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A Method of Trajectory Generation Which Improves Predictability of Vehicle Behavior

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In the recent automotive industry, the area of technologies known as "CASE" are capturing general interest. Among these letters, "A" which stands for automated driving technology in particular is being discussed and implemented for beneficial use in a variety of situations. Ideally, the automated driving system should provide passengers the sense of security and trust for its operation from the viewpoint of passenger's acceptance to the function. This study proposes a control method to make passengers feel secure by examining the effects on passenger's feelings and physical state about different traveling trajectories by the autonomous driving operation.

According to previous studies regarding the sense of security of passengers, while the unpredictability of vehicle behavior makes passengers anxious, an automated driving system that operates according to passenger's driving senses contributes to a greater sense of security. In order to improve predictability of vehicle behavior, it is important to integrate laws of physics into vehicle behavior that take into account sensory and operational characteristics common to humans.On the other hand, the deviation of vehicle behavior from passenger's prediction can be considered as physical load and mental load to passenger. Therefore, in this study, we define a sense of security as "a state of low physical and mental load due to predictable behavior".

Regarding the risk of deviation during automated driving, it is presumed that people feel more anxious about the risk of deviating toward the outside in curves.Therefore, it can be hypothesized that the mental load of a passenger depends on the perceived distance to the edge of the road in front of the vehicle and vehicle's speed when driving through a curve. Based on this hypothesis, when passing through a curve, the maximum mental load caused in the entire curve can be minimized by passing through the inside of the curve as much as possible when the front side of the vehicle is the nearest to the road edge. In other words, this control method synchronizes the lateral position with the change in the forward distance between the road edge when passing a curve, which makes it easier for passengers to visually understand that the vehicle's lateral position is controlled and to predict its movement. Then, we evaluated and compared the above trajectory (condition 1) and "a driving trajectory following the center of the lane (condition 2)" to verify to what extent this method improves predictability of vehicle's behavior.

In order to evaluate the predictability, we evaluated a passenger's body movement and gaze distribution through eye tracking, and conducted subjective evaluation. The results of the body movement measurements confirmed that upper body movements were inhibited and muscle strength was suppressed by the proposed trajectory. This shows that by predicting the behavior of the own vehicle, the passenger was eble to control the upper body movements and the muscular force by preparing the body in anticipation of forces.

Next, from the results of the gaze point measurement, we observed that the passenger was gazing at more distant positions on the road along the proposed trajectory (condition 1, Fig.1). This implies that because of the ease of predicting own vehicle behavior, the passenger had enough time to acquire information in the future (farther away). This is because the passenger already obtained and predicted information about the current environment in front of the vehicle.

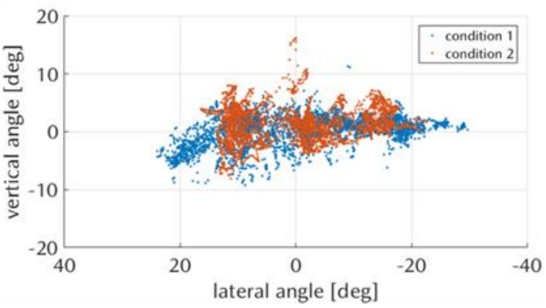

Fig.1 Gaze Distribution of the Passenger

Finally, the result of the subjective evaluation indicates that there is a significant difference between condition 1 and 2 in any of these questions (Fig.2). These results suggest that the trajectory in condition 1, together with the results of the body and gaze measurements, improves the sense of security by contributing to reduce the physical and mental load due to the increased predictability.

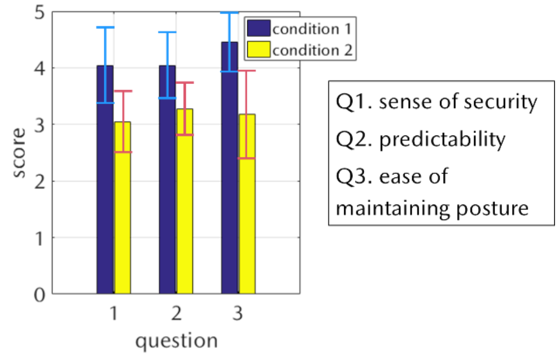

Fig.2 Score of Subjective Evaluation

In conclusion, the trajectory that increases the minimum forward distance and changes the lateral position on the road as the forward distance changes guides the gazing point farther away and stabilizes the body movents, thereby improving the predictability of the vehicle behavior.