Driver Fatigue State Estimation using Time Series Analysis of Body Acceleration

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Abstract— **The detection of driver fatigue is a longstanding issue in the field of biometric measurements. In this study, we examined the possibility of detecting the fatigue state of drivers using their body accelerations. Nine healthy subjects operated a driving simulator for one hour in the morning and one hour in the evening. A Holter ECG was worn and body acceleration was measured using a built-in triaxial accelerometer. The results of the comparison of body acceleration in the morning and evening showed that the variance of the data was larger in the afternoon for most subjects. By visualizing and comparing the time series within the same subject, this study showed that the variance of the driver's body acceleration increases with fatigue. It is expected that this method will be applied to improve driver safety in the future.**

Keywords— fatigue, body acceleration, time series analysis visualization, safe driving

I. Introduction

Driver fatigue causes a wide range of social problems. Traffic accidents are a serious social issue because they cause significant damage not only to drivers themselves, but also to other vehicles and pedestrians. In addition, mistakes made by drivers on the job due to driver fatigue cause a decline in productivity and quality. In particular, when drivers drive for long periods of time, their concentration and discernment may deteriorate, which is a contributing factor affecting the efficiency and safety of their work. Therefore, driver fatigue detection has been a longstanding issue in the field of biological measurement. Recently, the development of wearable sensor technology has made it possible to measure various bio-signals noninvasively. In this study, we investigated the possibility of detecting the fatigue state using the driver's body accelerations.

II. Methods

There were nine subjects; 7 healthy older (3 female) and 2 youngers. The subjects operated the driving simulator for one hour in the morning (approximately 8:00-9:00 AM) and one hour in the evening (approximately 5:00-6:00 PM). A Holter electrocardiograph (ECG) was worn during operation of the driving simulator, and body acceleration was measured using a built-in triaxial accelerometer. The sampling frequency of acceleration was 125 Hz, and the collected acceleration data were resampled at 2 Hz. The axes of acceleration (x, y, z) were squared and added and the square root was calculated the composite acceleration (BA), which was plotted every 10 minutes during simulator operation.

$$BA = \sqrt{x^2 + y^2 + z^2} \qquad (1)$$

III. Result

Comparing the data in the morning and evening, the variance of the data was larger in the evening for many subjects, and we were able to visualize the driver's tendency to some extent with a frequency resolution of about 2 Hz (Fig.1).

IV. Discussion

Driver accidents caused by fatigue tend to occur more frequently in the evening. Although the specific rate of accidents varies depending on various factors such as region, weather conditions, and traffic volume, it is believed that fatigue is a contributing factor in the evening. In this study, by visualizing and comparing time series trends within the same subject, it is possible that fatigue increases the dispersion of driver body acceleration, which may affect driving stability. Time series analysis is also useful for creating predictive models, we will now combine the ARIMA model and Lorenz plot analysis to verify chaos.

For more sophisticated analysis and for predicting fatigue, it is important to decompose changes in the data, which may be useful for finding outliers and periodic fluctuations. And it has been shown that older drivers are more likely to accumulate fatigue than younger, it is also necessary to examine the differences between the older and younger groups.

This study shows that time series analysis of body acceleration is useful for estimating the fatigue state of drivers. It is expected that this method will be applied to improve driver safety in the future.

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References

[1] Brown ID. Driver fatigue. Hum Factors. 1994 Jun;36(2):298-314. doi: 10.1177/001872089403600210. PMID: 8070794

[2] Fan C, Huang S, Lin S, Xu D, Peng Y, Yi S. Types, Risk Factors, Consequences, and Detection Methods of Train Driver Fatigue and Distraction. Comput Intell Neurosci. 2022 Mar 24;2022:8328077. doi: 10.1155/2022/8328077. eCollection 2022. PMID: 35371223

[3] Stern HS, Blower D, Cohen ML, Czeisler CA, Dinges DF, Greenhouse JB, Guo F, Hanowski RJ, Hartenbaum NP, Krueger GP, Mallis MM, Pain RF, Rizzo M, Sinha E, Small DS, Stuart EA, Wegman DH. Data and methods for studying commercial motor vehicle driver fatigue, highway safety and long-term driver health. Accid Anal Prev. 2019 May;126:37-42. doi: 10.1016/j.aap.2018.02.021. Epub 2018 Mar 9. PMID: 29530304

[4] Wang X, Chen L, Zhang Y, Shi H, Wang G, Wang Q, Han J, Zhong F. A real-time driver fatigue identification method based on GA-GRNN. Front Public Health. 2022 Oct 20;10:991350. doi: 10.3389/fpubh.2022.991350. eCollection 2022. PMID: 36339171

[5] Maynard S, Filtness A, Miller K, Pilkington-Cheney F. Bus driver fatigue: A qualitative study of drivers in London. Appl Ergon. 2021 Apr;92:103309. doi: 10.1016/j.apergo.2020.103309. Epub 2020 Nov 27. PMID: 33253978

[6] Lal SK, Craig A. A critical review of the psychophysiology of driver fatigue. Biol Psychol. 2001 Feb;55(3):173-94. doi: 10.1016/s0301-0511(00)00085-5. PMID: 11240213

[7] Tavakoli Kashani A, Rakhshani Moghadam M, Amirifar S. Factors affecting driver injury severity in fatigue and drowsiness accidents: a data mining framework. J Inj Violence Res. 2022 Jan;14(1):75-88. doi: 10.5249/jivr.v14i1.1679. Epub 2022 Feb 6. PMID: 35124683

[8] Fletcher A, McCulloch K, Baulk SD, Dawson D. Countermeasures to driver fatigue: a review of public awareness campaigns and legal approaches. Aust N Z J Public Health. 2005 Oct;29(5):471-6. doi: 10.1111/j.1467-842x.2005.tb00229.x. PMID: 16255451

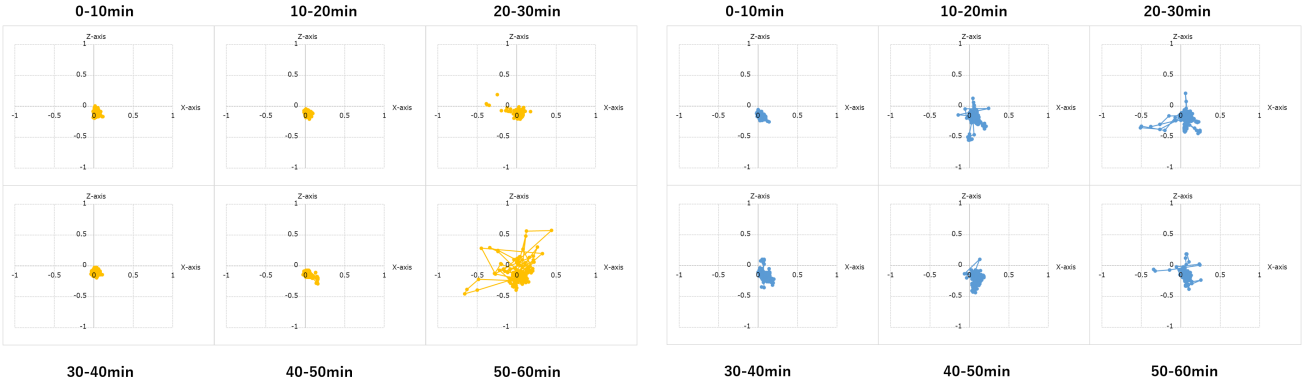

Figure 1. Time series comparison of composite acceleration

The left side (yellow) indicates morning operation and the right side (blue) indicates evening operation. Body acceleration at 0-10 minutes, 10-20 minutes, 20-30 minutes, 30-40 minutes, 40-50 minutes, and 50-60 minutes after the start of operation are plotted, respectively. The last part (50-60 minutes) showed a large fluctuation because the subject seemed to get off the seat. (This subject is an example of a young subject