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Evaluation of Interface Design for Recognition Phase Human-Automation Cooperation in Automated Driving

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Level 3 or Level 4 automated driving is tested to realize fully autonomous driving. Currently, the drivers are required to take over the vehicle control when the automated system cannot continue driving safely. There are many challenges in the control phase intervention, such as difficulty in control transition and high cognitive/mental demand.

Various factors require driver intervention in autonomous driving systems, ranging from hardware and software malfunctions to operational design domain (ODD). In these factors, the recognition phase is a fundamental element of an autonomous driving system, but there are technical challenges and the difficulty to perform perfect recognition due to the probability involved in the calculation. If recognition errors can be eliminated, the overall performance of automated driving is expected to be greatly improved.

Therefore, a recognition assistance interface has been proposed (Fig.1). The recognition assistance interface is an interface that shares recognition information of the autonomous driving system with humans and allows them to intervene in the recognition. It is expected that human intervention in the recognition phase (recognition intervention) can solve the challenges in recognition of automation and the conventional control intervention.

In previous studies, focusing on the recognition of pedestrians' crossing intention, the goal of the recognition intervention has been to prevent unnecessary evasive driving due to recognition errors. However, there are various recognition tasks in the real environment. In addition, pedestrians also require not only the intention to cross but also location detection and path prediction. It is difficult to deal with all of the recognition tasks with a single intervention goal or interface design.

Therefore, in this study, we categorized recognition tasks into two major categories and divided recognition intervention into two stages. The first stage includes simple errors in the automated system. In this stage, we expect that humans can intervene quickly and accurately using their intuition and common sense, and prevent unnecessary evasion due to recognition errors. The second stage includes technically difficult tasks for the automated system. Humans assist these tasks using situation awareness, experience, and interaction with surrounding road users. Extend the intervention time while performing evasive maneuvers because it is difficult to intervene within the limited time window.

To quantitatively evaluate the proposed framework, we conducted subject experiments showing driving scenes one after another. We selected three recognition tasks: traffic light recognition, pedestrian crossing intention, and pedestrian path prediction. Then we compare the intervention performance for these tasks in the driving scene.

The experimental results show that traffic light recognition, which is a relatively simple task, can be accurately intervened in a short time, and is feasible as the first stage recognition task. Given a sufficient amount of time, pedestrian path prediction could be intervened with the same accuracy as traffic light recognition. Therefore, it was shown to be suitable for the second intervention task. As for the pedestrian crossing intention, the intervention time was the same as that for the path prediction, and the accuracy was the lowest among the three tasks.

The two-stage design approach was qualitatively evaluated based on the cognitive process during the human intervention and the characteristics of automatic driving and quantitatively evaluated in the subject experiments. And the experiment results showed that some tasks are suitable as intervention tasks and others are not, and that when designing an intervention, it is better to select a recognition task that is similar to those used in everyday driving, rather than the simplicity of the cognitive process while intervention.

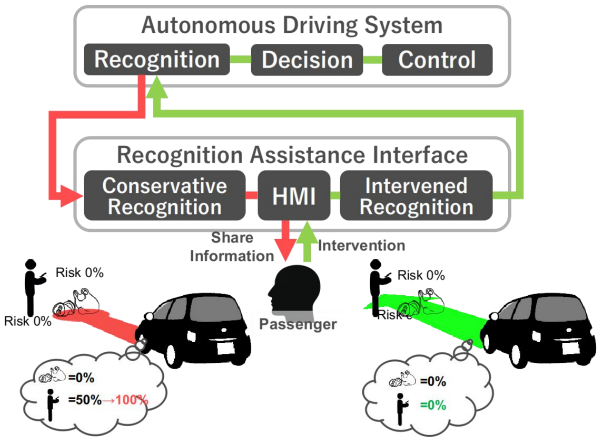

Fig.1 A Framework for Recognition Intervention. The autonomous driving system conservatively recognizes risks in the surrounding environment and shares the recognition information with humans. Human intervention in recognition information improves the naturalness of driving by preventing unnecessary evasive maneuvers caused by recognition errors.