The Best Rated Human–Machine Interface Design for Autonomous Vehicles in the 2016 Grand Cooperative Driving Challenge

Ola Benderius, Christian Berger, and Victor Malmsten Lundgren

***Abstract*— This paper provides an in-depth description of the best rated human–machine interface that was presented during the 2016 Grand Cooperative Driving Challenge. It was demonstrated by the Chalmers Truck Team as the envisioned interface to their open source software framework OpenDLV, which is used to power Chalmers' fleet of self-driving vehicles. The design originates from the postulate that the vehicle is fully autonomous to handle even complex traffic scenarios. Thus, by including external and internal interfaces, and introducing a *show, don't tell* principle, it aims at fulfilling the needs of the vehicle occupants as well as other participants in the traffic environment. The design also attempts to comply with, and slightly extend, the current traffic rules and legislation for the purpose of being realistic for full-scale implementation.**

***Index Terms*— Human–machine interface, autonomous vehicles, external interface.**

I. Introduction

THE recent development in research and the incipient commercialization of automated and autonomous vehicles suggests a revolution concerning human transportation for the coming decades. If one considers a full-scale transition from manually driven vehicles to automated ones a revolution, one may also argue that the automated vehicles in fact should be seen as something fundamentally different when compared to their manually driven counterparts. In a way, such an extensive event could be compared with the societal change that occurred when horse carriages were largely replaced by motorized vehicles. In fact, many of the human–machine interface (HMI) concepts can be derived from that time, for example the *dashboard* or the fact that the operator of a vehicle is still referred to as a *driver*. One may therefore identify clear traditional values concerning vehicle HMI. However, one may also conclude that HMIs from time to time may need to be redefined and modernized, which is suggested by the design proposed in this paper.

Manuscript received December 9, 2016; revised February 21, 2017; accepted June 11, 2017. Date of publication October 3, 2017; date of current version March 28, 2018. The Associate Editor for this paper was S. Shladover.
(Corresponding author: Ola Benderius.)

O. Benderius is with the Department of Mechanics and Maritime Sciences, Chalmers University of Technology, 412 96 Göteborg, Sweden (e-mail: ola.benderius@chalmers.se).

C. Berger is with the Department of Computer Science and Engineering, University of Gothenburg, 405 30 Göteborg, Sweden (e-mail: christian.berger@gu.se).

V. Malmsten Lundgren is with RISE Viktoria, 417 56 Göteborg, Sweden (e-mail: victor.malmsten@ri.se).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TITS.2017.2749970

The proposed design includes both an internal interface intended for the occupants of the vehicle, and an external interface intended for any other participants of the traffic environment. The design was demonstrated at the 2016 Grand Cooperative Driving Challenge in Helmond in The Netherlands, in front of two external academic experts, and it was rated the best design out of ten proposals. This paper gives an in-depth description of the design, along with some documented improvements from when it was first demonstrated. Parts of the HMI were already implemented into the open-source software OpenDLV[1] for driver-less vehicles, in which it will later be fully implemented and evaluated in real traffic scenarios.

A. Related Work

Even though this work includes both internal and external interfaces, this review will only cover external interfaces since they are considered to be more novel and to have a larger societal impact when introduced. In previous work of one of the authors, it was found that the pedestrians' perceived safety might be decreased when approached by a driver-less vehicle [1]. This might naturally be due to the fact that such vehicles are not yet a substantial part of human culture, but still it was shown that external interfaces are a possible solution to this problem.

So far there have been a few suggestions and demonstrated concepts on external interfaces. In 2012, a biomimetic interface for automated and electric vehicles was suggested [2]. Then in early 2015, Mercedes demonstrated a concept vehicle that visually projects a zebra crossing on the road in front of the pedestrian while also emitting auditory signal to indicate that it is safe to cross [3]. Later, Nissan showed a concept vehicle using a light strip around the vehicle and textual messages in the front windshield such as "after you" [4], [5]. Mitsubishi Electric has also demonstrated a concept where the vehicle direction of motion is projected onto road surface [6]. In addition, Google recently patented a concept [7], in which, for example, a flashing stop sign on the door of an automated vehicle informs pedestrians not to cross the street, and a robotic hand conveys various signals. A similar concept was tested in an experimental setting [8], where it was shown that the most important factor if a pedestrian is to cross a street is the gap size. It was also discussed that if vehicles are showing signs, there might be situations where

[1] See http://opendlv.org for more information.

unintended pedestrians may follow them and get into critical situations.

To conclude, all these concept designs seem to be in very early stages or OEM-specific, and no clear conventions are yet identified. Furthermore, the concept of combining internal and external interfaces, as the design proposed in this paper aims to do, are typically not considered. Most of the presented systems are also trying to initiate direct contact with pedestrians, for example in crossing scenarios, which may be problematic, as further discussed in the next section.

II. The Future of Vehicle HMI

International conventions concerning vehicle HMI were first formed in the 1949 Geneva Convention on Road Traffic. These conventions were further developed in the United Nations Convention on Road Traffic in 1968 [9], which eventually worked as the basis for legislation, in for example Europe [10] and the US [11]. However, since there is a common source for most legislation, there are some general rules. For example, when it comes to the color of automotive lighting where (i) all forward directed lamps should emit white or selective-yellow, (ii) direction indications should emit amber light, and (iii) red light must be used in the rear of a moving vehicle. There are also common rules about flashing light, stating that only direction indicators may flash, with the exception that one may flash the high beam headlights in order to alert a lead vehicle in, for example, an overtaking scenario. There are also several rules concerning the internal HMI of a vehicle, for example that there must be a speedometer and a steering wheel installed in the vehicle.

The work presented here suggests that the HMI for automated and autonomous vehicles may benefit from being evolved, motivated by the belief that these vehicles should be seen as something fundamentally different compared to traditional manually driven vehicles. In general, any new HMI for autonomous vehicles would therefore benefit from an unbiased re-design, and perhaps with new international conventions as a result. However, the suggestion is not to completely replace the current standards, but rather to complement existing conventions. With potentially no occupant in the vehicle in the case of a driver-less car for instance, one can argue that the vehicle needs to have well designed means of signaling its intentions, for example when overtaking or stopping at a pedestrian crossing. Furthermore it may be argued that a self-driving car would not require a traditional steering wheel or speedometer as required by current laws.

Recently, there have arguably been significantly larger technical requirements on the HMIs of modern vehicles as a result of increased development of new active safety systems for example. These systems often need to alert the driver in many different ways using, for example, audio signals, flashing heads-up-displays, and torque applied to the steering wheel. It might even be argued that the recent development has been somewhat driven by technical novelty and for commercial reasons, rather than simplicity, safety, and the users' needs in focus. In the authors' opinion, this development is not entirely positive since this significant increase in information from different in-vehicle sources may put additional cognitive load on the driver, and therefore increase the risk of misunderstandings in critical situations. Therefore, it might be beneficial to decrease the amount of information mediated to the driver in the future. Luckily, even though an autonomous vehicle will be much more technically advanced compared to the current vehicles, it may not necessarily need to convey more information to the driver since the driving task and safety of the vehicle will no longer be the responsibility of the driver. From the perspective of this work, the driver should not be viewed as a technical expert, or even someone who would be capable of treating system errors. Therefore, there will be no need to show what the vehicles sees since it should rather be assumed that the vehicle perceives everything it needs. However, the system should always supply safety related information, such as the *safety envelope* indicating the behavioral stress of the system, and should allow for some type of manual intervention.

Since the behavior of an autonomous vehicle will not only interact with the behavior of a driver, but also any human that it may come in contact with, the HMI should focus on the occupants of the vehicle *as well* as other humans that may interact with the system. Therefore, both an internal and external interface is clearly needed. In this work, it is argued that these two interfaces should aim for a high degree of consistency in what information is given and how it is presented. Based on the theory of *social constructivism* [12], the motivation for this coherence is to find an accepted design, which over time will act as a culturally shared understanding of vehicle behavior and intention. The design platform for this work is based on this theoretical framework, which suggests an overall design with few contradictions and with good possibilities for global standardization.

By looking at examples of the recent solutions as the ones presented in the previous section, one may notice that most of the proposed systems intend to do targeted interaction with other road users for external HMIs of autonomous vehicles. However, in complex environments with numerous pedestrians, cyclists, and other vehicles this might prove difficult simply because an unlimited number of different situations may arise and it might not always be entirely clear to any communication party that it is selected for such communication. It might be argued that with a limited capability of conveying intentions and vehicle state (e.g., a limited number of usable lamps), it would be impossible to support all these situations with a fixed repertoire of expressions.

Therefore, a *show, don't tell* principle inspired by human-animal interaction is employed, meaning that the vehicle will always clearly demonstrate its planned actions, but without any further motivation. For example, if a pedestrian and a bicyclist would approach a crossing at the same time, the vehicle would clearly indicate that it intends to stop and wait, but not state why this was triggered since this information easily could be misunderstood by the other involved agents. This principle is also motivated from the theory of social constructivism, as the design should not require foreknowledge about a variety of isolated and unlimited scenarios, since they would obstruct a culturally shared understanding of the overall vehicle behavior.

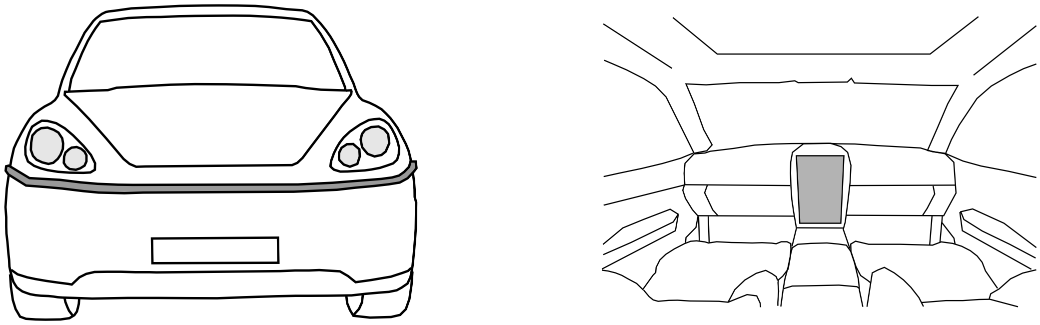

Fig. 1. Left panel: The external interface. In the envisioned solution, the direction indicators will be removed, and replaced with a more general purpose light bar (dark gray). Right panel: The internal interface. Most of the traditional HMI was removed, and replaced with a touch screen monitor between the two front seats (gray).

To conclude, the design presented in this work is based on the following design principles

- Any new HMI for autonomous or automated vehicles should be based on the current international conventions, even though some evolution might be needed.
- An HMI for self-driving vehicles should consider the occupants of the vehicle as well as any humans outside the vehicle.
- The internal HMI should be minimalistic but should report a safety envelope.
- The design should follow the *show, don't tell* principle.

III. The Proposed HMI Design

The design presented in this work includes complementary internal and external HMI, where the internal conveys information about the current traffic situation to the vehicle's occupants, and the external conveys the vehicle intentions to the surrounding traffic environment.

A. External Interface

The proposed HMI's external interface should be seen as a potential next step when it comes to automotive lighting HMI. It still follows the most basic international conventions as seen in contemporary systems. The hardware setup, as illustrated in the left panel of Fig. 1, is equivalent to the traditional setup except that the normal direction indicators have been replaced with a light bar capable of showing white and amber light. The light bar is used for three purposes: (i) to indicate the distance to the desired longitudinal position or tracked object, (ii) to warn any conflicting lead vehicle by flashing, and (iii) to indicate the intended direction of movement. An early prototype of the external interface is depicted in Fig. 2.

The distance to the desired longitudinal position or tracked object is indicated by the width of the lit area on the light bar. The width of the lit area represents the projected angle of the desired future position, or the projected angle of the tracked object, as given by

$$\psi = \arctan(\frac{w_l}{2d}) \quad (1)$$

$$a = 2b\tan(\psi) \quad (2)$$

where w_l and d are the width and distance to the lead vehicle, b is the distance from the front axle to the light strip, and a is the width of the lit area. Note that the width of the lit area, and its expansion, is not linear with respect to the distance to a lead vehicle. This is also believed to be a good design choice, since this reflects how humans perceive relative motion [13]. Also note that the vehicle will, whenever moving, show exactly one direction (e.g. a tracked vehicle or lane). If, for example, a vehicle cuts in front of the autonomous vehicle, that vehicle will, be treated as the tracked vehicle as soon as it conflicts the path and the light bar will update accordingly.

Fig. 2. The external HMI is exemplified on a truck. The light bar is showing red light for evaluation purposes; see the text for a description of the behavior.

The purpose of showing the width of any target is to indicate to other agents in the traffic environment what object the autonomous vehicle currently is focusing on. For example, if following a vehicle that is far away, the width of the lit area will be narrow but when approaching a vehicle the area will increase in length. Another important use case is when the vehicle intends to stop, for example before a pedestrian crossing, the light bar will then increase in length based on the distance to the intended stopping point, and right before stopping the complete light bar will be lit which will well in advance indicate the intention of the vehicle. Note that the purpose for stopping is not indicated, which is the intended behavior based on the discussion in the previous section.

There are two additional behaviors related to this design. Firstly, if the width of the light bar increases faster than

TABLE I
COLORS IN USE ON THE FRONT LIGHT BAR

ffffff	fff0e2	ffe2c6	ffd4aa	ffc58d
ffb771	ffa955	ff9438	ff8c1c	ff7e00

a certain threshold, for example when a lead vehicle is braking harder than expected, the light bar *and* the vehicle's headlights start to flash in order to alert any lead vehicle that the autonomous vehicle experienced unexpected looming. Secondly, every time the autonomous vehicle starts from standstill the light bar is slowly flashed five times before returning to normal operation.

The intended direction of movement is shown on the light bar in any one of the colors from a gradient of ten colors between the traditional white and amber, as listed in Table I. At any given time, only *one* color will be shown on the light bar as determined by the angle calculated from the center of the front axle to the intended target of movement. Since the behavior is symmetrical for either side, the color is determined by

$$n = 10 \quad (3)$$

$$r = 0.4 \quad (4)$$

$$\alpha = \arctan\left(\frac{rw}{2b}\right) \quad (5)$$

$$\beta = \arctan\left(\frac{w}{2b}\right) \quad (6)$$

$$\delta = \frac{\beta - \alpha}{n - 1} \quad (7)$$

$$i_c = \begin{cases} 1, & \text{if } |\phi| \leq \alpha \\ 1 + \left\lceil \dfrac{|\phi| - \alpha}{\delta} \right\rceil, & \text{otherwise} \end{cases} \quad (8)$$

where i_c is the index of the selected color ($i_c = 1$ is white, and $i_c = n$ is amber), w the width of the vehicle, b the distance from the front axle to the light bar, n the number of colors in the gradient, r the ratio of the width of the vehicle, which should be dedicated for white light, and ϕ the angle from the center line of the vehicle to the intended direction of movement as seen from the front axle. Also note that the angle ϕ of the target ultimately decides the color of the full width of the lit area, meaning that any selected color may spill over to areas that would normally be associated with another color (i.e., since only one color is allowed on the bar at any given time). Furthermore, when $i_c = n$ the lit amber area will also emit flashing light, to comply with the traditional lighting conventions when moving laterally.

There is also an auditory part of the external HMI that is activated under two conditions: (i) when the vehicle drives near pedestrians, and (ii) when there is a considerable risk of collision. When there are pedestrians near the vehicle, a ticking and easy locatable sound is played, and when there is a large risk of collision, the traditional horn is activated.

B. Internal Interface

The internal interface, as illustrated in the right panel of Fig. 1, redefines much of the contemporary internal HMI. First of all, the vehicle is symmetrical in this design, meaning that there is no intended driver seat.[2] Most of the traditional HMI is removed, including the steering wheel, pedals, gearshift, speedometer, fuel gauge, entertainment system, and so forth. The only HMI envisioned to be included in the autonomous vehicle is a larger touch monitor in the middle of the two front seats as well as some separate controls for climate control and windows – similar to the HMI found at passenger seats in today's aircrafts or trains for example. Furthermore, the HMI screen only shows very specific information and does not allow for much user input, only to start and stop the system, and to choose the destination. In the envisioned internal HMI, any interaction with dynamic information systems, such as the entertainment system or maps, are dependent on the use of personal mobile devices, such as smart phones. By doing so, content such as media can be highly personalized and allow for aftermarket adaptation. This design choice is especially motivated by (i) the rapid development of software services, and (ii) the intention of forcing a separation, for data security reasons, between safety critical vehicular systems and non-critical ones. Therefore, the vehicle should only contain a bare-minimum HMI for the actual transportation task and in-vehicle environment adaptation; any extra HMI, for example to access the vehicle's built-in speaker and microphone systems, or to access goods or logistics systems is brought by each user. Furthermore, following this principle, users would also be able to bring their same personal HMI to any vehicle they would visit.

The touch screen monitor is the main internal HMI. It is positioned so that all occupants of the vehicle should be able to see it clearly, and so that both occupants on the front row could interact with it if needed. The HMI can be in any of four different modes. The first is the `idle` mode, in which the user needs to tap a black logo screen in order to start the vehicle and proceed to the `input` mode. In this mode, the users will be presented with an on-screen keyboard where they may input a destination address. After confirming the destination, the user is presented with two numbers, the total time to reach the destination, and a list of stops along the way where the vehicle needs to refuel. After confirmation, the system changes to the third mode, the `driving` mode, during which the user will be presented with four types of information. The first is the current time along with time until the destination is reached and time until the next stop. The second and third type reflect the intended direction of movement and the distance to the nearest object in focus, as described in the previous section, and the fourth is the safety envelope. The three latter ones are all visualized as cloud-like glowing gradients that move over the screen surface. The intended direction of movement and the width of the target in focus are both closely resembling the visual representation of the external light bar, including any flashing behavior, but are instead shown as a black to white or amber cloud-like glowing gradient in the top of the screen.

The safety envelope is shown as a black to red gradient reaching in from the sides and at the bottom of the screen.

[2]This design is of course also of potential economic gain since the same design would be valid on all markets.

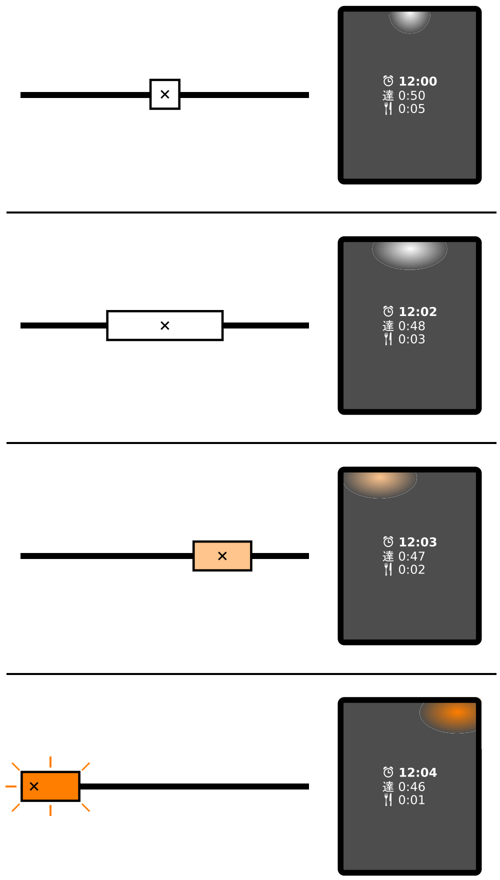

Fig. 3. Four side-by-side examples of different scenarios showing both the external and internal interfaces. In the top two scenarios, the autonomous vehicle is following a lead vehicle at a long and a short distance, respectively. The third scenario is a lane change to the left (e.g. an overtake), and the forth scenario is a right turn.

The amount of red on the screen as a direct correlation to the safety envelope and if it reaches critical levels it starts to flash. The exact implementation of this safety envelope is currently under prototypical realization and evaluation, but in general it is a reflection of the integrated untreated stimuli, or stress, inside the OpenDLV framework. For example, in tight city situations, in which it could be even impossible to successfully remove every single threat, a small amount of behavioral stress in the system would be unavoidable.

Furthermore, the `driving` mode allows for some user input, namely to tap the screen and choose one of three options: to (i) drive to a nearby rest area, gas station, or restaurant, (ii) change the final destination, or (iii) urgently stop at a safe place on the side of the road or in a parking space. There is also a fourth interface mode available labeled as the `manual` mode, in which the user can locally control the car by tapping on the screen. This mode is only available at low speeds, and the vehicle will drive automatically to any selected valid position. The manual mode should typically not be needed in urban areas, but is included for the purpose of, for example, parking the vehicle in an unstructured parking lot. In Fig. 3, side-by-side examples of both the internal and external interfaces are presented.

TABLE II
FINAL SCORING OF THE HMI DESIGNS IN THE 2016 GCDC

Team name	Score
Chalmers University of Technology (Truck team)	7.8
Halmstad University	7.4
Chalmers University of Technology (Car team)	7.4
Université de technologie de Compiègn (Heudiasyc laboratory)	6.8
University of Latvia / Institute of Electronics and CS (EDI)	5.4
KTH Stockholm (Truck team)	5.4
KIT Karlsruhe	4.2
A-Team Eindhoven (Fontys and TU/e)	4.2
Universidad de Alcalá (UAH)	4.2
KTH Stockholm (Experimental Car)	0.0

IV. JUDGING

The judging of the HMI was a separate evaluation criterion during the 2016 GCDC. It was carried out by external academic experts, namely Professor Marieke H. Martens at the University of Twente, and Associate Professor Jacques M.B. Terken at the Eindhoven University of Technology. The judges took no part in any of the other evaluation criteria in the competition, and they evaluated each team's HMI design individually based on an previously submitted video, an interview with team members, and a concept demonstration inside the vehicle. The judges had no requirement on the level of implementation, but rather judged the available implemented parts and the connected vision. The Chalmers Truck Team, represented by the authors of this text, got the highest scoring from the judges for their solution as seen in Table II. The detailed scoring was as follows (scoring between 0 and 10, where ten is the highest)

- Transparency: is it clear what the information means to potential target users? – **7**
- Innovation: does the interface contain novel interaction techniques? – **8**
- Aesthetics & Minimalism: does the interface provide a good user experience, and does it avoid clutter? – **7**
- Coherence & Consistency: does the interface give a well-integrated impression? – **8**
- Vision: does the user interface reflect a clear vision on what to achieve and how to achieve it? – **9**

A. Adjustments Since the 2016 GCDC

Since the HMI design was evaluated by the judges, there have been a few improvements that are described in this paper. The adjustments are

- In the original design, the light bar was flashing red when large looming was detected in-front of the vehicle. Due to international convention, as discussed in Sect. II, this was changed to the normal white and amber colors only depending on the current intended direction of movement. By doing so it is believed that the design gain in Transparency as well as in Coherence & Consistency, but it also gets an increased chance of being adopted.
- The different touch screen states were clarified in the paper for the reason of making the design easier to

standardize and implement, and possibly it would also gain in Aesthetics & Minimalism.

- The design concept of always slowly flashing the light bar five times before starting from stand-still was introduced in order to increase safety, which is believed to give an increase in Transparency.
- The auditory external HMI was added.

V. Conclusion

Society might be close to a revolution in the area of transportation due to the potential introduction of automated and autonomous vehicles. This implies that there is a need to redesign parts of the vehicle that have been taken for granted for many years. The work presented here suggests that both the internal and external HMI of the autonomous vehicles must be treated jointly to allow a seamless deployment of autonomous driving to the traffic with other vehicles, bicyclists, and pedestrians.

It was also noted that most existing solutions would not handle complex traffic situations very well, since they all rely on discrete and well-defined situations. The design presented here instead follows a *show, don't tell* principle, meaning that simply the behavior itself together with the conveying of intentions should be able to handle most situations. Furthermore, such a principle could, if being selected as the standard, be the basis for the building of a culturally shared understanding of vehicle behavior and intention.

The design outlined in this work was selected as the best out of ten proposals in an international competition and its formal evaluation is currently planned. Therefore, the effect on a variety of users inside and outside the vehicle during different traffic scenarios is subject to future studies. Special focus of such studies should be on the novel *show, don't tell* principle, and if vehicle behavior in most scenarios in fact can be conveyed by using the HMI presented here.

Acknowledgment

The authors are grateful to Chalmers University of Technology for supporting the research in preparation for the 2016 GCDC competition. The Chalmers Revere laboratory is supported by Chalmers University of Technology, AB Volvo, Volvo Cars, and Region Västra Göaland.

References

[1] T. Lagström and V. M. Lundgren, "AVIP—Autonomous vehicles interaction with pedestrians," M.S. thesis, Dept. Product Prod. Develop., Chalmers Univ. Technol., Gothenburg, Sweden, 2015.
[2] N. Pennycooke, "AEVITA: Designing biomimetic vehicle-to-pedestrian communication protocols for autonomously operating & parking on-road electric vehicles," M.S. thesis, Dept. Archit., Massachusetts Inst. Technol., Cambridge, MA, USA, 2012.
[3] *The Mercedes-Benz F 015 Luxury in Motion*. Accessed: Feb. 19, 2017. [Online]. Available: https://www.mercedes-benz.com/en/mercedes-benz/innovation/research-vehicle-f-015-luxury-in-motion
[4] E. Vinkhuyzen and M. Cefkin, "Developing socially acceptable autonomous vehicles," in *Proc. Ethnogr. Praxis Ind. Conf.*, 2016, pp. 522–534.
[5] *Nissan IDS Concept: Nissan's Vision for the Future of EVs and Autonomous Driving*. Accessed: Feb. 19, 2017. [Online]. Available: http://www.nissan-global.com/EN/NEWS/2015//STORY/151028-01-e.html
[6] *Mitsubishi Electric Introduces Road-Illuminating Directional Indicators*. Accessed: Feb. 19, 2017. [Online]. Available: http://www.mitsubishielectric.com/news/2015/1023.html
[7] C. P. Urmson, I. J. Mahon, D. A. Dolgov, and J. Zhu, "Pedestrian notifications," U.S. Patent 9 196 164, Nov. 24, 2015.
[8] M. Clamann, M. Aubert, and M. L. Cummings, "Evaluation of vehicle-to-pedestrian communication displays for autonomous vehicles," in *Proc. Transp. Res. Board 96th Annu. Meet.*, Washington DC, USA. Jan. 2017. [Online]. Available: https://trid.trb.org/view.aspx?id=1437891
[9] "Convention on road traffic," United Nations, New York, NY, USA, Tech. Rep. E/CONF.56/16/Rev.1/Amend.1, 1968. [Online]. Available: https://www.unece.org/fileadmin/DAM/trans/conventn/crt1968e.pdf
[10] "European council directive," Eur. Communities, Tech. Rep. 76/756/EEC, 1976.
[11] "SAE international standards," SAE Int., Tech. Rep. J578_201603, 2016.
[12] A. Kukla, *Social Constructivism and the Philosophy of Science*. London, U.K.: Routledge, 2000.
[13] D. N. Lee, "A theory of visual control of braking based on information about time-to-collision," *Perception*, vol. 5, no. 4, pp. 437–459, 1976.

Ola Benderius received the Ph.D. degree from the Chalmers University of Technology, Sweden, in 2014, focused on perception-based driver modeling and modeling of the human neuromuscular system. In 2015, he got involved to help building Chalmers' new research laboratory Revere, and from where he also led the Chalmers Truck Team to participate in the 2016 GCDC. He is an Assistant Professor with the Department of Mechanics and Maritime Sciences, Chalmers University of Technology. He is also one of the two architects behind OpenDLV.

Christian Berger received the Ph.D. degree from RWTH Aachen University, Germany, in 2010. He coordinated the project for the vehicle Caroline, which participated in the 2007 DARPA Urban Challenge Final. He was also part of the Chalmers Truck Team during the 2016 GCDC, and is one of the two architects behind OpenDLV. He is an Associate Professor with the Department of Computer Science and Engineering, University of Gothenburg, Sweden. His research expertise is on distributed software, embedded systems, and cyber-physical systems.

Victor Malmsten Lundgren received the M.Sc. degree in industrial design engineering from the Chalmers University of Technology, Sweden, in 2015. He is currently a Researcher with the Cooperative Systems Group, RISE Viktoria. His research interests include automated vehicle interaction, human–machine interfaces, and user experience.