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主 論 文 の 要 旨

論文題目　**Variable Selection for Personalized Driving Behavior Modeling and Application to Autonomous Driving (個人の運転行動に基づくモデリングのための決定変数選択と自律走行への応用)**

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論 文 内 容 の 要 旨

Autonomous driving technology design the design of personalized advanced driving assistance systems (ADAS) has received significant attention in recent years from the automotive industry. This attention spurred by the potential contributions of autonomous driving such as zero road accident, efficient road transport and positive social impact (i.e., reduced emission, energy consumption, and carbon footprint), has led to significant innovation and advancement of automated driving technology. In addition, advances in sensor technology, fusion of sensors such as LiDAR, radar, camera, ultrasonic, GPS and IMU have opened doors and minds towards the possibility of full (level 5) automated driving. According to the US Society of Automotive Engineers, there are six levels of automation in autonomous driving starting from level 0 to level 5. Currently, it is believed that the automotive industry is at level 4 (i.e., highway autopilot, urban and sub-urban pilot) of automation.

On the other hand, there are still some bottlenecks preventing the implementation and introduction of automated driving into our environment. These bottlenecks include human factors in form of acceptance, cooperation and unpredictable nature of the human, limitations of sensing technology and the high cost of automated vehicles preventing mass production. For the seamless introduction of autonomous vehicles in our roads, these bottlenecks must be tackled.

This research work focuses on the issue of the human factors preventing the realization of autonomous driving. It is expected that the natural evolution of autonomous driving will come in two parts. The first being mixed traffic, this means that automated vehicles and human driven vehicles are expected to participate together in the road traffic. It is unrealistic and extremely costly to develop new roads and infrastructure exclusively for autonomous vehicles. To be able to achieve mixed traffic of human-driven vehicles and automated vehicles (AV), AV and ADAS must be able to predict the cognitive aspect of the human driver. This is one of the sources of motivation for this research. The second part of this evolution is the transfer of personalized driver preferences into AV. This is based on the idea that humans are different even from a psychological point of view, and at such individual preferences will be demanded of from AV and ADAS. In order to be able to personalize the experience of autonomous driving, ways to detect and reflect driver's personalized characteristics need to be developed. This is also another motivation of this study.

From what we have seen so far, understanding the human driving behavior is essential for the realization of autonomous driving. This means that driver models that are capable of expressing or capturing the human driving behavior dynamics must be developed based on human driving data.

Many researches have been conducted to find suitable methods to express the human driving behavior quantitatively and qualitatively. One such method is the hybrid dynamical system (HDS) model which is capable of capturing the decision-making and the motion-control facets of the driving simultaneously, therefore leading to higher understanding of the human driving behavior.

However, the HDS model fails to address the issues, "how many behaviors? (i.e., how to decide the optimal number of modes)" and "how do these behaviors change? (i.e., how to explain the transition between modes)". In order to address these issues this research proposed new methods based on variable selection, thereby leading to a better and higher-level understanding of the cognitive aspect of the human driver.

This thesis is organized in six main chapters. In Chapter 1, the motivation and background of this study, literature review, aspects of the human driving behavior and the goal of this work are presented. The second chapter gives the background, starting from the basic methods to the novel methods that were used in this study to analyze and understand the human driving behavior. In chapter 3, real-road driving behavior, specifically, the car-following driving task is analyzed and modeled based on a novel method (consistent variable selection) proposed by the author. Chapter 4 moves from a simple driving task such as the car-following driving task to a more complex driving task like the overtaking driving behavior. In his chapter, the driver's decision in the overtaking driving behavior is modelled based on variable selection and logistic regression model while including the driver's gaze information as the driver's intention. In Chapter 5, the possible applications of the models developed by the proposed methods are discussed. Finally, chapter 6 concludes this research work.

This research at first, proposes the hybrid system model identified by a PWARX (piecewise affine autoregressive exogenous) model for modeling human driving behavior. In the proposed model, the mode segmentation is carried out automatically and the optimal number of modes is decided by a novel methodology based on consistent variable selection. In addition, model flexibility is added within the ARX (autoregressive exogenous) partitions in the form of statistical variable selection. The proposed method is able to capture both the decision-making and motion-control facets of the driving behavior. The resulting model is an optimal basal model which is not affected by the choice of data, where the explanatory variables are allowed to vary within each ARX region, thus, allowing a higher-level understanding of the motion-control aspect of the driving behavior, as well as explaining the driver's decision-making.

Secondly, the decision-making characteristics of the driver in the overtaking on the highway road was investigated. A novel method was proposed by introducing a logistic regression model accompanied by the statistical test technique, which does not require prior knowledge about the explanatory variables. Hypothesizing that the driver’s gazing behavior is crucial for the decision-making process in driving and hence, the line-of-sight information was introduced to estimate driver’s gazing behavior in the model of driver’s decision specifically for reproducing the overtaking driving behavior accurately.

In conclusion, through this research activity, the dynamics of the human driving behavior could be understood at a higher level by improving the HDS in terms of deciding how many behaviors and finding out how those behaviors change.