博士学位論文審査要旨

２０２０年7月１３日

論 文 題 目： Developing an Autosteering of Road Motor Vehicles in Slippery Road Conditions
（滑りやすい路面条件における自動車の自動操縦に関する研究）

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要　　旨：

The objective of this research is to propose an approach of minimizing the need of yielding the control to the human driver (and consequently, minimizing the probability of startle effect) of a car in challenging environmental conditions by guaranteeing an adequate automated control in these conditions. Focusing on slippery roads as an instance of challenging conditions, and steering control as an instance of control, we aim at developing such an automated steering that controls the car adequately in various road surfaces featuring low friction coefficients without the need of driver's intervention. In order to develop such an automated steering we employed an in-house evolutionary computation framework – XML-based genetic programming (XGP). The obtained experimental results indicate that the controller, featuring a relaxed, arbitrary structure evolved by XGP outperforms both the canonical servo- (PD) and PID controllers in that it results in a minimal deviation of the car from its intended trajectory in rainy, snowy, and icy road conditions. The research could be viewed as a step towards the evolutionary development of automated steering of cars in challenging environments.

This thesis researches the developing – via genetic programming – of autosteering of road motor vehicles in slippery road conditions.

よって、本論文は、博士（工学）（同志社大学）の学位を授与するにふさわしいものであると認められる。

総合試験結果の要旨

２０２０年7月１３日

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The research has been presented in two full papers in Algorithms journal in 2018, Vol.11(7), and 2020, Vol 13(2), and in two peer-refereed conferences – SICE in 2018 and IEEE International Conference on Advanced Intelligent Mechatronics in 2019. The dissertation has been orally defended on July 11, 2020, from 10:00 to 11:45.

The following meeting of the committee of investigators and judges of the dissertation has concluded that the defender has demonstrated sufficient academic abilities. The dissertation has been written and presented orally in English.

よって、総合試験の結果は合格であると認める。

博 士 学 位 論 文 要 旨

論 文 題 目： Developing an Autosteering of Road Motor Vehicles in Slippery Road Conditions
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氏　　名： ALEKSEEVA NATALIA MIHAJLOVNA

要　　旨：

In the nearest future, the human driver is viewed as a reliable backup even for the fully automated road motor vehicles (cars). Indeed, the driver is assumed to swiftly take the control of the car in cases of suddenly occurring (i) challenging environmental conditions, (ii) complex unforeseen driving situations, or (iii) degradation of performance of the car. However, due to the cognitive overload in such a sudden, stressful takeover of the control, the driver would often experience the startle effect, which usually results in an unconscious, instinctive, yet incorrect response. An extreme case of startle is freezing, in which the driver might be incapable to respond to the sudden takeover of control at all.

The possible approaches to alleviate the startle during the takeover of control (i.e., the automation startle) include an offset- (i.e., either early- or delayed-), gradual yielding the controls to the driver. In the cases considered above, however, these approaches are hardly applicable because of (i) the presumed unpredictability of the events that result in the need of takeover of control, and (ii) the severe time constraints of the latter.

Conversely, the *objective* of our research is to propose an approach of minimizing the need of yielding the control to the driver in challenging environmental conditions by guaranteeing an adequate automated control in these conditions. Focusing on slippery roads as an instance of challenging conditions, and steering control as an instance of control, we aim at developing such an automated steering that controls the car adequately in various road surfaces featuring low friction coefficients without the need of driver's intervention.

In order to develop such an automated steering we employed an in-house evolutionary computation framework – XML-based genetic programming (XGP) – which offers a flexible, portable, and human readable representation of the evolved optimal steering functions. The trial runs of the evolved steering functions were performed in the Open Source Racing Car Simulator (TORCS), which features a realistic, yet computationally efficient simulation of the car and its environment.

The obtained experimental results indicate that due to the challenging dynamics of the unstable car on slippery roads, neither the canonical (tuned) servo-control (as a variant of PD) nor the (tuned) PID-controller could control the car adequately on slippery roads. On the other hand, the controller, featuring a relaxed, arbitrary structure evolved by XGP outperforms both the servo- and PID controllers in that it results in a minimal deviation of the car from its intended trajectory in rainy, snowy, and icy road conditions. Moreover, the evolved steering that employs anticipated perceptions is even superior as it could anticipate the imminent understeering of the car at the entry of the turns and consequently – to compensate for such an understeering by proactively turning the steering wheels in advance – well before entering the turn. The obtained results suggest a human competitiveness of the evolved automated

steering as it outperforms the commonly used alternative steering controllers proposed by human experts.

The research could be viewed as a step towards the evolutionary development of automated steering of cars in challenging environmental conditions.