Lumbar Cushion based Real-time ECG Sensing System for Monitoring Driver's State

J. Son, *Member, IEEE*, B. Kim, and M. Park
Daegu Gyeongbuk Institute of Science & Technology, Daegu, Republic of Korea
json@dgist.ac.kr

***Abstract*— As driver's inattention becomes one of the major causes of traffic accidents, there have been many researches for monitoring driver's health and cognitive states. In this paper, a non-intrusive real-time ECG system based on capacitive sensing method was proposed. To verify the ECG sensing system, on-road experiment was conducted on three different types of road environment. As a result, the ECG waveforms were successfully obtained and clearly displayed on the smart phone via Bluetooth communication. The robustness of the ECG signal was improved by placing the sensors on the lumbar support cushion of the seat.**

I. Introduction

It is known that driver's inattention is a leading cause of traffic accidents. According to a car accident report, driver's inattention, e.g. distraction and drowsiness, contributes to 25 percent to 78 percent of all crashes [1]. In order to improve road safety, it is essential to monitor driver's health and mental states. Typical sensing systems for monitoring driver's states can be categorized as a vision based system and a physiological signal based system. A vision based system uses eye movement and facial expression to estimate a driver's state. In this case, the implementation cost is relatively high due to precision sensing devices and image processing technologies. It also has limitations in detecting driver's impaired health states. However, a physiological signal based system, which uses cardiac activities, e.g., Heart Rate (HR) and Heart Rate Variability (HRV), can estimate driver's drowsiness, mental workload and health states efficiently [2,3].

Typical electrocardiogram (ECG) sensors require conductive gel to ensure low-impedance electrical contact between the sensor and skin [4]. To avoid this inconvenience in the real world application, there have been many attempts of attaching ECG sensors to steering wheel or seatback. In general, seat-mounted ECG sensor systems have been recognized as a stable measurement method in driving situations due to less movement artifact under driver's steering activities. However, Baek et al reported that movement artifacts with high-frequency components were observed in seat-mounted ECG sensors due to seat vibration and lateral movements of skin [5]. To minimize seat vibration induced noises and increase robustness of the system, this paper proposes a lumbar support cushion based ECG sensing system.

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II. Implementation of ECG Sensing System

A. ECG Sensing System Overview

As shown in Figure 1, the proposed non-Intrusive ECG sensing system consists of electrodes, analog filter circuits, amplifier circuits and Bluetooth module. In this system, the electrodes uses capacitive sensing method based on capacitive coupling without skin contacts. Driver's cloth works as an insulator between two conductors; electrode on seat cushion and driver's skin. When electric potential is detected from skin, the signal is transferred to the sensing plate. Obtained signal passes low pass filter to remove noise and then amplifies through amplifier circuits. The amplified signal passes high pass filter and it is converted to digital signal (10bits). Finally, the converted signal is transmitted to a monitoring system via Bluetooth module or serial communication.

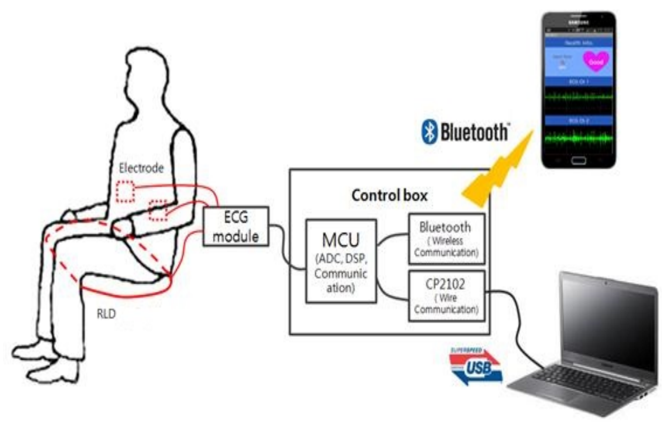

Figure 1. ECG sensing system overview

B. Active Electrode Design

The amplitude of physiological signals is lower than mV level, and noises arise while signals pass from input terminal to instrumentation module. To lower the impedance, voltage followers were designed. Input terminal of an op-amp used coupling capacitor to pass AC components and block DC components from the sensing plate. Active shield that reduces noise and improves robustness was built by sending signals from the input terminal op-amp to case shield.

C. Driven Ground Plane Circuit Design

In this system, a capacitive driven ground plane circuit design [6] was employed for ECG measurements. The common circuit used a conductive fabric sheet placed on the seat cushion to increase capacitive coupling.

D. R-Peak Detection

Amplified ECG raw data passed band pass filter (5-20Hz) and it was differentiated to analyze variation of the signal. Then, absolute values were taken for avoiding negative peak problems. The signal was squared and passed low pass filter for the smoothing effect. Threshold for finding R-peaks was set based on each maximum peak values of the signal, which improved accuracy of heart rate detection.

E. Communication and Monitoring System

The detected R-peaks data were transmitted to a monitoring device via cable or wireless communication. In this application, the USB and Bluetooth wireless communications were used. No interference problems occurred on ECG data via wireless communication. An Android application was developed for monitoring the ECG states in real-time and providing ECG waveforms, detected R-peak, and driver's state, e.g., heart rate is normal or not.

III. ON-ROAD EXPERIMENT

A. Field Operation Test Scenario

On-road experiment was conducted to test the ECG sensing system. As shown in Figure 2, the ECG sensors were placed on the lumbar support cushion, the conductive fabric sheet was located on the seat cushion, and smart phone was mounted on the front mirror. The driver wore cotton shirts and leaned against the seatback with fastening seatbelt. The driving courses consist of three different types of road environment; urban road, curvy hill, and straight highway. The driver spent three minutes of practice driving, and the experiment was preceded if the driver felt comfortable with the ECG sensing device. Average velocities of the vehicle on urban road, curvy hill, and highway were 60km/h, 40km/h, and 100km/h, respectively.

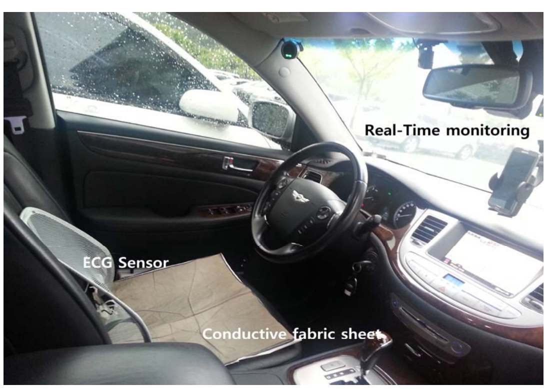

Figure 2. Non-intrusive ECG sensing system

B. Test Results and Discussion

The ECG waveforms were obtained via wireless communication. Figure 3 shows three ECG waveforms acquired from urban road, curvy hill, and highway. Although ECG signals from curvy hill and highway had some noise than urban road, R-peaks can be clearly detected for all data. The results suggested that the lumbar support cushion based ECG sensing system could reduce the noise from the vehicle vibration and driver's movements.

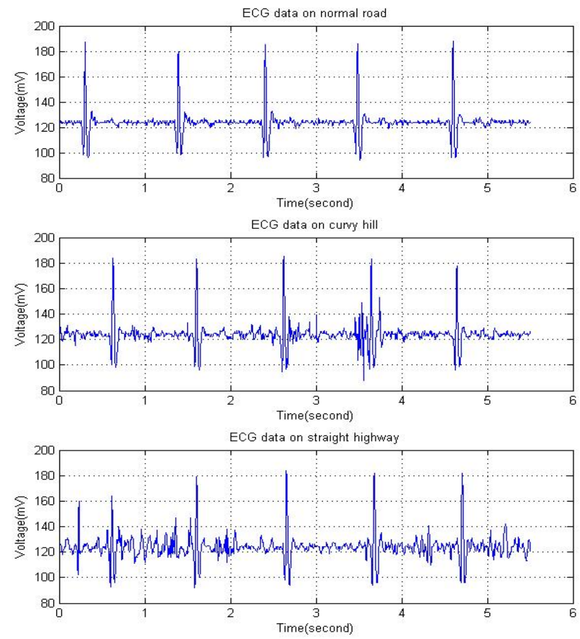

Figure 3 ECG data acquired from three different types of road environments.

IV. CONCLUSIONS

In this paper, a non-intrusive ECG sensing system was proposed to monitor a driver's real-time cardiac signals and estimate driver's health and cognitive states. The performance and robustness of the proposed ECG sensing system was tested by on-road experiments. As a result, the ECG waveforms were successfully obtained and classified R-peaks for all types of road environment. For the future work, the validation test should be conducted with large numbers of participants.

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