別紙４－１（課程博士（英文））

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Abstract（Doctor）

Title of Thesis	Interaction Design of Sociable Driving Agents as an Effective In-Vehicle Interface

Approx. 800 words

With the advancement of the technology, the interaction design of the dashboard of the cars have been changed a lot in the last years. The amount of buttons have been becoming increasingly confusing and sensory overload. On the other hand, a great deal of research has been conducted on highly autonomous vehicles which make their own driving decisions that minimise human interventions with the vision of decreasing human errors and achieving a safer, more energy efficient and more comfortable mode of transportation. The autonomous cars hold much more functionalities compared to the cars on the road today. Therefore, the design of the dashboard for the expected self-driverless cars should be created in a way that intuitively understandable by the wide range of users considering their naivety on the technology and cultural background, etc. It has been claimed that the human brain has evolved to be highly adaptive in social interactions therefore, people tend to anthropomorphise the technology. From the drivers' perspective, we believe that it is crucial to interact with an in-vehicle interface system in such a social, natural and familiar manner to reduce mental workload and create a more sociable environment inside a car. Since human brain has been evolved to be an expert in social interactions, social robots are envisioned as having the ability to interact with humans (and others) socially in order to achieve their designated goals. With this respect, a social robot platform what would mediate the interactions between a car and a driver can be effective in terms of obtaining environmental information and understanding the vehicle's intentions while interacting with the driver socially. In this thesis, we address several problems regarding to the interaction between such a social interface and a driver.

Firstly, we propose a social interface named NAMIDA that incorporates three conversational robots that can decrease the number of directed utterances towards a driver through a turn-taking process among the robots. First, we evaluated this model by employing virtually embodied social agents. Through this model, we show that drivers can gain necessary location-based information without joining the conversation among the robots. The results of our pilot study revealed that the proposed multi-party conversation based interaction model is more effective in alleviating certain workload factors for drivers compared to a conventional one-to-one communication based approach that directly addresses the driver. Then, we built and used our robotic driving agents to conduct an

experiment to investigate the lifelikeness and distractedness of the interaction of the multi-party conversation of three robotic agents and the one-to-one conversation between one robot with a driver. In this study, we show that overhearing information from the physically embodied multi-party conversation based driving agent system is perceived as possessing more lifelike characteristics compared to a conventional, one-to-one communication based driving agent that directly addresses the driver. Also, the proposed approach reduced the distraction level and increased the enjoyment of the drivers. Through these two studies, we demonstrated that an interaction design with the multi-party conversation of the driving agents can be more efficient and enjoyable when the driver's attention is required on driving (manual driving).

Considering the current researches on the autonomy Level 3 of the autonomous vehicles (limitedly autonomous), depending on the circumstances along the road (i.e. bad road conditions), the driver should take-over the control from the autonomous mode as smooth and rapid as possible. Therefore, our next study investigated a paradigm for keeping the drivers' situation-awareness active during the autonomous driving by utilising our social robot system, NAMIDA. We analysed the effectiveness of NAMIDA on maintaining the drivers' attention to the road, by evaluating the response time of the drivers to a critical situation on the road. An experiment consisting of a take over scenario showed that existence of NAMIDA significantly reduced the response time of the drivers with eye gaze behaviours of the robots. In addition, we inferred that the robots facilitated the drivers to put them in social confirmity where the drivers' attention was on the road more often when the robots were always watching the road. However, in this study, the effects of eye gazing behaviours of the robots on the perceptions of the drivers in terms of comprehending the intention of the robots and feeling the autonomous driving safer remained unknown.

In order to achieve a reliable interaction with the autonomous cars, intersubjectivity should be built between the autonomous car and the human operator where the human will believe that the car possess the same intentions with the human. One critical social cue for human to understand the intentions of others is eye gaze behaviours. In our next study, we demonstrated that when the robots followed the eye gaze behaviours of the driver, the perception of the intersubjectivity and the autonomous car as a social entity were increased. The results of this study also revealed that the autonomous system was perceived safer and more enjoyable compared to the condition with not using the robots and the condition with using random gazing behaviours of the robots, respectively.