Brussels, Tuesday, 30 October 2018

Position Paper on Human Factors

Summary

The CARTRE theme group on Human Factors (HF) addresses the interaction of automated vehicles with drivers/passengers and other road users with a focus on the transition towards higher automation levels (SAE level 3, 4 & 5) on all types of public roads including complex urban conditions. The primary focus of the **Human Factors** theme group is safety. The highly related aspect of **Acceptance** of automation by individual users and by society is addressed by the user acceptance theme group in CARTRE[1].

The CARTRE theme group on Human Factors (HF) has collected and structured key challenges in the field of human factors of automated driving. Thus we present a vision and research agenda setting the scene for 2040.

We have structured the Human Factors challenges in three lines.

1-Automated vehicles allowing manual driving

How can we ensure a safe evolution towards a future where manual driving is the exception?

A. How can we predict and deal with effects of vehicle automation on humans such as misuse, skill degradation?
B. How can we shift control from the driver to the vehicle automation and return control back to the driver?
C. How can we make the vehicle automation adaptable to user needs and states?
D. How can driver state monitoring contribute?
E. How can automation overrule the driver and prohibit the driver from dangerous actions, in an acceptable and legal manner?

2-All automation levels including driverless vehicles

How can we ensure a safe interaction with all kinds of other road users?

F. How can we develop vehicle control strategies which are intuitive and acceptable for other road users?
G. How can communication (using visual, auditory or wireless) contribute to a safe and acceptable interaction?
H. How can remote supervision contribute to (perceived) safety and acceptance?
I. How can remote control take over and deal with abnormal situations?

3-Design and verification

Can we sufficiently understand the human interaction with automation to propose systematic approaches for design and verification?

J. How can we systematically design and evaluate automation and human machine interfaces to ensure a safe and acceptable interaction?
K. How can human factors evaluation be incorporated in legal and consumer test procedures?

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The challenges outlined above will have to be addressed for diverse traffic systems worldwide. This will create an immense challenge, given the huge variations in transport systems, vehicle types and human behaviour.
The human factors community will need to develop an understanding of this wide range of interactions, and use this to develop systematic methods to design and evaluate the human interaction with automation.
Ideally, such methods would include human behavioural models (adaptive as experience is accumulated), as these would allow efficient and safe evaluation of large numbers of scenarios. However, major efforts will be needed to develop and validate suitable human behavioural models and simulation methods.

As a human factors community we aim to ensure a safe and acceptable introduction of automation on public roads. This will enable a drastic reduction of fatalities and injuries, and a greatly improved mobility. These will only be achieved if HF is well integrated in the design and verification of automated vehicles.

Introduction

Road transport is an essential part of society but the burden of traffic crashes, congestion, and pollution is enormous. Automated driving has the potential to resolve these problems. Several vehicles already automate longitudinal and lateral control but still require a capable driver to monitor the automation (SAE[2] level 2). Car makers already announce the next automation levels (SAE levels 3&4) allowing drivers to take their eyes off the road and engage in other activities. In SAE level 3 the driver is still expected to be able to resume control appropriately in a reasonable time frame. In SAE level 4, vehicles will transition to minimal risk when drivers fail to resume manual control.
The above deployment of level 4 automation in cars and trucks, which still have steer and pedals, is currently the primary focus of the automotive industry. In parallel, we see an increasing number of projects focussing on driverless vehicles and functions (Citymobil, GATEway, WEpods, UBER) aiming to integrate autonomous transport systems into complex real-world urban environments. These include driverless buses and taxis which are no longer equipped with steer and pedals. These also include driverless operation in parking and vehicle sharing. In “driverless” operation some level of remote human supervision is foreseen, for instance by means of a control room. Driverless vehicles will initially have a limited operational design domain and will hence also be level 4 in the SAE definition. Once they can safely cover “all” public roads they will reach level 5.

The CARTRE theme group on Human Factors (HF) has collected and structured key challenges in the field of human factors of automated driving. Challenges and statements were collected and structured through several conference calls, email feedback and the CARTRE on-line system. The results were further discussed in CARTRE theme group meetings, and a first version of this position paper was published in May 2017. This version provides a thorough revision, incorporating review results from several CARTRE events, where we restructured and reformulated the challenges in order to create a more ambitious vision setting the scene for 2040. This revision also includes findings from recent projects.

1. SAE J3016 (2016). Surface Vehicle Recommended Practice. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. http://standards.sae.org/j3016_201401
2. CARTRE Thematic Interest Group User awareness, users and societal acceptance and ethics, driver training

Challenges

In 2040 we envision a transport system with a great penetration of driverless vehicles, sharing the road with pedestrians and cyclists. These pedestrians and cyclists may well be equipped with real-time communication enhancing the safe interaction with automated vehicles. 24/7 transport is available for everyone in many regions. We may still have hubs connecting transport modes, for instance using fast rail for long distance, and driverless pods for last mile transport tuning the supply to the demand. As automation technology matures, door2door automated driving may even cover all the demand as most public roads will allow SAE level 5 automation.
Manual driving may still be allowed, but probably not on all roads and times, and automation may have the authority to overrule the driver and prohibit the driver from dangerous actions. The use of old-timers (=current vehicles) may be constrained to private properties or limited public road sections and time periods. A majority of vehicles will be “public” or “shared” but it may still be possible to have a private automated vehicle that can be customizable to the clients’ wishes. Control rooms could act as supervisors of automated vehicles’ traffic being able to arrange technical assistance, social assistance to users, and may interact with other road users.

Based on this vision we have structured the Human Factors challenges in 3 lines:

1-Automated vehicles allowing manual driving

How can we ensure a safe evolution towards a future where manual driving is the exception?

L. How can we predict and deal with effects of vehicle automation on humans such as misuse, skill degradation?
M. How can we shift control from the driver to the vehicle automation and return control back to the driver?
N. How can we make the vehicle automation adaptable to user needs and states?
O. How can driver state monitoring contribute?
P. How can automation overrule the driver and prohibit the driver from dangerous actions, in an acceptable and legal manner?

2-All automation levels including driverless vehicles

How can we ensure a safe interaction with all kinds of other road users?

Q. How can we develop vehicle control strategies which are intuitive and acceptable for other road users?
R. How can communication using (visual, auditory or wireless) contribute to a safe and acceptable interaction?
S. How can remote supervision contribute to (perceived) safety and acceptance?
T. How can remote control takeover and deal with abnormal situations?

3-Design and verification

Can we sufficiently understand the human interaction with automation to propose systematic approaches for design and verification?

U. How can we systematically design and evaluate automation and human machine interfaces to ensure a safe and acceptable interaction?
V. How can human factors evaluation be incorporated in legal and consumer test procedures?

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Statements

In the HF Themes expert group the following statements for each of the challenges listed above were defined. Statements were collected and structured through several conference calls, email feedback, stakeholder feedback and the CARTRE on-line system.

1-Automated vehicles allowing manual driving

Challenge A: How can we predict and deal with effects of vehicle automation on humans such as misuse, skill degradation?

It was agreed within the group that we need to further explore the role change the human will experience when using automated vehicles (from driver to passenger) and understand the Human Factors effects. In particular we shall study human automation interaction in real vehicles, on public roads with experienced users.

Regarding the effects of automated vehicles on driver skills there was a strong agreement within the group that automated driving will lead to a deterioration of driving skills. With higher automation levels "all responsible humans" may be able to operate vehicles, but with lower levels of automation, driving education and assessment will remain essential. The group saw a need for a revision of driving school curricula but did not agree on the question in which form drivers should be trained (e.g. in simulators) or on the question if drivers need to be requested to drive manually during a specific portion of their driving time. Training may also be provided on road by automation tutoring and testing drivers in the ability to drive manually and to use the automation.

Challenge B: How can we safely shift control from the driver to the vehicle automation and return control back to the driver?

Transitions of control from automated to manual driving have been researched extensively in critical scenarios, and recently also in non-critical scenarios. The recent project HFAuto concludes[3]: *.."safety concerns remain for take-over requests (TOR) where the automation requests the driver to take back control. Several recent studies still show some collisions and road departures in safety critical TOR. …Thus, we tend to conclude that even with substantial time-budgets, advanced interfaces and DSM, human drivers will not always regain control of their vehicles safely and appropriately, where lane changes involving other road users are a particular concern. When drivers do not react appropriately to the TOR, it is desired that the automation detects this and transitions to minimal risk. If such minimal risk solutions are implemented for all possible events, this will result in SAE level 4 automation."*

Challenge C: How can we make the vehicle automation adaptable to user needs and states?

Within the discussion group there was a strong consensus that the automated vehicle should be designed following adaptive automation principles that allow for adaptability of the HMI design in general. As examples the following were discussed: adaptability of the interaction design in take-over situations and adaptability of the driving manoeuvres and driving style of the automated vehicles based on user preferences, needs and user states. There might be also very different expectations across different regions of the world that need to be considered in the interaction design process. However, it shall be realised that such adaptation will complicate design and testing procedures, and may conflict with a need to harmonize interfaces.

Challenge D: How can driver state monitoring contribute?

For this challenge the group discussed that the human factor in monitoring vehicle behaviour and take over control might be also relevant for SAE level 4 or 5. The role of the driver as a monitor is seen as an issue for SAE level 3 in particular. However, also in level 4 and 5 there may be situations where the driver wishes to intervene. A driver may feel discomfort or mistrust the system. There was a strong agreement that as long as vehicles allow the driver to take manual control, continuous driver monitoring is needed to ensure that the user on-board behaves as intended. However this creates the challenge of defining desired and tolerable states for a wide population, and on acceptance

3. Happee R, de Winter JCF, Kyriakidis M (2017). HFAuto D5.3 Roadmap for market introduction of highly automated driving. http://hf-auto.eu/?page_id=58

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of the assessment by DSM. Driver state monitoring will presumably detect the most apparent aberrant states and misuse such as drivers leaving the driver seat or sleeping. However, in detecting the more subtle states such as vigilance a fully robust and timely detection seems not within reach. Thus, we expect DSM and in particular eye tracking and head tracking to provide a valuable contribution to the safety of automated vehicles, but DSM may not be sufficiently robust to provide full certainty on driver readiness to resume control.
Monitoring users of automated vehicles may address further challenges in detecting motion sickness or other deviant states and social interactions between users. This information can be used to adapt the driving style in case of motion sickness or invoke control assistance.

Challenge E: How can automation overrule the driver and prohibit the driver from dangerous actions, in an acceptable and legal manner?
There was a strong disagreement or non-consensus voting on statements related on how to ensure that the users on-board behave as intended. This was reflected in strong disagreement/non-consensus in statements such as "If the driver does not behave as expected some form of "penalty" is needed." A particular challenge will emerge in dealing with situations where the automation detects misuse or other risk-elevating behaviour by the human driver. Here automation can be provided with the authority to overrule the driver, but this imposes challenges in term of acceptance and liability.

2-All automation levels including driverless vehicles

Challenge F: How can we develop vehicle control strategies which are intuitive and acceptable for other road users?
As automated vehicles will be rolled out gradually and driven within complex, mixed traffic environments the participants of the group saw a strong need for automated vehicles to understand the intent of surrounding traffic participants (like human drivers currently do).
The participants of our discussion group believe that automated vehicles will change the current traffic situation in a way that a new traffic system will emerge, where new human behaviour, when interacting with automated vehicles, may emerge and that this behaviour is relatively unknown at the moment. For example, other road users might take advantage of automated vehicles and cross the road because the automated vehicle will stop anyway.
Where vehicle control strategies shall be intuitive to other road users, they shall also be intuitive and comfortable to vehicle users. A particular concern is self-driving car sickness which may prohibit users from taking their eyes off the road, and use the driving time for work or leisure acitivities.

Challenge G: How can communication (visual, auditory or wireless) contribute to a safe and acceptable interaction?
The intention of the automated vehicle should be explicitly communicated to the human driver and the surrounding traffic participants. This also covers the need for the design and development of new interaction means between automated vehicle and external traffic participants. This includes so-called "external HMI" which communicate the AV intentions by means of external displays, sound messages or wireless communication.

Challenge H: How can remote supervision contribute to (perceived) safety and acceptance?
This challenge was raised late and the discussion was inconclusive, and still open for research. The topic covers all issues that are related to remote operation and control of automated vehicles. There is only very little knowledge at the moment how remote operation affects Human Factors relevant measures such as the perceived safety and acceptance of on-board users of AVs.

Challenge I: How can remote control takeover and deal with abnormal situations?
This challenge was raised late and the discussion was inconclusive, and still open for research. More knowledge is needed if remote operation is a promising solution for situation in which the user on-board is not able to take over or for vehicles where not control elements are installed any longer for users on board. Remote operation could help to solve abnormal situations. Beside all technical questions, there is only little knowledge at the moment how such a

work place for remote operators should be designed and in which situations the remote operator is able to handle abnormal situations safely.

3-Design and verification

Challenge J: How can we systematically design and evaluate automation and human machine interfaces to ensure a safe and acceptable interaction?

When designing an automated driving system the human should be seen as a part of the system and the human needs should be considered from the beginning of the design process. On a general level the group further discussed and agreed that we need some kind of standardization for the user interface and the interaction design and evaluation of automated vehicles.

The participants of our discussion group believe that automated vehicles will change the current traffic situation in a way that a new traffic system will emerge, where new human behaviour, when interacting with automated vehicles, may emerge and that this behaviour is relatively unknown at the moment. For example, other road users might take advantage of automated vehicles and cross the road because the automated vehicle will stop anyway.

Challenge K: How can human factors evaluation be incorporated in legal and consumer test procedures?

Regarding testing and certification there was a strong consensus that we need to develop dedicated Human Factors test procedures to ensure safety of interaction with user on-board and other road users. However there was a strong disagreement or non-consensus which test environment would be best for doing such tests as participants do not fully agree with the assumption that simulator studies on automated vehicle effects such as hand-over time, trust and skill degradation show comparable results to real vehicle studies. Driver modelling can also be an option.

Future research needs

The challenges outlined above will have to be addressed for diverse traffic systems worldwide. This will create an immense challenge, given the huge variations in transport systems, vehicle types and human behaviour.

The human factors community will need to develop an understanding of this wide range of interactions, and use this to develop systematic methods to design and evaluate the human interaction with automation.

Ideally, such methods would include human behavioural models (adaptive as experience is accumulated), as these would allow efficient and safe evaluation of large numbers of scenarios. However, major efforts will be needed to develop and validate suitable human behavioural models and simulation methods.

The foreseen change of the transport system calls for a proactive HF approach. The research and industry community is often incrementally introducing technology, and then testing how humans use and appreciate the technology.

We propose a proactive approach first defining ambitious long term objectives (e.g. SAE level 4 & 5), and then defining steps towards these levels. We may define the desired human interaction with automation, and then systematically design automation and interfaces to achieve this. In this respect, it will be increasingly important to adopt a systems approach with the possibility of redesigning the entire transport system.

Below we highlight topics for near term research (results achieved in 5-7 years)

- Study how humans interact with automated vehicles in several scenarios, focus on urban areas, and systematically explore differences between regions and cultures.
- Conceptualise new interaction means for automated vehicles (eHMI), especially with surrounding traffic participants and develop methods to design the safe, intuitive interaction of AV with other road users.
- Focus on SAE level 4 automation rather than level 3, and addressing automation versus human conflicts in cases where the human fails to adequately resume control. Should the automated system be able to postpone driver take-over (SAE level 3/4) and how should this be realized (freeze steering wheel, disconnect steering wheel, put enormous counter torque on steering wheel, etc.)?
- Find design solutions and standards for HF challenges such as misuse, skill degradation, level of trust and acceptance, motion-sickness during non-driving activities in highly automated vehicles.

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- Study the benefits of adaptability of AVs to different user needs, user states and user groups.
- Study how new traffic environments can enhance the acceptable introduction of AVs.
- Use first data of field studies such as L3 Pilot to study human automation interaction.
- Study and design remote control for AVs.
- Work towards harmonized HF/HMI design and test procedures ensuring the safe and acceptable human interaction with AVs, to be included in consumer and legal test procedures.

Expected Impact

As a human factors community we aim to ensure a safe and acceptable introduction of automation on public roads. This will enable a drastic reduction of fatalities and injuries, and a greatly improved mobility.
These will only be achieved if HF is well integrated in the design and verification of automated vehicles.

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