講演番号	081

文献番号	20225081

Driver's Sleepiness Estimation Using Millimeter Wave Radar and Camera

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KEY WORDS: **Human engineering**, **Driver condition**, **Driving support,** Camera, Arousal estimation (C2)

Accidents caused by sleepiness are frequent and have become a serious issue in traffic accidents. In order to prevent that, this study purpose to develop a non-contact and multi-step technique to estimate sleepiness. From previous research and related works, the millimeter-wave radar can be employed to monitor heartbeats without contact and to classify sleepiness. However, the classification of that is limited to "sleepy" and "wakeful", which is shortcoming in practical applying where detailed estimation are required. In addition, since the measurement is performed by a single non-contact sensor, the accuracy requirements are not satisfied. Therefore, it is significant and necessary to improve the type of sensor utilized and the method of analysis. In this paper, we proposed a method to measure biometric data by combining a camera on millimeter-wave radar to improve the recognition accuracy, while maintaining non-contact approach. We calculated 14 indices in the heartbeat system using the same method as previous, 2 indices in the camera system and total of 16 indices setup for estimation. For the analysis part, we changed to the multiple regression analysis method, while using the variable reduction method in order to perform detailed estimation (5-level estimation). Also, we used a 5-level rating by facial expression evaluation as a model value, which is considered to get highly reliable. The experimental data collection scenario was set up on a course that make people sleepy, and experiment through driving simulator. Then, data from that course of 15 people who with sufficient sleepiness were selected for estimation work. To divide the obtained data for training and testing, two commonly used estimation ratios as 6:4 and 8:2, then the well accuracy was obtained with the 8:2 split ratio as a result. The average of correctness rate was 70%, the degree-of-freedom-adjusted coefficient of determination was in the low 0.7, and the RMSE (Root Mean Square Error) ranged from 0.5 to 0.6. Although not highly accurate, the results indicate that estimation is possible with a certain degree of accuracy. However, some of the data did not have good evaluation indicators. Since the camera system indicators cannot be used because the head hangs down after dozing off. Also, sleepiness is difficult to be expressed in facial expressions and greatly affects the camera system indicators, and the indicators values cannot follow the detailed changes in sleepiness. The method for improving is to capture features of sleepiness other than the eyes, such as the detection of a drooping head.

Moreover, the author verified the commonality of indicators and coefficients. The multiple regression analysis method was performed again using the top seven indicators in order of influence and adoption, and the overall accuracy was slightly lower. However, since the variability became smaller, it is possible to estimate with stable accuracy and consider to sufficiently practical. This greatly reduced the computational cost and easily achievable in realizing real-time estimation. On the other hand, attempts to standardize the coefficients resulted in a significant decrease in accuracy, and the analysis was far from practical. A possible countermeasure to this problem is to change the standardization method, that would possible to keep updating the numerical values needed for the analysis while covering individual differences.

Furthermore, since this experiment was conducted in a limited environment with only subjects in age of 20s, it is necessary to verify whether the experiment can be applied to the other age groups and environments. Therefore, the challenge is to construct a system that can be instantly estimated by anyone with stable accuracy.

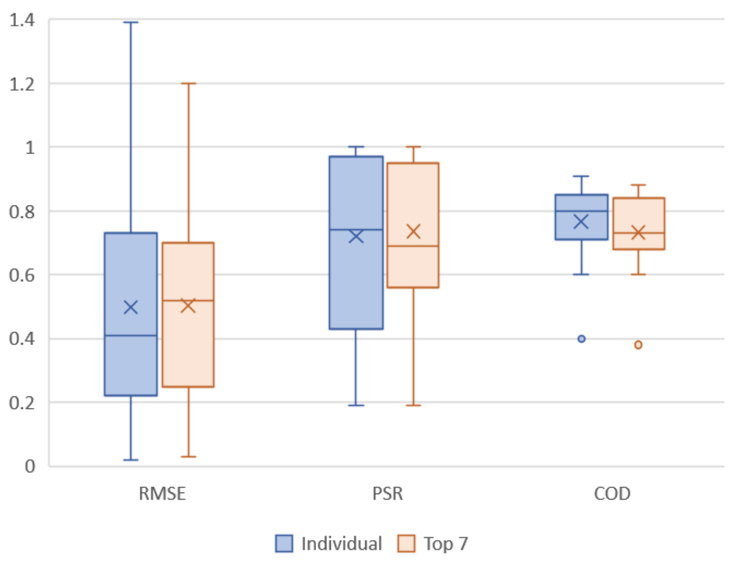

Fig. 1 Results of sleepiness estimation