Driver Pose Estimation from Steering-wheel Occluded Image by Using Image Inpainting

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It is reported that fatal bus accidents have remained at the same level for 10 years, so further efforts are required to reduce the accidents. Because inappropriate driving posture is a factor of human error, many researchers try to estimate drivers' driving postures and provide assistants. Most of the studies target ordinary vehicles and use multiple cameras to capture the driver's face and body separately because of the narrow interior space. On the other hand, because the bus has a larger interior space, we try to capture both driver's face and body using only one camera to reduce monetary and computational costs. After much consideration, we found that the camera must be placed behind the steering wheel to avoid obstructing the driver's view and capture both driver's face and body. However, the steering wheel occludes part of the body, which reduces the accuracy of posture estimation. To improve posture estimation accuracy, we proposed a system to detect and remove the steering wheel from the driver's image using Image Inpainting. The system structure is shown in Fig. 1. The system first detects the region of the steering wheel using a semantic segmentation method, then removes the steering wheel from the image, and rebuilds the lost region using an Image Inpainting method.

From many kinds of semantic segmentation models, we selected DeepLabV3Plus because the results of Image Inpainting largely depend on the pixels around the inpainted area and DeepLabV3Plus has a high performance on object boundary recognition. Then, we compared two kinds of Deep Learning-based Image Inpainting methods, which are Globally and Locally Consistent Image Completion (GLCIC), and Pluralistic Image Completion (PIC). We obtained a large realistic bus driving data that had already been recorded from a bus company, and extracted 1000 images randomly from 5 buses and 14 drivers. Then we labeled the steering wheel area for semantic segmentation and labeled the bounding box and 7 key points (nose, left and right shoulders, left and right elbows, left and right wrists) of the driver for pose detection.

As for system evaluation, we introduced Openpose and Alphapose to detect drivers' postures on the original images and the images inpainted by each Image Inpainting method. Here, the labeled steering wheel area was used. By calculating the mean Average Precision (mAP) of the pose detection, we found that the pose estimation could be improved by removing the steering wheel from the image. Moreover, the PIC model had the best performance, which increased the mAP by 0.120 when using Alphapose for pose estimation. Then, we applied DeepLabV3Plus for automatic steering wheel recognition and used PIC for Image Inpainting. The results showed that the mAP was only decreased by 0.067 for Openpose and 0.001 points for AlphaPose. This result indicates that it is possible to automatically estimate the steering wheel area while maintaining the accuracy of the pose estimation. From the above experiments, we could confirm that the proposed system is useful to improve the pose estimation accuracy.

Furthermore, because the PIC model has a feature that it could provide multiple inpainting results by changing a variable z from a prior distribution, we tried to find if there is an optimal variable z for all the drivers or one driver. After experiments, we found that the pose estimation could be improved by tuning the variable *z* for each driver. In future works, we will try to develop a learning system that semi-automatically finds appropriate variable *z* to improve the accuracy of the Image Inpainting, and evaluate driving behaviors using the proposed system.

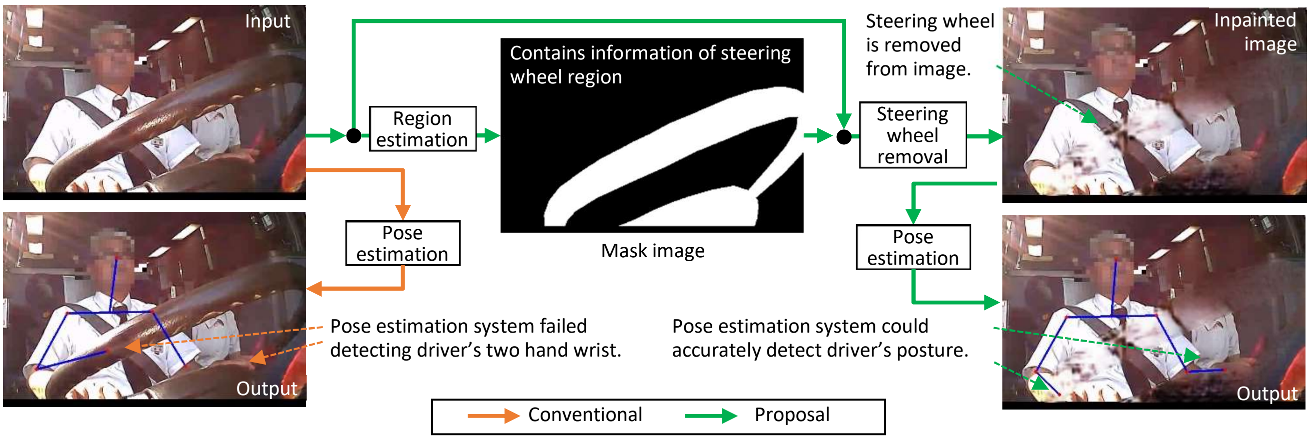

Fig. 1 Proposed pose estimation system using image inpainting