SCIENCE CHINA
Information Sciences

• PERSPECTIVE •
Special Focus on Human-Robot Hybrid Intelligence

May 2019, Vol. 62 050201:1–050201:3
https://doi.org/10.1007/s11432-018-9766-3

Challenges and countermeasures of interaction in autonomous vehicles

Deyi LI[1,2], Meng LIU[1], Fei ZHAO[3] & Yu LIU[1*]

[1]*State Key Laboratory of Software Development Environment, School of Computer Science and Engineering, Beihang University, Beijing* 100191*, China;*
[2]*Chinese Academy of Engineering, Beijing* 100036*, China;*
[3]*School of Transportation Science and Engineering, Beihang University, Beijing* 100191*, China*

Received 27 August 2018/Revised 20 November 2018/Accepted 11 January 2019/Published online 22 February 2019

Citation Li D Y, Liu M, Zhao F, et al. Challenges and countermeasures of interaction in autonomous vehicles. Sci China Inf Sci, 2019, 62(5): 050201, https://doi.org/10.1007/s11432-018-9766-3

Autonomous vehicles can bring changes into ways of traveling, traffic, and even production modes [1]. At present, the majority of researches [2] on autonomous vehicles are limited in perception, planning, decision-making and other calculation front, while interactive cognitive perspective is barely looked into. The interactive sector involved in self-driving is rather sophisticated [3]. However, to the best of our knowledge, there is no relevant literature that offers any insight from the angle of interaction. Interactive technology is an essential core in autonomous driving system, which involves not only human-computer interaction (HCI). This study firstly introduced various interaction modes and measures, and further analyzed the complexity and significance of interaction. As a conclusion, an interactive cognition-based solution and an interactive bus-based communication method were put forward, making an attempt to provide a certain perspective for the research and resolution of interactive obstacles in self-driving.

Modes and methods of interaction. From the perspective of physical space, the interactions in autonomous driving are classified into inner-vehicle interaction, vehicle-body interaction, inter-vehicle interaction, remote interaction, and debugging interaction, wherein the last one is noticeably special, containing the actual realization of all autonomous driving functions stretching from the vehicle to the remote. Interactions are generally designed to satisfy both driving tasks and entertaining needs. The complicated nature of the interaction in self-driving results in a variety of interactive modes.

• Inner-vehicle interaction. Inner-vehicle interaction is a people-centered process designed to formulate driving tasks, grasp driving condition, conduct navigation and identification, provide passengers with basic entertainment service and necessary information, secure human safety, and interact with possible vehicle driving system for driving control. Inner-vehicle interaction subjects are consisted of driver, passengers, smart devices, service tools, and safety equipment. Inner-vehicle interaction involves audio, vision, and action.

• Vehicle-body interaction. Vehicle-body interaction is to achieve the communication among car's upper-and-underlying control units, mechanical equipment and electronic equipment, transmit commands, and provide feedback of car's working state. Vehicle-body interaction subjects are consisted of underlying layer, calculation units (the driving brain) and so forth. Communication modes cover controller area network (CAN) and Ethernet.

• Inter-vehicle interaction. Inter-vehicle interaction is a sophisticated process responsible for the interaction between self-driving car and external smart devices, perception of external environment, exchanges with certain supply-type infras-

* Corresponding author (email: buaa_liuyu@buaa.edu.cn)

tructures, HCI (sound & light warning, collision proof and visual warning), as well as the interaction with service facility, surrounding vehicles, police and pedestrians. Via communication channels such as Internet, the IoT, and the IoV, vehicles can convey their driving routes and other information to nearby vehicles, pedestrians and intelligent service equipment. Perception sensors include position sensors, radar sensors, and vision sensors. Inter-vehicle prompt modes include display, car lights, whistle and other methods.

• Remote interaction. Tasks of remote interaction include vehicle order, operation, scheduling, customer service, monitoring of vehicle performance, and interventions dealing with possible emergencies. Remote interaction subjects are made up of command & dispatch system, customer service, operators (monitoring vehicle operation, overseeing vehicle's underlying data, and handling potential intervention scenarios), passengers. Remote interaction puts high demands on communication methods of Internet and so forth.

• Debugging interaction. Before the system is put into operation, specialists are required to deploy or update the modules for self-driving functions. Technicians must be sure to carry out troubleshooting and maintenance after a system failure occurs. And tester shall examine the vehicle's underlying equipment, communication function, and driving brain. Furthermore, emulators are commonly used to assist with debugging (improve driving capabilities by taking advantage of virtual environments).

Complexity of interaction.

• The complexity of interactive tasks. In driverless system, reliable interaction is essential to ensure safe autonomous driving, accurate environmental perception, and comfortable passenger experience. By taking advantage of interactive technology, autonomous driving vehicle is able to complete a series of challenging driving tasks such as automatic cruising, overtaking, merging, and unmanned parking [4]. To achieve viable and solid automotive interaction technology and high-quality user experience, expertise in a wide range of sectors such as automotive electronics, communication, software engineering, artificial intelligence, ergonomics, and psychology must be integrated together.

• Absence of cognition for interaction. A high-performance inner-vehicle microelectronics platform is where the tasks of self-driving system to be performed. Contributed by deep learning technology, a range of high-performance computing hardware has emerged. However, these platforms are experiencing the lack of research on interactive cognitive technologies, interactive tools & methods, and hardware interfaces necessary for interactive cognition.

Significance of interactive cognition. Self-driving car is positioned as an interactive wheeled robot capable of autonomously nailing various driving tasks and coping with uncertainties that may be encountered in driving [4]. Except for staying consistent with vehicle dynamics, it is necessary for self-driving cars to be equipped with human-like anticipation, control and other cognitions. Through online interactive learning and accumulating driving skills, self-driving cars will develop intensive and efficient emergency respond ability. From the perspective of interaction, we suggest that there are several man-machine relationships: human teach wheeled robots how to drive; unmanned driving under people's monitor; unmanned driving with self-study capability; robots teach human to drive.

To this end, we have solid reasons to conclude that interaction of unmanned driving is extremely complicated in terms of interaction subjects, modes, tasks and cognitions, to name but a few. The major threshold of viable unmanned driving not only lies in the car itself, but it is the humanoid that matters the most. Solid interactive and cognitive ability is the key for self-driving cars to be put into use and accepted by the public.

Interactive cognitive solutions.

• Interactive cognition. This study carried out a case study of external interaction scheme, thereby introducing interactive cognitive [5] solutions. By drawing insight of the interactive cognition of human drivers during driving, and taking into account the driving-related interactive and cognitive tasks, driving brain is developed, which is then used to integrate calculative cognition (allowing machine to actively perceive, reason, and learn from the world), memory cognition (transient memory, working memory, and long-term memory), and interactive cognition. Driving brain includes specifically-designed hardware and software, wherein hardware referred in this study is a multi-networked computer with distributed architecture, which is composed of multiple processor chips and switch chips. And the software is to design the driving brain's software architecture, formalize interactive cognition, conduct self-learning, and anticipate driving behavior.

(1) Formalization of interactive cognition. Self-driving vehicle comes with target optimization and formalization of driving cognition in line with multiple constraints. To express environmental information in a uniformed manner, this study proposed a method where information acquired via

various sensors (cameras, radars) is mapped to the driving dynamic display. With log-polar coordinate system as a carrier, environmental information is integrated into the driving dynamic display. Driver's behavior abstracted as cognitive arrows is matched to driving dynamic display, thus a bank of "driving dynamic – cognitive arrows" paired displays can come into being.

(2) Self-learning. Self-learning module is designed by applying deep learning and evolutionary learning, which enables autonomous vehicles to pick up driving skills from human drivers. Abstract arrows are designed to indicate experienced driver's control of throttle, brake and steering wheel, and then matched with the driving dynamic display gained by perception, generating fragmented and paired displays of "driving dynamic – cognitive arrows", thereby drawing out driving memory. Images, point clouds and other raw data are considered as instant memories. Driving dynamic display is seen as working memory, and the abstraction and summary of driving dynamic displays serve as long-term memory. Driving brain is able to make suitable decisions by comparing current cognitive scene and stored memories. Self-learning indicates the computational cognition, memory cognition and interactive cognition equipped by driving brain.

(3) Anticipation. During unmanned driving process, driving brain will carry out real-time search to go through its memories, so as to directly find or reason out the cognitive arrows conforming to the driving condition by then, and to output corresponding commands.

• Interactive bus design. Effective data communication is necessary for decent interactive cognition. Traditionally, interaction modules fall into the category of decision module. However, the effect of interactive performance on the real-time data transmission may jeopardize driving safety [6]. To this end, the interactive cognitive system is designed to be independent from the decision bus to guarantee the real-time performance of both self-driving car's interaction and data transmission.

Multi-bus structure is applied by the hardware architecture on microelectronic platform, which includes interactive bus, learning bus, and working bus, wherein each bus is separated by Ethernet. The cognitive data transmission, driving dynamic display, and module searching are all followed out via the working bus. Commissioning staff can debug driving brain online, while driving dynamic display and corresponding cognitive arrows are sent to memory modules and self-learning modules, which are linked to learning bus independently, thereby boosting the speed of self-learning process. The interactive bus and its connection modules are a critical part of the multi-bus architecture. They are used to link together various interactive modules of multiple participants and vehicles involved in self-driving process. Via CAN bus, driving brain can connect to the underlying layer of the car, therefrom sending out commands and acquiring the performance of the underlying layer.

Conclusion. By closely drawing insights from various interaction modes and methods involved in autonomous driving, the complexity and significance of the interaction are then analyzed. In the end, with driving brain as the carrier, an interactive cognition scheme has been introduced from the perspectives of interactive cognition and interactive bus design. This study took a long hard look on the necessity of interactive cognition in self-driving and specific reflections. Furthermore, this study demonstrated the innovative designs in terms of multi-bus communication involved in interactive cognition. By taking advantage of interactive cognitive technology, driver's interactive cognition online can be transformed into the interaction between machine and the surrounding world. This integration of computational cognition, memory cognition, and interactive cognition is ushering in the era of autonomous driving.

Acknowledgements This work was supported by State Key Laboratory of Software Development Environment (Grant No. SKLSDE-2017ZX-18).

References

1 Burns L D. Sustainable mobility: a vision of our transport future. Nature, 2013, 497: 181–182
2 Eskandarian A. Handbook of Intelligent Vehicles. London: Springer, 2012
3 Basu C, Singhal M. Trust dynamics in human autonomous vehicle interaction: a review of trust models. In: Proceedings of AAAI Spring Symposia, Palo Alto, 2016. 85–91
4 Maurer M, Gerdes J C, Lenz B, et al. Autonomous Driving. Berlin: Springer, 2016
5 Li D Y. Interactive cognition (in Chinese). Robot Ind, 2016, 5: 12–22
6 Bhat A, Aoki S, Rajkumar R. Tools and methodologies for autonomous driving systems. Proc IEEE, 2018, 106: 1700–1716