Graduate School of Creative Science and Engineering
Waseda University

博　士　論　文　概　要
Doctoral Dissertation Synopsis

論　文　題　目
Dissertation Title

Gaze Zone and Drowsiness Identification in Unconstrained Scenarios for Advanced Driver Assistance Systems

先進的運転支援システムのための運転シーンを限定しない視線及び眠気の識別に関する研究

申　請　者
(Applicant Name)
Catherine Elena LOLLETT PARAPONIARIS
ロレット　パラポニアリス　カテリン エレナ

Department of Modern Mechanical Engineering, Research on Human-Robot Interface

December, 2022

概要の説明書

Exists converging evidence that driver's inattention and drowsiness are major contributing factors in fatal and injury crashes. If vehicles are equipped with Advanced Driving Assistance Systems (ADAS) that can detect driver's distraction and drowsiness ahead of time, the system will be able to not only warn, but also take control of the situation in our near-future autonomous vehicles, preventing large-scale traffic accidents and contributing to traffic safety.

Tracking driver's head and eyes can provide a reasonable assessment of a driver's state. Several previous studies have implemented this kind of classifiers. However, they carry out their experiments in ideal conditions. Making this classification under unrestricted conditions is extremely difficult, leading current studies to a very poor performance. My research focuses on developing a high-performance driver gaze and drowsiness classifier under unconstrained conditions. Having a high-performance system in unrestricted conditions implies being able to identify distractions with less mistakes and thereby reducing automobile accidents significantly. Some of these challenging situations are mask-wearing faces, face occlusions, eyeglasses reflection, strong daylight variations, profile face poses, face and eyes facing different directions, etc. Also, many of them use expensive sensors, equipment sensitive to light, or complex systems. Furthermore, no former research explicitly does experiments with highly unconstrained datasets.

For implementing a robust gaze and drowsiness classifiers was developed two modules: module one, recognizes driver's gaze direction and module two recognizes the driver's drowsiness. This study involves six key steps to achieve a robust and portable system:

1.Frames' Lab's color space manipulation: To address the strong light variation issue, equalize the brightness of my frames by manipulating its Lab's color space's luminance channel using a Contrast Constrained Adaptive Histogram Equalization is one of the keys of this study.

2. Robust recognition of face, eyes, and body-joints landmarks: Combining an anchor-based real-time face detector with a normalized dense alignment for landmark identification that incorporates 3D eyelid and facial expression

movement tracking for face and eye landmarks detection makes the data less noisy. In addition, was used an online optimization framework for the shoulder joints recognition that builds the association of cross-frame poses and form pose flows robust to unconstrained situations body pose. This gives robustness to strong light condition variations and various facial occlusions as could be masks, scarves, eyeglasses reflections, eyeglasses stick, small eyes, partial occluded pupils, and profile face poses. Furthermore, because the feature vectors are based on these normalized landmarks, the amount of training data required is greatly reduced because the pattern is very clear.

3. DNN models structure and introduction of novel feature vectors parameters: For module 1, the framework involves two main models, Face Frontal and Face Profile DNN model. Since the geometric facial structure varies per person, the feature vector parameters consist of different relations between pupil and eyes landmarks in proportion to the driver's geometrical face configuration. Each model's classifies different standard known common areas to be checked by drivers. It considers as well when the driver's face and eyes are facing to different directions. This is a per-frame classification.

4. GRU model structure, introduction of lower-face contour and chest movement landmarks: For module 2, eyes, lower-face contour, and chest movement are considered. In contrast to other studies, I do not consider the mouth closure part of my feature vector since masks cover it. Adding the lower-face contour and chest movement as possible parameters to my feature vector is one of the strongest contributions to solve the mask-wearing situation issue for the drowsiness classifier. This classification is video based. For the eyes, the closure is measured for each frame. For the face contour and chest movement, each current landmark position is subtracted from their first frame (original) position. Finally, the driver's drowsiness is derived by fusing spatio-temporal features based on the before-mentioned subtractions used as the feature vector of my Gated Recurrent Units (GRU) based model.

5. Portability and extensivity, as it needs only one camera and a computer.

6. Generalization, as it can classify correctly regardless of the subject.

Moreover, the performance of the proposed system was compared to the overall general approach and show the importance of each stage of the proposed pipeline. Results over a dataset involving highly unconstrained driving conditions demonstrate that this work outperforms classifying the driver's gaze zone and drowsiness correctly in various challenging situations.

List of research achievements for application of Doctor of Engineering, Waseda University

Full Name： Lollett Paraponiaris　Catherine Elena　　seal or signature

Date Submitted(yyyy/mm/dd): 2022/12/08

種類別 (By Type)	題名、　発表・発行掲載誌名、　　発表・発行年月、　　連名者（申請者含む） (theme, journal name, date & year of publication, name of authors inc. yourself)
査読論文 ○	[1] Catherine Lollett, Mitsuhiro Kamezaki, and Shigeki Sugano. "Single Camera Face Position-Invariant Driver's Gaze Zone Classifier based on Frame-Sequence Recognition using 3D Convolutional Neural Networks," Sensors, vol. 22, no. 15, 2022.
講演 （査読有り） ○	[2] Catherine Lollett, Mitsuhiro Kamezaki, and Shigeki Sugano. "Driver's Drowsiness Classifier using a Single-Camera Robust to Mask-wearing Situations using an Eyelid, Lower-Face Contour, and Chest Movement Feature Vector GRU-based Model," In Proceedings of the 2022 IEEE Intelligent Vehicles Symposium (IV), Aachen, Germany, 4–9 June 2022.
○	[3] Catherine Lollett, Mitsuhiro Kamezaki, and Shigeki Sugano. "Towards a Driver's Gaze Zone Classifier using a Single Camera Robust to Temporal and Permanent Face Occlusions," In Proceedings of the 2021 IEEE Intelligent Vehicles Symposium (IV), Nagoya, Japan, 11–17 July 2021.
○	[4] Catherine Lollett, Hiroaki Hayashi, Mitsuhiro Kamezaki, and Shigeki Sugano. "A Robust Driver's Gaze Zone Classification using a Single Camera for Self-occlusions and Non-aligned Head and Eyes Direction Driving Situations," In Proceedings of the 2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Toronto, ON, Canada, 11–14 October 2020; pp. 4302–4308.
	[5] Hiroaki Hayashi, Mitsuhiro Kamezaki, Udara E. Manawadu, Takahiro Kawano, Takaaki Ema, Tomoya Tomita, Lollett Catherine, and Shigeki Sugano, "A Driver Situational Awareness Estimation System Based on Standard Glance Model for Unscheduled Takeover Situations," In Proceedings of the IEEE Intelligent Vehicles Symposium, Paris, France, 9–12 June 2019; pp. 718–723.
講演 （査読なし	[6] Catherine Lollett, Mitsuhiro Kamezaki, and Shigeki Sugano. "DNN-based Driver's Eyelid Closure Classifier using a Single Camera Robust to Challenging Driving Scenarios," 第39回日本ロボット学会学術講演会（RSJ), 2021.
	[7] Lollett Catherine, Hayashi Hiroaki, Kamezaki Mitsuhiro, Sugano Shigeki. "2D CNN Driver's Gaze Direction Classification in Non-Aligned Head and Eyes Direction Situations," 第37回日本ロボット学会学術講演会（RSJ), 2019.