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主 論 文 の 要 旨

論文題目　**Model-based approach for the estimation of drivers' mental workload with involuntary reflex eye movement**
(モデルベースアプローチによる不随意性眼球運動を用いたドライバの心理負荷推定手法に関する研究)

氏　　名　**LE ANH SON**

論 文 内 容 の 要 旨

Traffic accidents, a key point in transportation, taking around 1.2 million lives every year, reducing 3% of gross domestic product, become a big problem in over the world, especially in developing country where the people try to become more advanced economically and socially (World Health Organization). According to United State National Highway Traffic Safety Administration (2010), human error accounts for 94% of traffic accidents, it means that the drivers can prevent the crash by avoiding dangerous behavior especially driver distraction that include visual, manual and cognitive demands.

On the other hand, in the aspect of technology, with the development in bioengineering, the advanced driver assistance system (ADAS) has been proposed to help the driver in the driving process for safety and better driving. By using input from multiple data sources include imaging, LiDAR, radar, and so on, the ADAS system can automate lighting, provide adaptive cruise control, incorporate GPS/ traffic warnings, connect to smartphones, automate braking, alert driver, show the blind spots, and so on. The technology makes it possible to create a new ADAS system which can reduce the number of accidents by alerting or turning on automating braking system when it can capture the driver distraction.

There are several previously studies relating to evaluate driver distraction, especially in the real time, which is the first step for creating ADAS system. In sum, the methodology for indicating driver distraction can be categorized into three groups: subjective measures, performance-based measures, and physiological measures. However, in the driving condition with visual stimulus and vibration from the vehicle, the most potential method is used physiological measure especially eye movement. Moreover, because of the low accuracy, up until now, the method using eye movement to indicate the driver distraction in the real situation has not been established.

A central goal of this thesis is to improve the methodology to detect driver distraction by using eye movement. To do that, there are several ways that proposed in the previous such as pupil diameter, saccades, or other. By considering the driving conditions, in this study, we applied the most possible method to update to detect drivers' mental workload that use the difference between simulated eye movement by vestibulo-ocular reflex model plus optokinetic model and measurement one.

This research begins by briefly summarizing the analysis of driver accident and the main cause of traffic crash in Chapter 1. In addition, new technology in transportation is discussed, especially the advance driver assistance systems. Based on that, the importance of capturing driver cognitive distraction is pointed out. This chapter also presents the problem statement, objective, and the research outline for clearer understanding of our proposal. And then, in Chapter 2, the eye autonomy and the application of eye movement in transportation are briefly described.

In order for better understanding about mental workload, in Chapter 3 gives a deep review of vestibulo-ocular reflex (VOR) model, optokinetic response (OKR) model, final common path, as well as detection of driver distraction. Taken Chapter 1, Chapter 2, and Chapter 3 together, the previous research suggests that the drivers' mental workload can be evaluated by monitoring eye and head movement. By considering the advantage and disadvantage of each method in case of driving, the eye simulation model proposed by Merfeld and Zupan is selected to increase the accuracy for simulating eye movement in natural situations.

In Chapter 4, with the main aims to introduce a novel methodology of developing the parameter identification for vestibulo-ocular reflex model, the review of genetic algorithm (GA) method and how to optimize the results of it are discussed. One interesting finding by using secondary data, the results of GA method show better performance than previous one. In addition, the results from 12 participants clearly support the hypothesis by improving the parameter identification method, the eye can possible to simulate even with changing gaze.

To simulate the eye movement in the realistic traffic environment, the combination of the VOR and OKR is presented in Chapter 5. Within this chapter, the effect of visual stimulus on eye movement during driving is investigated by examining two cases: driving with/without visual stimulus by means of a driving simulator. By comparing the observed eye movement and the simulation, the results indicate that after consisting of both VOR and OKR model, the eye movement is more accurate than VOR model only even in a naturalistic situation with optic flow of the visual scene.

Taken the new parameter identification method and consisting of both VOR and OKR models together, In Chapter 6, the relationship between eye movement and driver distraction with a driver simulator is explored. Within this chapter, three types of experiment are made: 1) evaluate driver distraction with changing gaze, 2) evaluate driver distraction with a stimulating environment, and 3) explore the different of eye performance under mental workload between young and old group. The results of analysis confirm the relationship between eye movement and driver distractions. Furthermore, the effect of mental workload and aging on driver distraction is analyzed. The results indicate that the older group shows worse performance compared with a younger group, especially under the distracted driving condition.

Chapter 7 presents a validation of the hypothesis in actual situations. The experiment in the real vehicle is conducted in two cases: 1) evaluation driver distraction for the participant in the passenger seat and 2) evaluate driver distraction for the driver who control the actual vehicle. This results clearly support the hypothesis that our method can be applicable for evaluating driver cognitive distraction not only in a driving simulator but also in actual vehicles.

Finally, Chapter 8 summarizes research conclusions and provides some recommendations for future work. This work successfully to increase the accuracy of eye movement simulation by using vestibule-ocular reflex model. Furthermore, by consisting vestibule-ocular reflex model with optokinetic response model, the eye movement can be simulated with good matching even in natural situations. This study also contributes to confirm the hypothesis that the driver distraction can be evaluated by using the gap between eye movement simulation and measurement, made it possible to create a program that can detect the cognitive distraction while driving as an input for driver assistance system.