TEXTILE CAPACITIVE ELECTROCARDIOGRAPHY FOR AN AUTOMOTIVE ENVIRONMENT

Bhavin Chamadiya, Stephan Heuer
*Research & Development, Daimler AG, Hanns-klemm str. 45, Boeblingen, Germany
FZI Forschungszentrum Informatik, Karlsruhe, Germany
bhavin.chamadiya@daimler.com, heuer@fzi.de

Manfred Wagner*, Ulrich G. Hofmann
Institute for Signal Processing, University of Lübeck, Lübeck, Germany
manfred.mw.wagner@daimler.com, hofmann@isip.uni-luebeck.de

Keywords: Non-contact electrocardiography (CCECG), Textile electrode, Realistic driving situation, In-car vital parameter monitoring.

Abstract: Growing mobility demand in the western world intensifies the concern for automotive safety and health monitoring in daily life. This study shows one solution to integrate textile based, capacitively coupled electrocardiography into a car considering a real automotive environment. Electrodes based on conductive textile were integrated into a car seat. Contact ECG and non-contact CCECG measurements were done in different situations like driving high speed on highways, on surface streets, with various clothes and others. The influences of various car functionalities on the measurement were detected. Feasibility to measure Electrocardiography is discussed to evaluate continuous non-contact monitoring for safety, healthcare and comfort as well.

1 INTRODUCTION

Automotive safety is a crucial topic, with human mobility difficult to imagine without individualised automobiles. Even though a growing number of passive car safety solutions have been implemented over the past decades and led to a decrease in fatalities the human driver is still the primary cause for accidents.

A number of biomedical and monitoring systems have been incorporated in automobiles for healthcare (D’Angelo et al., 2010) as well as safety (Lee et al., 2007) improvement. However, physiological monitoring is still a nascent tool for real automotive healthcare and safety, mainly due to difficult handling of monitoring equipment outside a laboratory.

As such, non-contact measurements of driver’s vital parameters by unobtrusive monitoring might improve general traffic safety immensely.

Consequently the focus of this study was to integrate capacitive electrodes for electrocardiography in a real automotive environment. Vital sign recordings have been performed while driving in several real world situations.

2 MATERIALS AND METHODS

2.1 Capacitively Coupled Electrocardiography (CCECG)

The seemingly only customer acceptable method to acquire ECG signals from the driver of a car would be a non-contact one, since it avoids the bodily contact and limitations of a regular monitoring device. We chose, due to their simpler implementation, a capacitive coupling (CC) to the drivers bio-potentials, thus avoiding any type of galvanic connection between the driver and the measurement system (Harland et al., 2002).

Unlike conventional ECG systems that use low impedance electrical contacts to acquire electrical signals from the body‘s surface, CCECG systems require a capacitive (very high impedance) contact. Hence body and electrode form a plate capacitor to carry a signal from the body to a very high input impedance preamplifier (Lim et al., 2006). Signals from two preamplifiers are fed to a differential amplifier and thus remove most of the common mode signal. To further improve common mode rejection, a driven seat circuit is used (Kim et al., 2005). Additionally the signal is algorithmically processed in real time in order to remove other unwanted signals from it. A sketch of the potential integration of sensors is depicted in figure 1, including steering wheel integrated biosignal measurement (Heuer et al., 2010).

Figure 1: Textile CCECG integration concept in INSITEX *project.*

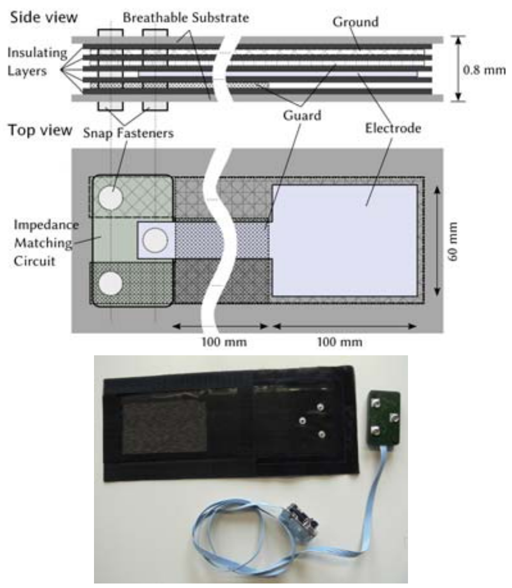

Figure 2: Structure of the textile electrode (top), Implemented electrode with preamplifier module (bottom).

2.2 Textile Electrode

Intense testing of rigid PCB electrodes led to the conclusion, that a flexible and soft electrode structure is essential for a useful CCECG. Thus our electrode is made up of three layers of conductive textile for electrode (sensor area), guard and ground respectively as depicted in figure 2 (top). The conductive layers are isolated against each other with insulating PU films. The textile is washable and breathable Eblocker from Novonic (E-Blocker from novonic® Novonic, 2010).

The three conductive layers of the assembly are attached to the preamplifier module by their respective connection through three conductive snap fasteners.

2.3 System Integration

To make the integration suitable for both a seat in lab and car, electrodes are fastened into a seat cover of the Mercedes Benz C-class (W204 series).

Figure 3: The electrodes and incised seat cover with Velcro (top left), the electrodes when fastened into the seat cover (top right), the seat cover applied on the car seat.

To hold the electrodes tight to the seat cover, Velcro ribbons are attached around their rims and the seat cover incision as shown in figure 3. Hence it maintains a stable, robust and yet removable configuration. Signals from the electrodes are taken through the visible blue ribbon cables to commercial 9 pin D-sub connectors (figure 3).

2.4 Measurement Setup

The seat cover is applied to a C class car seat both in lab and in a real car as well; figure 3 shows the arrangement inside the car.

The outputs of the electrodes are fed to a signal processing box. Both inputs to the box are filtered with high pass filter (0.8 Hz) to remove baseline drift and DC offset. The differential of the signal is further filtered with a band pass and 50Hz notch filter before any amplification.

The pre-processed analog signal is digitised with a data acquisition card (NI U-9162) for further processing and final display in LabVIEW 2009.

The driven seat textile electrode is spread beneath the cushion cover of the car seat to reduce common mode noise.

3 MEASUREMENT RESULTS

The CCECG measurement system has successfully gathered data for various real driving situations. Measurements in conditions like driving on highways, surface street driving, enabling car functions while driving, by putting on different clothes on the subject etc. have been performed. Non-contact ECG recordings under different road conditions are displayed in figure 4.

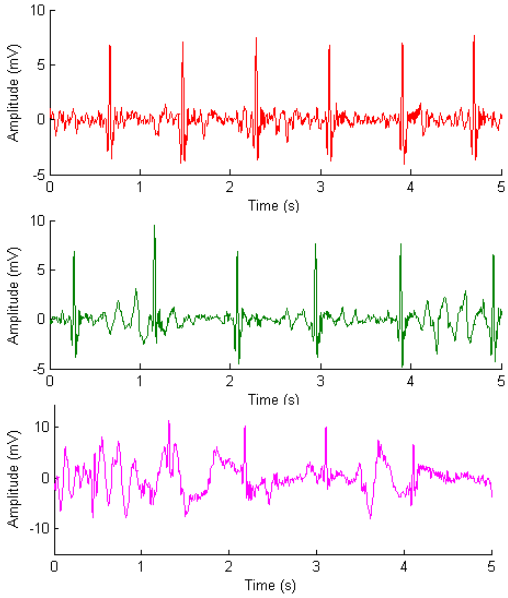

Figure 4: The CCECG result on highway (top), city street in good condition (middle), uneven street in city (bottom).

During all the measurements, the driving subject wore a t-shirt (100% cotton) with 0.68 mm thickness and a pant (wool and polyester) with 0.29 mm thickness. The subject was 56 years old with height and weight, 182cm and 92kg respectively and was driving at speed of 100-120 km/h in normal condition on highway and in the city street 40-60 km/h.

Due to the massive amount of electrical appliances in contemporary cars, it was crucial to test the influence of those functionalities on the measurement during real driving. Figure 5 shows the low influence of telephone usage (top), automatic seat adjustment by DC motors (middle), and electrical seat heating (bottom).

Complete of many more functionalities will be presented elsewhere.

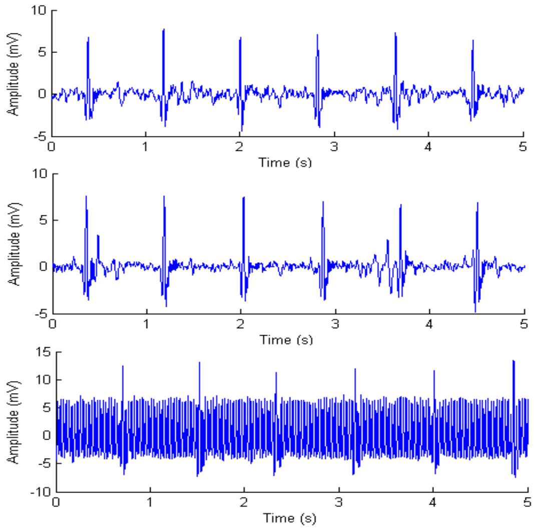

Figure 5: CCECG results from different driving activities: hands-free telephoning (top), adjusting the driver's seat (middle), with seat heating level 1 & 2 enabled (bottom).

Figure 6 shows a clear and strong effect of the drivers clothing on the signal quality, since this will strongly influence the capacitive coupling and thus the monitoring result. The clothes consisted of a winter jacket made up of 85% polyester and 15% polyamide with 0.35 mm thickness, a rain jacket made up of 100% nylon lined with 0.44 mm PU and a sportcoat made up of 55% linen and 45% viscose with 0.85 mm thickness.

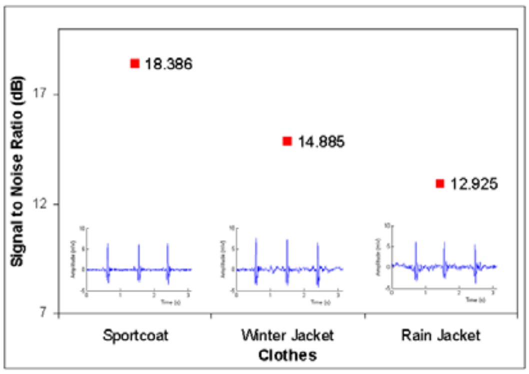

Figure 6: Signal to noise ration of the CCECG signal with various clothes and respective CCECG Signals.

4 DISCUSSION AND CONCLUSIONS

A practical approach to integrate a textile CCECG system has been implemented in our experiments.

Measurements during common driving situations could be demonstrated. It can be observed that only driving on bad and bumpy roads (hence strong car and body movement) did interfere with the monitoring by causing rapid base line drifting.

Some of the seat functions also have influences from mild to intense on the signal as depicted in figure 6. Interference from automatic seat adjustment while driving was minor as the function is enabled by DC motors driven with 50Hz pulses (Chamadiya et al., 2008) and the body maintained a stable contact with the electrodes in the seat. Low frequency base line drift and 50Hz hum noise from the DC motors were filtered by the monitoring system. Seat heating with level 1 and 2 showed major effects on the monitoring results as they had a PWM signal of 24 Hz (Chamadiya et al., 2008). However, we speculate that interfacing our monitoring setup with the car‘s own controls and sensors could alleviate the severity of these distortions.

Clothes in general did have an impact in the signal-to-noise ratio, but did not prohibit heart rate monitoring and require further investigation.

Summing up, this work demonstrates promising non-contact monitoring results with a textile CCECG system in real world driving situations. The system shows a strong potential to be incorporated in a car for long term ECG measurement for safety and healthcare.

ACKNOWLEDGEMENTS

We would like to thank the BMBF (German Ministry for Education and Research) for funding the work of INISTEX project.

REFERENCES

D’Angelo, L., Parlow, J., Spiessl, W., Hoch, S., Lüth, T., 2010. A system for unobstrusive In-Car Vital Parameter Acquisition and processing. *4th International Conference on Pervasive Computing Technologies for Healthcare.* Garching, Germany 22-25 march 2010.

Lee, H., Kim, J., Kim, Y., Baek, H., Ryu, M., Park, K., 2007. The relationship between HRV parameter and stressful driving situation in the real road. *6th International Special Topic Conference on ITAB.* Tokyo, Japan 2007.

Harland, C. J., Clark, T. D., Prance, R. J., 2002. Electric potential probes-new directions in the remote sensing of the human body. Measurement Science Technology 13, 2002, pp.163-169.

Lim, Y., Kim, K. and Park, K.,. (2006) ECG measurement on a chair without conductive contact. *IEEE Transactions on Biomedical Engineering,* Volume 53 (No.5/May), pp.956-959.

Chamadiya, B., Heuer, S., Hofmann, U., Wagner, M., 2008. Toward a capacitively coupled Electrocardiography system for car seat integration. *4th European conference of the international Federation for Medical and Biological Engineering.* Antwerp, Belgium 23-27 November 2008. Springer-Verlag Berlin Heidelberg 2008.

Heuer, S., Chamadiya, B., Gharbi, A., Kunze, C., Wagner, M., 2010. Unobtrusive in-vehicle biosignal instrumentation for advance driver assistance and active safety. IEEE EMBS Conference on Biomedical Engineering and Science. Kuala Lumpur, Malaysia 30 November-2 December 2010.

Kim, K., Lim, Y., Park, K., 2005. Common mode noise cancellation for electrically non-contact ECG measurement system on a chair. In *TEMPLATE’06, 27th Annual Conference on Engineering in Medicine and Biology*. Shanghai, China 1-4 September 2005. IEEE.

E-Blocker, 2010. E-Blocker product information. [online] Available at: <http://www.novonic.de/web/NovNeu_FDI.nsf/id/pa_novonic_e_blocker_e.html> [Accessed 22 August 2010].