Development of a system for detection of driver impairment

Karel Brookhuis¹, Dick de Waard¹, Evangelos Bekiaris²
¹Traffic Research Centre, University of Groningen, The Netherlands
²Truth, Athens Branch, Greece

ABSTRACT

The aim of SAVE project in the EU fourth-framework ATT programme is to develop an integrated system (in-vehicle SAVE unit) that will in real time monitor driver state and undertake emergency handling, prior and during the emergency situation. This will be realised by instant detection of driver impairment and the feasibility of a shift of the car status to automatic driving mode in case of emergency, to effectively and safely control the vehicle. The Integrated Monitoring Unit (IMU) module of the SAVE system aims to detect deterioration in driver performance as a result of alcohol abuse, fatigue, breakdown or inattention. The driver impairment monitoring system should be able to do this on the basis of changes in vehicle parameters and some observable driver parameters (eyes and head) only.

INTRODUCTION

Ten years ago Smiley & Brookhuis (1987) concluded that some 90% of all traffic accidents can be attributed to human failure in general. It is now estimated that at least 30% of all serious accidents are to be attributed specifically to problems concerning driver state, i.e. conditions such as alcohol or drug abuse, fatigue or drowsiness, prolonged periods of inattention and health problems (cf. Bassuge, 1995). The costs of accidents for society are enormous and the accident rate should be decreased drastically. The prevention or reduction of traffic accidents requires countermeasures that have to be devised and introduced to prevent those behaviours contributing to accidents. In Europe, the USA and Japan, combined ergonomic and engineering approaches to both hazard assessment and the indication of drivers’ performance limits have developed into research and development of new and relevant (primary) safety measures. Brookhuis & Brown (1992) argue that an ergonomic approach to behavioural change via engineering measures, in the form of electronic driving aids, should be adopted in order to improve road safety, transport efficiency and environmental quality.
The Commission of the European Union launched an ambitious programme in the field of road transport informatics and telecommunications to improve road safety, transport efficiency and environmental quality. The programme seeks to create favourable conditions for the development of an integrated road transport environment through collaborative efforts in information technology and telecommunications applied to road transport. It seems likely that this comprehensive concept reduces political objections to the introduction of many safety measures which include constraints on individual drivers' freedom. Any measure that marginally constrains individual road user behaviour in order to improve safety is even more acceptable if it can be shown incidentally also to reduce traffic congestion and air pollution. Certain projects within this programme aim to detect inadequate vehicle control under conditions where the driver's cognitive, perceptual and motor abilities may become impaired (i.e., accident risk is increased). The SAVE project (System for effective Assessment of the driver state and Vehicle control in Emergency situations) is such a project.

The aim of this project is to develop a demonstration prototype of an actual product (in-vehicle SAVE unit) that will in real time detect impaired driver state and undertake emergency handling, prior and during the emergency situation occurrence. This will be realised by instant detection of driver impairment, whereupon firstly the driver is warned, then if necessary drivers in the immediate environment and ultimately an emergency centre, hence shifting the car operation to an automatic driving mode, in order to ensure safe control of the vehicle.

Integrated Monitoring Unit

Central to this approach is the development of an in-vehicle Integrated Monitoring Unit (IMU), introduced and found feasible in former EU projects (DREAM and DETER, see De Waard & Brookhuis, 1991, Fairclough, Brookhuis & Vallet, 1993). It concerns the development of a prototype subsystem, capable of detecting driver impairment from vehicle sensors alone. The IMU itself is divided into three functional units, the vehicle sensors that collect instantaneous driving data, an advanced diagnosis or classification subsystem that analyses and interprets this data and the storage / retrieval device which is used as a template of normal driving behaviour. The diagnosis or classification subsystem consists of a series of processing algorithms in sequence centered around a Neural Network (Hernandez & Esteve, 1996). The sequence consists of pre-processing by Independent Component Analysis (a for this purpose more suitable form of Principal Component Analysis), processing by Artificial Neural Net (using Barycentric Correction Procedure Sequential Learning algorithm), after which final diagnosis is performed with the aid of Fuzzy Logic.

The flow of information from vehicle sensor to interpretation and action proceeds as follows. Data are collected from the vehicle sensors and processed into the form of critical vehicle para-
meters, i.e. those driver actions that are indicators of psychological impairment. The data are interpreted by the classification algorithm with reference to the storage/retrieval data base that holds the normative driving pattern but can include a record of the individual driver's normal style of driving too. The output from the neural net system diagnoses either normal or abnormal driving. In the latter case a separate part of the system will select and produce appropriate actions, such as warning message(s) or starting the Automatic Control Device that takes over vehicle control.

In the present SAVE project several studies have been carried out that contribute to a stepwise approximation of the determination of critical driver actions and the assessment of their critical values with respect to psychological impairment. Critical driver actions, as derived from DETER and earlier studies, are lateral position handling, steering wheel handling, speed management, headway control and pedal use. In the present phase of the SAVE project several new driver state related measures are being studied with respect to their value for the classification subsystem. Three sensors are developed to produce the measures, an eye-lid distance/closure sensor, a steering wheel grip sensor and a head position sensor.

With respect to the classification of normal versus abnormal driving, critical values of driver actions are of two types, absolute and relative. Absolute critical values refer to levels of measured driver actions that would imply a direct, acute danger of accident involvement to the vehicle and driver. For example, driving at 0.1 second time-headway to a lead car whereas a minimum human reaction time in laboratory circumstances is around 0.2 seconds. Relative critical values are individual and refer to decrements in driver actions that indicate psychological impairment, without direct relationship to likelihood of accident involvement. For instance, if a person, who is inclined to avoid risks and normally drives at 2 seconds headway to a lead vehicle, now drives at 1 second, he is probably not in an optimal condition. For a more extended review on critical values, see Brookhuis (1995).

Detection of impaired driving, after alcohol, while hypovigilant and inattent

Several limited validation experiments have been carried out in the project so far, two of which will be treated briefly here. The first one concerns a study of actual driving on a closed circuit while alcohol-intoxicated and driving at night, under hypovigilance conditions (Fairclough, 1996). Subjects drove for one hour after alcohol consumption, aiming at 0.1 % BAC (1 promille). Although not all subjects were equally intoxicated, their state of intoxication was approximately similar. The classification procedure was based on six variables in this experiment, speed, distance to a lead vehicle, lane position, steering wheel position, position of break and gas pedal. For the intoxicated driver, a correct diagnosis was made in 86% of the
time. The sleep deprivation data were far less convincing, only 30% (above chance level) was correctly diagnosed.

The second study concerns an experiment in the driving simulator of the Traffic Research Centre (see for instance Van Winsum & Van Wolffelaar, 1993), involving 20 subjects that were tested under two conditions, alert and while their attention was distracted up to several seconds (De Waard, Van der Hulst & Brookhuis, 1997). Subjects were called by car-telephone and asked to search for a telephone number on an alphabetically ordered list, clipped on the dashboard. The classification procedure was based on a larger number of variables this time, i.e. position of all pedals, speed, steering wheel position, lateral position, distance to a lead vehicle (in time and distance), time-to-line crossing and time-to-collision. Although at the moment of writing not all data were analysed, the SAVE diagnosis subsystem was able to classify the data correctly in 85%-90% of the cases so far.

All analyses were performed off-line up to now. In the final validation phase of the project (1998), the IMU will be built in the project’s demonstrator vehicle and in some of the vehicles (real and simulator) at the test-sites. On-line tests will be carried out to enhance the final system in order to maximise the hit rate, but also and more importantly, to absolutely minimise false alarms. The latter requirement is crucial with respect to acceptance by the public, in particular the driver population. A further requirement for the system to be acceptable is the turn-around time for the diagnosis procedure. The final system should be able to process a classification within very short time, say less than 100 msec, in order to be able to diagnose driver impairment reliably within one second, based on a reasonable number of classifications, i.e. at least ten.

**Prospects of the SAVE system**

The SAVE system aims to be the telematics’ answer to driver emergency situations in the sense of impaired driver condition. As such it should be conceptually integrated in the ‘information era vehicle’. This is specified by the following main objectives of the project:

- To effectively monitor the driver state.
- To detect in real time critical conditions of the driver, i.e. drunk, fatigue and critical incidents to his health.
- To establish criteria for emergency control decision.
- To provide feedback to the driver and to inform other drivers in the direct environment of the driver’s condition both before the incident (accident avoidance) and after it (call for help), by a multimedia approach.
• To effectively and safely control the vehicle, in case of serious driver impairment.
• To enhance the personal mobility of People with Special Needs and Elderly.
• To enhance vehicle safety.

Although the integrated system is of unique value, a large number of SAVE subsystems, or combinations of them, could be of great value on their own. The main innovations proposed by this project, linked to the above objectives, are the following:

• Integrated approach to the problem of driver related emergencies.
• Detection of unusual driver behaviour (for instance, ill-health, alcohol or hypovigilance).
• Car emergency control unit (connected to panic button or as stand alone).
• Introduction of various ATT aids to be used in Driver impairment related Emergencies.
• HMI between drivers and cars, to inform them about their own condition.
• Multimedia communication of a car with its environment in cases of emergency.
• New Telematic Service for emergencies.

In accidents all over Europe around 50,000 people are killed and over 1,500,000 are injured each year. In economic terms this means that:

• Around 70 billion ECU’s are spent each year on medical treatment of injured people in accidents and thousands man-years of work are lost. These numbers are bigger than the Gross National Product of several EU countries!
• Social funds in the order of billions ECU’s are devoted annually to medical services and rehabilitation for people, becoming temporarily or permanently disabled due to accidents.

SAVE intends to bring down accident rate significantly, effectively reducing the driver impairment related accidents that form over 30% of the total. The benefit to the economy and people’s welfare throughout Europe is therefore obvious, even if SAVE manages finally to prevent only a limited number of incidents. For example, a mere 5% reduction to road casualties implies about 2500 less deaths and 75000 less injuries per year, which sums up to around 500 MECU gain annually for the European economy. Also since accidents due to loss of vigilance tend to be more severe than the average, even that figure may be an underestimation of the actual economic gain.
References


