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A Framework of the Non-critical Spontaneous Intervention in Highly Automated Driving Scenarios

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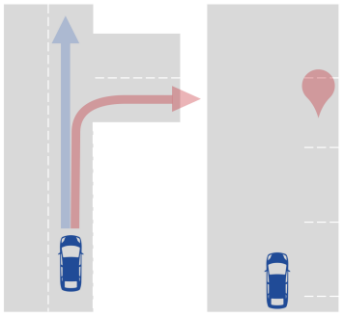

Figure 2: Intervention of Navigation Level. Left: AV wants to go straight, human driver want to turn right. Right: Human driver chooses a parking slot to stop.

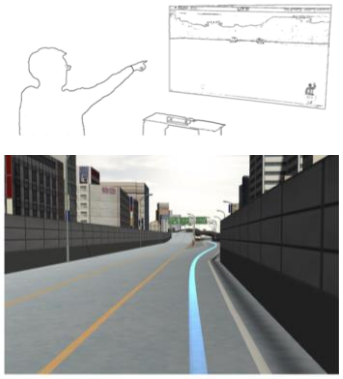

Figure 3: A concept of intervention in the Navigation Level [15]

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Abstract

One trend in the development of autonomous driving is to take the human completely out-of-the-loop. However, we believe that there are good grounds to keep the human in the loop, at some level of control (in particular tactical control), even in the case of full automation. One reason to do so is that the technology may not be flexible enough to always behave according to human needs and preferences, which may vary across people and situations. There are still many scenarios driver want to spontaneously intervene the behaviour of the system, e.g. picking up a friend in a crowded area, selecting a parking lot, that the driver would not like to follow a big truck and want to turn to another road to explore and find new places. In this paper, we present a framework of human intervention in Non-critical Spontaneous Situations (NCSSs). The framework facilitates a systematic definition of these scenarios, which ensures that all relevant aspects are addressed when eliciting requirements or validating concepts.

Author Keywords

Shared control; highly automated driving; Framework; human-machine cooperation.

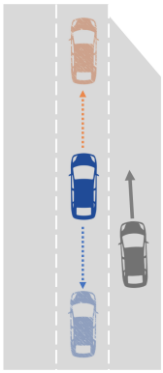

Figure 4: Maneuver Level intervention: the system wants to deaccelerate (change to light-blue car position), human driver wants to accelerate (change to light-orange car position).



Figure 5: A concept of the intervention in the Maneuver Level [9]

ACM Classification Keywords

• Human-centered computing~HCI theory, concepts and models

Introduction

Nowadays, it seems that the development of autonomous driving technology is pushing the drivers away from their maneuver position. However, it does not mean that in the highly autonomous conditions the vehicles will not interact with their driver any more. For more than one hundred years, cars fulfil our basic needs of autonomy and freedom, which will not vanish in the autonomous driving era. Therefore, we may assume that there are still many scenarios where the driver wants to spontaneously influence the behaviour of the autonomous driving system (Non-critical Spontaneous Situations, NCSSs [15]). These scenarios include picking up a friend in a crowded area, merge out to get a coffee and selecting a parking lot etc. Or just because the driving style of a system does not meet the current preference of the driver, for example, when the driver would like to reduce the distance from the front car, would not like to follow a big truck or would like to turn to another road to explore and find new places. As a result, the human and autonomous vehicle still need to communicate and cooperate even in highly autonomous driving, the system should raise and not replace the driver. To in-depth investigate the interaction modality, we need to analyze the factors that influence the cooperation between the autonomous driving vehicles and human at which traffic conditions. As a result, it is necessary to develop the framework of the factors, which is intended to provides an overview over the most relevant elements that influence the NCSSs and to serve as a basis for concept development and further research. With the framework, researchers can depict scenarios through the quantitative variables and in-depth develop novel HMI concept for NCSSs.

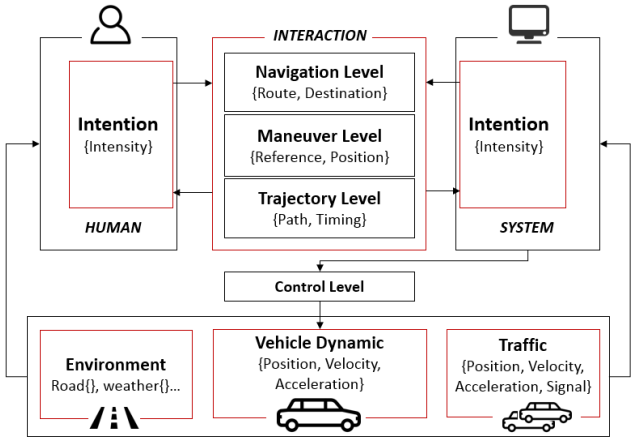

Figure 1: The framework of the cooperation in the NCSSs.

A framework for the NCSSs

The framework can be used to describe the cooperation flow which is relevant for a specific research question. In the previous research, some frameworks of the shared control between human and automation were proposed. Bengler et al. [5] suggested a taxonomy of cooperative systems divided the cooperation into five layers. Flemisch et al. [7] proposed a common framework of the cooperation between human and machine, which distinguishes the human-machine cooperation, cooperative guidance and shared control. Biondi et al. [6] pointed out the limitation technology-centered taxonomies of automation and reviewed previous framework and models regarding human-system cooperation. However, there is no systematic framework, which specifically focuses on the NCSSs. In this research, a framework, which classifies the

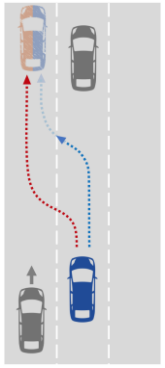

Figure 6: Trajectory Level intervention. Both the system and driver want to change to left lane, but they have different path and time planning: The system want to change lane after the left vehicle passing, but human driver want to change lane now.



Figure 7: The Scribble.

different attributes that influencing the negotiation between an automated vehicle (AV) and human, was, developed (Figure 1). There are five main components in the framework: Intention of human and system, Interaction in different Levels, Environment, Vehicle dynamic and Traffic. Each component contains some variables. The variables are the basic parameters of the use cases, which can directly contribute to the interaction design. In the following part, each component of the framework, and how they link with each other were proposed.

Intention

All the actions of controlling or intervening the controlling of the vehicle are driven by the intention. Intention is determined by external attributes (environment, ego vehicle dynamic and surrounding traffic), and influenced by the inner factors. For the driver, the inner factors are their motivation, the short-term goal, mood, experience etc. For the system, the inner factor might be the pre-set code of conduct etc. Intensity is the variable of the intention, which is the willingness to control the vehicle to achieve his/her or its planning. It is not a binary, but a continuous value. In the previous research of the shared control of highly automated driving, haptic feedback was widely used as an interaction method for the negotiation between human drivers and system [8][4][3][1]. The force input reflects the intensity of the intention of the driver and the feedback reflects the intensity of the system. Terken et al. [14] proposed a device *Stewart* which enables AVs to provide force feedback to drivers (Figure 8). The strength of the force transforms the environmental information in the driving context, which provides the intention of the autonomous vehicle. In the *H-Metaphor* project [2][8][4][3], researchers suggested the shared control of a highly automated vehicle can be seen as riding a horse. They developed several haptic devices, which can be seen as reins, to enable driver switching from different automation level. The haptic device can detect the grasping force of drivers and generate force feedback to drivers as well. The intensity of the force is seen as the parameter of the willingness to get back the control authority.

Interaction

Driven by the intention, diver and system have their planning of controlling the vehicle. In the component of the interaction, they exchange their planning. The exchanging activities can be differentiated by levels, from strategical guidance to a specific control. Hoc et al. [10] suggested three levels of cooperation: a meta-level, a planning level and an action level. Based on the previous research[13][11], Flemisch et al. [8] suggested a common model which divides the driving process into four different levels: Navigation level, Maneuver level, trajectory level and control level. In this study, we utilise Flemish's framework to divide interaction component into four levels. In the NCSSs, human delegates the driving task in the control level to the system, but can intervene system's planning in the navigation, manoeuvre and trajectory levels.

- Navigation Level:

The navigation level is the long-term planning of a route in the road network to reach a certain destination. This sub-component has at least two variables: 1)Route and 2)Destination. Weisse et al. [16] introduced a use case which driver can negotiate with the system to change the current route (Figure 2 left). Tscharn et al. [15] proposed a concept that driver

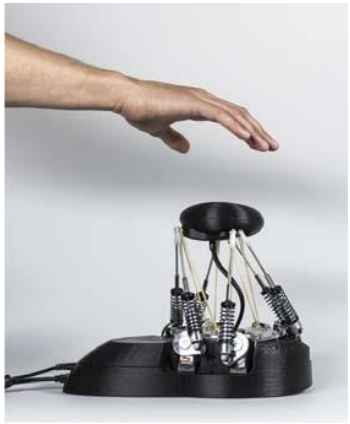

Figure 8: The Stewart.

can tell AV to stop at a certain location through gesture and speech input (Figure 2 right and Figure 3).

- Maneuver Level:

The manoeuvre level represents the mid-term planning how to manoeuvre through traffic, which can be described in a semantic way such as "turn left", "merge out" or "overtake". Basically, the manoeuvre is to set a new position of the vehicle. To clarify the new position to move, 1)the target position and 2)the framework of reference are two essential variables. In a simulator study, Guo et al [9] suggested a concept which human driver can intervene in highly automated driving vehicle behaviour in this Level. This concept holds that while the right vehicle wants to merge into the highway, the system can provide two plausible manoeuvre plans, accelerating or deaccelerating, and show its current decision. A human driver can intervene system's decision by push or pull the button on the console (Figure 3). This concept enables the driver to change the vehicle's position relative to the merging-in vehicle.

- Trajectory Level:

While the manoeuvres are more abstract, the trajectory is more concrete [8], which provides short-term planning for the vehicle movement. It contains both space and time dimensions, which can be described by 1)path and 2)timing variables. Figure 6 shows a use case in which a driver wants to intervene in the trajectory level. The system and driver have the same manoeuvre aim, but they have a different path and time planning: The system wants to change lane after the left vehicle passing, but human driver wants to change lane now. Previous research also explored the interaction at this level. In the previous research, Felix proposed a haptic control device *Scribble* [12], by which the driver can "draw" the path for the AV to follow (Figure 7).

Vehicle Dynamic

Human and system make the decision according to the status and capabilities of the ego vehicle, and the result of the negotiation between human and system imposes on the movement of ego vehicle. Therefore, the vehicle dynamic is an important component of the NCSSs. This component includes many variables, three essential ones are 1)current position, 2)velocity and 3)lateral/longitude acceleration. The attribute of the ego vehicle dynamic also influences the behaviour of surrounding traffic.

Traffic

The traffic component describes the status of other road users nearby. It includes the variables of their position, velocity, acceleration and signal (e.g. indicator) etc. The variables of traffic attribute are the important parameters for human and system to make a plan.

Environment.

There are many sub-components in the environmental factors that may influence NCSSs. Researchers need to clarify which ones are relevant to their topic. Normally, the most essential component is the road, which includes variables such as width (the number of lanes), curvatures, types (e.g. highway, urban road) etc.

Conclusions and Future Works

In this research, we propose a framework of human intervention in NCSSs and systemically categorize different factors that influence the cooperation between human and system. In the future, the concepts in this

domain will be generated and elaborated under this framework, and the user scenarios will be depicted through adjusting components and variables that are proposed in this study.

References

1. David A Abbink, Mark Mulder, and Erwin R Boer. 2012. Haptic shared control: smoothly shifting control authority? *Cognition, Technology & Work* 14, 1: 19–28.

2. Eugen Altendorf, Marcel Baltzer, Matthias Heesen, Martin Kienle, Thomas Weißgerber, and Frank Flemisch. 2014. H-Mode: A haptic-multimodal interaction concept for cooperative guidance and control of partially and highly automated vehicles. *Handbook of Driver Assistance Systems: Basic Information, Components and Systems for Active Safety and Comfort*: 1–16.

3. Marcel Baltzer, F Flemisch, E Altendorf, and S Meier. 2014. Mediating the interaction between human and automation during the arbitration processes in cooperative guidance and control of highly automated vehicles. In *Proceedings of the 5th international conference on applied human factors and ergonomics AHFE*.

4. Marcel Baltzer, Daniel Lopez, Marting Kienle, and Frank Flemisch. 2015. Dynamic distribution of control via grip force sensitive devices in cooperative guidance and control. *Berliner Werkstatt Mensch-Maschine*.

5. Klaus Bengler, Markus Zimmermann, Dino Bortot, Martin Kienle, and Daniel Damböck. 2012. Interaction principles for cooperative human-machine systems. *it-Information Technology Methoden und innovative Anwendungen der Informatik und Informationstechnik* 54, 4: 157–164.

6. Francesco Biondi, Ignacio Alvarez, and Kyeong-Ah Jeong. 2019. Human–Vehicle Cooperation in Automated Driving: A Multidisciplinary Review and Appraisal. *International Journal of Human–Computer Interaction*: 1–15.

7. Frank Flemisch, David Abbink, Makoto Itoh, Marie-Pierre Pacaux-Lemoine, and Gina Weßel. 2016. Shared control is the sharp end of cooperation: towards a common framework of joint action, shared control and human machine cooperation. *IFAC-PapersOnLine* 49, 19: 72–77.

8. Frank Ole Flemisch, Klaus Bengler, Heiner Bubb, Hermann Winner, and Ralph Bruder. 2014. Towards cooperative guidance and control of highly automated vehicles: H-Mode and Conduct-by-Wire. *Ergonomics* 57, 3: 343–360.

9. Chunshi Guo, Chouki Sentouh, Jean-Christophe Popieul, Jean-Baptiste Haué, Sabine Langlois, Jean-Jacques Loeillet, Boussaad Soualmi, and Thomas Nguyen That. 2017. Cooperation between driver and automated driving system: Implementation and evaluation. *Transportation Research Part F: Traffic Psychology and Behaviour*.

10. Jean-Michel Hoc. 2001. Towards a cognitive approach to human–machine cooperation in dynamic situations. *International journal of human-*

computer studies 54, 4: 509–540.

11. Raja Parasuraman, Thomas B Sheridan, and Christopher D Wickens. 2000. A model for types and levels of human interaction with automation. *IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans* 30, 3: 286–297.

12. Felix Ros. 2017. Scribble. Retrieved from http://www.felixros.com/scribble.html#big_wrap

13. Thomas B Sheridan. 1976. Toward a general model of supervisory control. In *Monitoring behavior and supervisory control*. Springer, 271–281.

14. Jacques Terken, Pierre Levy, Chao Wang, Juffrizal Karjanto, Nidzamuddin Md Yusof, Felix Ros, and Sergej Zwaan. 2017. Gesture-based and haptic interfaces for connected and autonomous driving. In *Advances in Human Factors and System Interactions*. Springer, 107–115.

15. Robert Tscharn, Marc Erich Latoschik, Diana Löffler, and Jörn Hurtienne. 2017. "Stop over there": natural gesture and speech interaction for non-critical spontaneous intervention in autonomous driving. In *Proceedings of the 19th ACM International Conference on Multimodal Interaction*, 91–100.

16. Gina Weßel, Constanze Schreck, Eugen Altendorf, Yigiterkut Canpolat, and Frank Flemisch. 2017. Learning from the Best–Naturalistic Arbitration for Cooperative Driving. In *International Conference on Applied Human Factors and Ergonomics*, 631–642.