Giese K., Hönig F., Erzigkeit A., Soutschek S., Hornegger J., Kornhuber J.

Development of a Computerized Diagnostic System for Elderly Drivers: A Feasibility Study

Abstract

As a basis for research on automatic diagnostic systems for elderly drivers addressing biological markers and psychological reaction patterns underlying the ability to safely driving a car, we develop a data acquisition framework for synchronously recording various physiological signals, audio and video. Other supplementary driving data such as GPS location information are provided for retrospective interpretation. In preliminary evaluations on a test drive, we compare relaxed and stressed driving periods. We find highly significant and meaningful differences for the recorded physiological parameters. These promising results are an indication that our approach is suited for collecting, interpreting and analyzing relevant data.

Introduction

The human factor – delayed reaction time, inattention or information overload – is the prime cause of road accidents. This is especially evident for elderly drivers – a fast-growing group due to demographic change. Problems such as declines in working memory function, lessening selective attention skills and speed of information processing ([1], [2]) contribute to the increasing involvement into accidents per mile driven with age. Another group of drivers that is particularly affected are stroke patients with possibly impaired cognitive skills during their rehabilitation.

One line of research approaches the issue by providing technical assistance for the driver e.g. through car-to-car communication or car-to-x, i.e. traffic management systems. Further, driver interfaces are being designed that specifically account for recent neurological findings about the human information processing system [3]. Complementary to these efforts is the approach to obtain and utilize live information about the drivers' current cognitive or emotional state from psychophysiological measures. In [4], Healey and Picard show that under certain preconditions, stress can be recognized from physiological signals in real-world driving conditions. Such information could be used, for example, to adapt the behavior of in-car assistance systems accordingly.

Fit4Age[1] encompasses research projects into ambient assisted living (AAL) systems as well as into individual properties of elderly persons. Thus, it provides a suitable research environment for this area. Within Fit4Age and in cooperation with fahrer-projekt.de, an initiative aiming at improving drivers' competence and driving safety, we are developing a diagnostic system for elderly drivers addressing biological markers and psychological reaction patterns to estimate the ability to drive a car safely.

To establish the technical and methodological basis for this project, we have developed as a first step a setup of sensors detecting and recording biological functions and other information during driving school lessons. We chose that domain for this study because firstly, a driving instructor – mandatory during driving lessons in Germany – is present which is important for safety and legal reasons. Secondly, a wide range of psychological reaction patterns can be expected as learners from novice level up to relatively experienced drivers (shortly before the driving exam) are available for data collection.

Data Acquisition Setup

We record several physiological signals from the driver: electrocardiogram (ECG), electromyogram (EMG), abdominal respiration (Resp), skin conductivity (SC) and skin temperature (Temp) during the lessons. The sensor configuration is depicted in Fig. 1 and 2. For acquisition, we use the *NeXus 10* (mindmedia, Netherlands) device which picks up the signals at a rate of 2048 Hz (ECG/EMG) or 256 Hz (other signals) and sends them to a Notebook via Bluetooth in real-time where it is stored on hard disk using the API provided by mindmedia. Using two *fire-i* (Unibrain, USA) cameras (cf. Fig. 1), we capture the driver (standard lens, 42.25°) and the scene in front of the car (wide angle lens, 107°) with a resolution of 320x200 pixels at 30 frames per second. On a separate notebook, the video streams are compressed on-line using the open-source software *mencoder*, and saved to hard disk. The power supply is taken directly from the car battery using a 300W DC to AC converter. Further, an AT 831B lapel microphone (audio technica, USA) records speech from the driver, and a T.Bone GZ400 (Thomann, Germany) boundary microphone picks up ambient sounds. A *LD-3W* GPS module (Nokia, Finland) delivering location data at approximately 1 Hz and three axis *JoyWarrior24F8* acceleration sensor (Code Mercenaries, Germany) operating at 20 Hz add their data to the protocol. Finally, the assistant operating the equipment logs any special events.

Great care has been taken to exactly synchronize all recorded modalities. As each recording device has its own clock generator, it does not suffice e.g. to simply start each device at the same time; clock inaccuracies typically cause different modalities to drift apart by several seconds already after half an hour. Therefore, each physiological sample, video frame, audio buffer, GPS data item, acceleration sample and log entry receives a timestamp from the system clock of the recording notebook at the instant it is observed. As two notebooks are used, the difference between the two clocks is

---

[1] www.fit4age.org

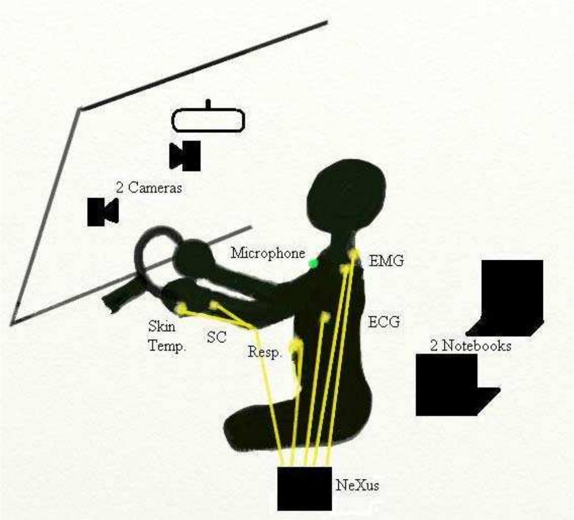

Fig. 1: The learner wears five sensors: electrocardiogram on both sides of the chest, electromyogram on the left shoulder, a belt capturing abdominal respiration, skin conductivity on the left wrist and skin temperature on the side of the left little finger.

registered regularly using socket communication over Ethernet. With this mechanism, it is assured that each instant in time of the recordings can be located in all recorded modalities.

During the lesson only the driving assistant sees the data that are recorded. Thus, after attaching sensors, and adjusting cameras and microphones, learner and driving instructor are not involved with the data collection and not aware of the body parameters, and the lesson can take place as normal as possible. Also, we avoid telling the learner that one of the most desired states to be recorded is stress in order not to hinder stress induction.

Fig. 2.: Sensor placement and connection to the NeXus-10 device attached to the side of the seat.

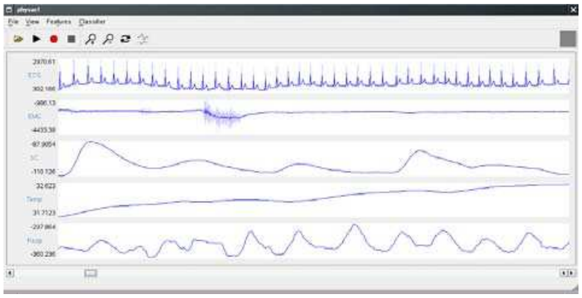

Fig. 3: Section of the recorded physiological signals: ECG, EMG, SC, Temp and Resp (from top to bottom).

First Results

The recording setup proposed above has been developed and evaluated during several test drives and has proven to be well suited for the given task. The recorded physiological signals contain a number of artifacts, but overall, they seem to be of sufficient quality. A section of the sensor readings is plotted in Fig. 3. The video recordings give a good impression of the traffic situation and road events and of the driver's behavior. Example images are given in Fig. 4. The GPS recordings can be used to visualize the traveled distance (cf. Fig. 5). Summing up, the data collection setup provides an excellent basis for studying psycho-physiological diagnostic systems for car drivers. The driving log, video and audio, and also the supplementary data provided by GPS and acceleration sensor offer a number of ways to retrospectively determine driving conditions or psychological states and thus to establish a ground truth for analysis of the physiological signals.

During one test drive, we instructed the driver to alternate between a relaxed and fast, presumably stressed, driving style. Thus, two relaxed segments (21 minutes cross-country, 25 minutes motorway/city) and two stress segments (10 minutes cross-country, 6 minutes motorway) were identified. When comparing the recorded physiological parameters between the relax and stress condition, significant differences were observed: the heart rate determined from ECG is significantly[2] higher under stress; standard deviation of SC (over windows of 10 seconds, a measure of the height and number of orienting responses) is significantly higher under stress; skin temperature as well as its gradient are significantly higher during relaxed driving; the velocity of the breathing pattern (averaged over 10 seconds) is significantly higher under stress. These findings are consistent with effects of stress reported in the literature and support our conjecture that with the chosen data acquisition method, different psychological states can be observed and distinguished using the physiological measurements.

---

[2] We employ the Wilcoxon rank sum test with continuity correction and $p=10^{-4}$.

Fig. 4: Images from the two installed video cameras.

Discussion

In this paper, we have presented a data acquisition framework for completely synchronized, physiological and multi-modal monitoring of car drivers, which is to be the basis for developing diagnostic systems for elderly drivers. By its multi-modality, it not only provides various physiological readings, but also offers many ways for retrospectively interpreting the different stages of the recording. Using no special hardware but only consumer electronic products, it is a low-impact but powerful setup that is easy to replicate. As a promising first result, analysis of a test drive showed significant and meaningful differences in the physiological readings during relaxed and non-relaxed segments.

In the future, we will record car driving learners during different stages of their training. We also consider to record stroke patients during rehabilitation and/or a cross-section of healthy, normal drivers. If the evaluation of these recordings is successful, we plan to continue our studies with elderly people.

For analysis, we will apply a comprehensive feature extraction module that has shown to be both competitive to state-of-the-art physiological features and suited for real-time processing [5]. Apart from identifying categorical ground truth labels for intervals as above, we will also apply the feeltrace approach [6] to derive (value- and time-) continuous ground truth labels. We have already applied this approach successfully to user-independently estimate continuous stress ratings from physiological signals on data collected using a driving simulation [7].

Another possible application of our setup could be medical diagnosis and prevention, identifying disturbances of physical health or contributing to psycho-educational programs focusing on stress reduction by monitoring biological markers.

Acknowledgements

This research project is supported by the BFS1 Bavarian Research Association “Zukunftsorientierte Produkte und Dienstleistungen für die demographischen Herausforderungen – FitForAge”. We are very grateful to the Thomas Walch driving school (Nuremberg, Bavaria) and the Geromed GmbH (Spardorf, Garmany) for the continuing support. We would also like to thank the SMS AG Schmidt Engineering, Schmidt Motorsport, Cadolzburg (Bavaria) for their help in setting up an installing the car recording equipment.

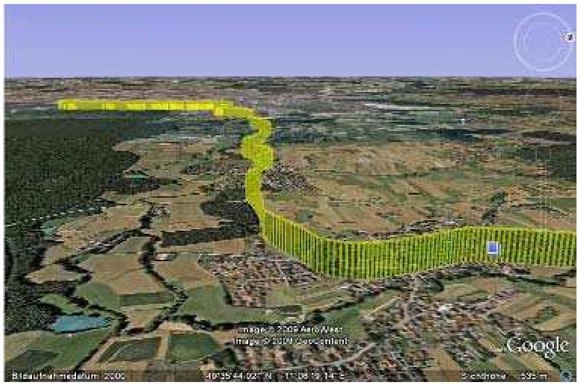

Fig. 5: Part of a driven route as recorded by the GPS module, visualized using Google Earth.

Literature

[1] Alicandri, B. et al.: *Judging the gap*, Road Management & Engineering Journal, May 9, 1997

[2] Staplin, L. et al., *Intersection negotiation problems of older drivers*, Vol. I and II, NHTSA, report No. 1446/FR. Sept. 1998

[3] Ho, C. and Spence, C.: *The multisensory driver. Implications for ergonomic car interface design.* Ashgate 2008

[4] Healy, J.A. and Picard, R.W.: *Detecting stress during real-world driving tasks uUsing physiological sensors*, IEEE Transactions on Intelligent Transportation Systems, 2: 156-166, 2005

[5] Hönig, F. and Wagner, J. and Batliner, A. and Nöth, E.: *Classification of user states with physiological signals: On-line generic features vs. specialized feature sets*, Proceedings of the 17th European Signal Processing Conference (EUSIPCO-2009), to appear.

[6] Cowie, R. et al.: *Feeltrace: An instrument for recording perceived emotion in real time* Proc. ISCA ITRW on Speech and Emotion: Developing a Conceptual Framework, Belfast 2000

[7] Hönig, F. and Wagner, J. and Batliner, A. and Nöth, E.: *Predicting continuous stress ratings of multiple labellers from physiological signals*. Analysis of Biomedical Signals and Images (BIOSIGNAL 2008), Brno 2008

Affiliation of the first Author

Katrin Giese
Lehrstuhl für Mustererkennung, Universität Erlangen-Nürnberg
Martensstraße 3
Erlangen, 91058
Germany
Katrin.Giese@stud.informatik.uni-erlangen.de