situations and prevent accidents by means of targeted interventions: “active hazard braking” to prevent impending rear-end collisions, “integrated Lateral Assistance” against unintentional lane departure, “Intersection Assistance”; and for tasks such as entering, turning, or traversing an intersection, which require simultaneous attention to different, spatially separated areas of the driving environment. Special sensors and algorithms will detect hazards threatening the safety of cyclists and pedestrians and proactively take protective measures. The degree of support supplied by the assistance functions will be tuned to the driver’s alertness and driving style but will also be adapted to the traffic situation. The combination of sensitivity to individual characteristics and situation-adaptive assistance will form a key element in improving future traffic safety. To this end, the partners in the research project Active Safety are developing high-performance sensors to measure not only the external vehicle environment, but also the momentary state of awareness and reaction capability of the driver.

Ask the project leader: four questions to Dr. Ulrich Kressel

Dr. Ulrich Kressel heads the Active Safety project within the Aktiv research initiative and is a senior scientist in charge of developing pattern recognition and situation analysis algorithms at the Daimler research center in Ulm, Germany.

1. By the year 2010, the EU aims to cut the number of accident fatalities in half compared to the year 2000. How will the assistance systems of the research project Active Safety contribute to this goal?

In the project Active Safety, we have targeted the key traffic situations in which accidents currently occur most often. We are thus focusing, first, on driver assistance systems that can prevent rear-end collisions on highways and run-off-road crashes. Second, we are developing systems to support drivers in difficult situations at intersections – involving crossing traffic as well as pedestrians and cyclists.

2. From truck drivers to pedestrians: where do you see the main advantages of vehicle assistance systems for road users?

Anyone can be distracted from time to time, whether it is the pedestrian who steps into the street without looking or the truck driver who glances at his navigation device. In contrast to human beings, assistance systems remain continually alert and can react promptly and decisively in such situations.

3. Seat belt pre-tensioners, airbags, ESP: Automotive research has been investing in novel safety technologies for decades. What will be the role of future driver assistance systems?

Our vision is that future assistance systems should inform the driver according to the situation, issue warnings as required, and intervene autonomously in emergencies. These tasks require comprehensive measurement of the vehicle environment by sensors – radar, lidar, and cameras. The challenge will be to analyze, combine, and evaluate the flood of diverse data sources (for example, cameras generate 25 frames per second) in real time.

4. Can you assess the significance of active safety technologies for Germany’s stance within the international economy?

The development of these assistance systems will strengthen the competitive position of German industry in a key future market, intelligent vehicle safety technologies. It is important that we implement these novel assistance systems for automobile customers in a practical and affordable way, so that they can be offered in all vehicles.
A split-second advantage

“Active Hazard Braking” will provide maximum protection with minimal delay. Often, only a second separates the moment of hazard detection from the last instant for a successful emergency braking intervention supporting an inattentive driver.

Saving precious split-seconds can help prevent dangerous rear-end collisions. This is the strategy behind “Active Hazard Braking”: an automatic emergency braking system will detect imminent collisions on the highway already in advance, warn the driver promptly, and begin braking if required to avoid an accident.

This innovative braking assistant includes several novel functions: forward-looking sensors will locate moving or stationary obstacles; the precise moment of braking will be adapted to the alertness of the driver and the momentary traffic situation. This degree of adaptive functional precision goes far beyond current braking assistance systems.

The basis of this novel braking system is precise, real-time interpretation of the traffic situation. For this reason, sensor data are continually collected and monitored to track the detailed driving state, including the vehicle’s speed and acceleration, the driver’s current actions and maneuvers, the positions and speeds of leading and following vehicles, the geometry of the road, etc. This information is evaluated and interpreted in real time by intelligent algorithms to identify those rare situations that require assistance. The engineers in Aktiv appreciate that a particular driving maneuver might be considered routine in one scenario but signal an acute hazard in another. For example, a rapid narrowing of the gap to the car in front might indicate a lapse of attention leading to an impending collision, but it could also represent anticipation, e.g. a fully controlled passing maneuver on a two-lane country road; in the case of a truck approaching a hill, the driver might temporarily decrease following distance to avoid losing momentum.

Even at maximum braking deceleration, it takes a vehicle

3.4 seconds to stop from 120 km/h

To initiate the correct braking action, the assistant needs to recognize the situation as a whole. In order to achieve a rapid reaction in the entire range of possible traffic scenarios, the engineers are developing appropriate adapted strategies for each driving situation that can arise on highways and roads. If the driver approaches an obstacle or car ahead very rapidly and the system detects a probable lapse of attention, the system can issue a warning and prepare for emergency braking; however, once the driver has recognized the hazard and initiates braking, the braking reaction should be supported, but the driver must remain in control. At the first sign that the driver has begun steering to avoid the hazard, the system should postpone any planned braking intervention.

In addition, the different requirements of passenger cars and trucks will be taken into account. In trucks, avoidance of unnecessary sharp braking maneuvers is of particular importance, for reasons of economy and safety; hence, in trucks, there is a stronger emphasis on warning at an earlier stage and incorporating the driver’s reaction into any system intervention. Warning thresholds and timing also differ between passenger cars and trucks due to their different lengths, longitudinal acceleration and braking characteristics, steering capabilities, and so forth.

The crucial issue is how the system should use the few seconds available. Consider physical limitations of the worst case, a stationary object on a high-speed road. The sensor detection range is about 150 meters. If an object at this distance is detected while the vehicle is moving at 120 km/h, the time to collision is 4.5 seconds. The system then has 1.1 seconds to answer the following questions: Is the object relevant? Is it in the same lane? Can the vehicle steer around it? Is an automatic emergency braking intervention needed? If braking is required and the driver has not perceived the object, the last chance to avoid a collision is 1.1 seconds after detection.
More comfort in curves

Another 80 meters: the curve comes closer and closer, yet the engineer driving the car doesn’t react – his hands rest on the steering wheel. Now only 40 meters until the curve is entered: still no reaction. Suddenly, as if by command, the steering wheel slides through his fingers.

Precise knowledge of the vehicle environment constitutes an essential prerequisite for the “Integrated Lateral Assistant” to act comfortably in the varied spectrum of traffic situations. To this end, various sensors scan the space in front of the vehicle, and the system fuses the information from all of the individual sensors into a consistent, comprehensive picture. The assistance system processes this environmental information and generates a lateral guidance control signal. This control signal is used by the power steering.

Development of the “Integrated Lateral Assistant” focuses on several aspects. One of these is to support the driver while passing through narrow construction zones. For example, if a vehicle needs to merge into a narrow construction zone lane at 60 km/h, the radar and video sensors mounted in the front of the vehicle should be capable of “comprehending” the complex situation immediately: concrete blocks marking the lane boundaries, vehicles in parallel lanes, and typically sudden changes of direction.

In contrast, lane keeping on highways generally involves much higher speeds, which need to be taken into account by the engineers. It is clear that this problem calls for a forward looking lateral assistance function. This in turn requires sensors able to measure traffic flow and lane curvature up to large distances in front of the vehicle. Additional information concerning the roadway curvature can be obtained from the digital map by using GPS positioning data.

Using this database, the assistance system can at any given time forecast the ideal vehicle trajectory during the next few seconds. This can be thought of as a virtual chalkmark along the roadway. The system’s support for the driver in keeping the vehicle safely within the lane can then be oriented onto this ideal virtual trajectory. In contrast to the case of a vehicle driving through a narrow construction zone, there is more leeway in normal traffic, i.e. the boundaries are less constraining. In this case, the goal of the engineers is to select a trajectory providing maximum comfort within a range of allowable trajectories. For example, while passing a truck, the assistant increases the lateral separation appropriately. As a further example, the assistant straightens out the trajectory in curves by “cutting” the curve slightly, similarly to a human driver. An additional longitudinal assistance system can simultaneously adjust the vehicle speed.

The Integrated Lateral Assistance function adapts 360,000 times per hour to the vehicle environment.
Alert assistants

Although drivers express their individuality to a degree by their choice of automobile model and equipment, individual characteristics such as driving style, performance, and the driver’s current condition also have a strong impact on safety. Hence, assistance systems should match their support exactly to the driver’s capabilities and requirements.

Whether it be "Active Hazard Braking", "Integrated Lateral Assistance", "Intersection Assistance", or "Pedestrian and Cyclist Safety" – a safety system can only reach its full efficiency if the assistant is optimally adapted both to the traffic situation and to the current actions and capabilities of the driver. The single most critical characteristic to monitor is the driver's state of awareness and alertness. In the sub-project "Driver Awareness and Safety", engineers and psychologists are cooperating to develop high-performance sensors that can be used to monitor the driver’s alertness with sufficient precision. Intelligent algorithms will fuse and interpret the measurements so that the resulting estimates can be accessed by any safety system in the vehicle to adapt warning, action, and intervention strategies and ultimately to ensure an optimal driving maneuver for the situation. The safety strategies involve concentrating the attention of the driver on the driving situation, avoiding lapses and errors, and consequently avoiding accidents.

With the development of individually adaptive assistance functions, the researchers are exploring a new dimension of vehicle safety. At the same time, methods are required that can convincingly demonstrate the safety performance of these functions during the development and optimization process. These methods include systematic experiments planned in driving simulators or test sites. The researchers are also analyzing existing accident data in order to identify the accident savings potential of these systems at an early stage. Legal issues such as liability and regulatory approval as well as the long-term effects of assistance functions on driving behavior are also being investigated.

Tuned to the driver
Alert or inattentive? To answer this question, the researchers are pursuing two complementary strategies: by means of a video camera in the cockpit, the driver’s patterns of eye movements and the blink frequency are measured. Whereas the driver’s viewing direction implies whether he is currently concentrating on the road or whether his attention is momentarily diverted, the blink frequency is an excellent fatigue indicator. The camera adapts its field of measurement flexibly to the seated height and head position of the driver.

In parallel, sensors in the vehicle are queried to characterize driving behavior and operation of the vehicle: for example, the strength and frequency of acceleration and braking maneuvers, as well as the turning angle and dynamics of steering wheel movements are observed. At the same time, the system monitors the driver’s operation of the radio, the navigation device, or any of the other cockpit buttons and switches. The individual driving style is determined at the beginning of each trip, i.e. the system “learns” the driver’s behavior and uses this information as a base for the information measured subsequently during the trip.
Crossings under control

Intersections demand a high level of concentration. Within a fraction of a second, the driver needs to filter out the relevant information and react quickly and decisively. This task is demanding. In the future, intersection assistance functionalities will support the driver in safely fulfilling it.

Intersections are highly complex traffic clusters that can subject drivers to an intense stimulus overload. Critical situations can quickly arise if the driver is distracted for a brief moment or incorrectly interprets the traffic scenario. In the future, intersection assistants will support drivers by appropriate warnings and corrective interventions: situations such as entering, crossing traffic, and turning will be supported, as well as distance control to the car in front. These assistance systems will help to avoid intersection accidents and thus significantly improve safety for all road users.

In order to tackle the complexity of traffic situations at intersections as efficiently as possible, the engineers are relying on the principle of teamwork. The idea is for intelligent electronics to work hand-in-hand with drivers, taking advantage of their experience: analysis of the current traffic situation is performed by on-board sensors and computers – reliably, thoroughly and in real time. While powerful sensors monitor the vehicle environment, intelligent algorithms evaluate the measured data.

In addition, vehicles can communicate directly with each other via WLAN and exchange important data such as current location, speed, and heading. The assistance system continuously evaluates all available data within a warning, action, and intervention scheme. Based on the current traffic situation, the system tests if (and when) the driver needs additional information, so that, if possible, warnings are only issued if they are really necessary. The driver retains control over maneuvers that have already been initiated.

Because of the conflict potential, left turns (in countries that drive on the right) are among the most hazardous driving actions. In the future, a hypothetical scenario might be as follows: the driver approaches the intersection and begins signaling. He perceives a vehicle coming from the opposite direction but proceeds anyway, having severely underestimated the oncoming vehicle’s speed. At this point, the intersection assistant issues a warning, which can be optical by a pop-up symbol on the windshield head-up display, acoustical (e.g. a gong), or haptic, for example, via pedal feedback. If the driver hasn’t reduced speed, the system intervenes by starting a warning braking maneuver. As a last resort, an emergency stop can be initiated, but only if the driver still continues the maneuver and an unavoidable collision threatens.

The basis for reliable performance of the assistance function is a thorough analysis of the traffic environment and driver behavior. Object identification algorithms based on radar and high-resolution lidar sensors, updated every 20 milliseconds, provide information on the distance, velocity, and relative heading of all nearby road users.

The vehicle’s own location, including lane position, is determined precisely and is transmitted along with kinematic data to other road users by WLAN. Information on upcoming traffic signs and traffic lights is either received via WLAN from downstream vehicles or directly detected by a video camera. Based on this kinematic information, the “Intersection Assistant” projects the trajectories of all objects in space and determines the risk of collision. At the same time, interior sensors and on-board network and bus data reveal whether the driver is operating a vehicle device, and this information is evaluated to estimate the attention state and reaction time of the driver. If a collision is likely, the driver is alerted as quickly as possible, thus effectively reducing the risk of an accident in the intersection.

About 7,000 vehicles travel through intersections in Germany every second.
Precisely examined

First an arm is visible, then a leg. Now the head appears, and finally – the whole pedestrian, abruptly taking faster steps, but then finally stopping after all.

In a typical camera image, the shapes of pedestrians are exceptionally varied, while cyclists have a more characteristic appearance. Identification of unprotected road users within a complex traffic scene and detection of hazardous situations are the goals of the sub-project “Pedestrian and Cyclist Safety”. These are prerequisites for the next step: the engineers intend to develop an assistance system that will use this detection process to prevent accidents with cyclists and pedestrians or, in case of an unavoidable collision, take effective protective measures.

At the core of the safety assistant are intelligent sensors connected to high-performance vehicle electronics. Within milliseconds, the system detects whether any cyclists or pedestrians are present who could enter the roadway and whether there is any risk of a collision. Depending on the traffic scenario, the assistant will adapt its support to the situation by means of a multi-stage warning and action approach: to this end, the project partners are following several different approaches in system development; for example, some of these approaches are designed to warn unprotected road users who are within about two seconds of a possible collision. If no reaction is detected, the system triggers a braking maneuver 0.5 seconds prior to the projected collision. If a collision is unavoidable, protective devices such as external airbags or moveable hoods are deployed in order to soften the impact for the cyclist or pedestrian.

Identification of unprotected road users is performed primarily using video cameras, supplemented by data from distance measuring devices such as short-range radar. Driver alertness and status can be observed by interior video cameras or can be estimated using vehicle data. Correct decisions for or against a supporting action depend on rapid and efficient processing of sensor data in analytic algorithms. Hence, a reliably functioning interface between sensor data and analytic algorithms is a prerequisite for high performance in terms of preventing accidents or at least minimizing their consequences.

In designing the safety system, the engineers are focusing attention on typical urban scenarios with pedestrians and cyclists crossing a street: three-fourths of light and heavy injury accidents involving pedestrians and cyclists occur in urban zones, according to the results of an analysis of the GiDAS (German In-Depth Accident Study) database.

Within this scenario, the goal is to obtain a systematic profile of unprotected road users, valid despite the variation in their images, and to record the structures in a database. Pedestrians and cyclists can then be extracted from the images by comparing with known patterns.

In order to achieve a correct interpretation in real time, the engineers have specified two pattern recognition strategies that precisely determine how the video and radar images are to be analyzed. First, a component-based approach is used to characterize “objects” in the images as potential road users by identifying various body parts. In this way, the cyclists and pedestrians in the images are reduced to their essential component structures. Component reduction in turn implies certain relationships and plausibility conditions: limbs are always connected to a thorax; feet must stand on the ground; the head is usually the topmost component of the object, etc. Almost simultaneously, the view-based approach provides information as to whether a pedestrian is visible from the front, the rear, or the side. Thus, the direction of movement and – by analysis of image sequences – the velocity of the object can be measured. The structures obtained in this way are compared with reference patterns known from the database, and using this information the system determines the optimal course of action.
Specialists for complex situations

Comprehensive analysis for targeted support – this is the principle behind advanced driver assistance systems of the future: within a fraction of a second, with the aid of accurate sensors, high-performance on-board computers will construct a virtual model of the events surrounding the vehicle, the current traffic situation will be carefully analyzed to determine whether an intervention should be triggered via the vehicle’s electronic systems. Assistance functions, which up to now have usually been designed to focus on a single objective and traffic situation, will soon be merged and intelligently coordinated.

Cooperatively acting assistance systems are the wave of the future in active vehicle safety; market-ready systems will be developed by the partners in the short or medium term. In this way, the project Active Safety will generate benefits not only due to improved road safety, but also in economic terms due to the technology stimulus in Germany in order to reap the economic benefits of this technological lead in the international context; the research initiative Aktiv is closely cooperating with political and scientific representatives through committees and conferences.

Charting the course for the future

Program coordinator Eberhard Hipp, head of development at MAN Nutzfahrzeuge AG, works as the interface between federal ministries, European research initiatives, and the Aktiv partners. This responsibility requires a global perspective.

What are the advantages and potential benefits of cooperation on applied traffic research among competitors in the automobile industry?

The research initiative enables coordinated design of innovative vehicle safety technologies and traffic management. Together, the course will be charted concerning which research goals to pursue during the next ten years, and how these objectives can be anchored in regulatory legal guidelines. In addition, automobile manufacturers and suppliers will have the opportunity to specify and develop novel technologies together, resulting in compatibility and interoperability in multiple applications.

Where do you see technological challenges for Aktiv?

One of the essential pre-requisites for the high-performance, advanced driver assistance systems that we are developing is precise measurement of the traffic environment. Efforts should be made to allow the same sensors to be installed in all vehicle types so that they can be mass produced at an affordable price.

Uniform human-machine interfaces are essential for the efficiency of assistance and traffic management systems. How do you go about creating the legal and political basis for tomorrow’s technologies today?

Innovative technologies can only establish themselves successfully within the automobile market if manufacturers and lawmakers agree in advance on uniform operation. Cross-sectional projects such as “Driver Awareness and Safety” in Aktiv represent key steps toward this goal. Here, the technical and legal requirements for different vehicle categories as well as for suppliers and responsible public authorities will be determined.

From the first idea to vehicle implementation backed by regulatory approval – where are the chief obstacles?

Novel technological discoveries and development of new standards for vehicles and road traffic are closely intertwined. Most often, severe discrepancies between existing legal regulations and emerging technologies have to be resolved. In my view, this area presents one of the greatest challenges: successful introduction of novel traffic technologies requires a parallel, concerted effort to evolve the current legal and regulatory framework so that it will encompass research results representing the future state of the art.
Research product: Experimental vehicles

In June, 2008, the research initiative Aktiv will offer a first taste of these innovative technologies at the Federal Road Authority (Bundesanstalt für Straßenwesen) in Bergisch Gladbach, Germany. The project Active Safety will present more than 20 vehicles demonstrating how assistance systems will lead to improved safety and driving comfort in traffic flow of the future. Experts representing automobile companies and suppliers, specialists from public authorities and research institutions will be able to experience and test first hand the performance of these novel functions and the innovative coordination of future assistance systems. Together with participants from the partner companies, the visitors will have the opportunity to discuss the impact of insights gained from currently available statistics and detailed accident analyses on the specification and implementation of each assistance function.

All demonstrator vehicles will be equipped with an extensive array of sensors, and the latest results of algorithms for vehicle environment measurement and situation analysis will be explained in the vehicles by experts. The cross-sectional project “Driver Awareness and Safety” will show how driver alertness can be measured, for example, by cameras. In the project “Intersection Assistance”, car-to-car communication by WLAN as well as measurement of the vehicle environment by autonomous on-board sensors will be demonstrated live in a number of intersection scenarios. The researchers will demonstrate automatic pedestrian detection as well as warning and information strategies including novel human-machine-interface components for the “Integrated Lateral Assistant” and the “Active Hazard Braking”.

All these systems will be perfected and further calibrated to typical road conditions by 2010: during this period, systematic testing of the assistance functions by independent institutions and evaluation by future customers will take place. An important focus is the interface between the driver and the assistance system. The implementation of the interface will be subject to intense investigation and technical optimization.

The project Active Safety will offer the opportunity to explore and delve into the novel safety functions and to obtain a detailed overview during the final “road show” in the summer of 2010. Representatives of funding agencies, decision makers of the partner companies, technical experts, and the interested public will be able to take test drives with demonstrator vehicles and experience for themselves the future of safety assistance.
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