A "Driver-more" Approach to Vehicle Automation

Andrea Castellano, RE:Lab Srl, Italy, andreacastellano@re-lab.it**, Serena Fruttaldo,** RE:Lab Srl, Italy**, Elisa Landini,** RE:Lab Srl, Italy, **Roberto Montanari,** RE:Lab Srl, Italy, **Andreas Luedtke,** Offis, Germany

ABSTRACT

The scope of this paper is to describe an innovative interaction paradigm between the driver and highly automated vehicles, developed in AutoMate EU project. This new interaction modality is based on the cooperation, i.e. the mutual support in perception and in action between the driver and the car. The cooperation aims to exploit and make concrete the complementarity of the human and the automation.

The concept and the implementation have been tested by evaluating the system that more than others allows the driver to cooperate with the vehicle, i.e. the HMI. This tool has been selected since it enables the interaction, and indeed the cooperation, between the vehicle and the driver. The users were asked to interact with the HMI: a set of questionnaires was administered in order to test how this interaction paradigm is perceived and to measure the workload related to the interaction. The main impact of this approach is to increase the comfort and the acceptance of this disruptive technology, since the conceptual solution of mutual support can improve the relationship between these two agents, creating a third agent, the team, made of human-like technical solutions.

Keywords: HMI, Vehicle automation, Human-automation interaction, Negotiation-based communication, Cooperation.

1 INTRODUCTION

In the next few years, vehicle automation will change radically the conception of the driving task and the relation between the driver and the vehicle. Different approaches have been used to reach the full automation (Jian et al., 2015), taking into account the human factors related to the driving task (Cunningham, 2015).

At the moment, the mainstream approach is to reduce the role of the driver through the automation, chasing the so-called driverless approach. This safety-oriented paradigm seems to put limited consideration into the role of the human, replacing his/her role with the automation. Moreover, the traditional approach at vehicle automation is based on task distribution. The cooperative approach follows the principle of flexibility in task distribution; in order to achieve this flexibility, based on the current demands of the situation, on the capabilities and on the state (attention, readiness) and the capabilities of the human driver, as well as on the automation, in the joint driver-vehicle a close coordination between driver and automation is needed. The traditional, technological, approach is expected to transform advanced driver assistance systems gradually into fully autonomous cars.

But until the driver is in the loop (i.e. not fully autonomous), we must develop an interaction strategy that leverages on both the strengths of the automation and the driver to overcome their limits and cope with the

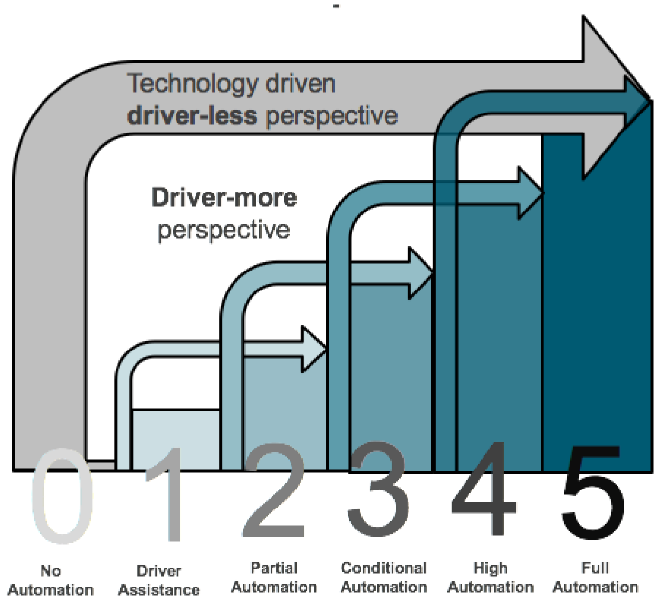

Figure 1: Driverless and "driver-more" approach to vehicle automation

complexity of the real world.

2 BACKGROUND

Two agents can be described as in a cooperative situation if they meet two conditions: (i) each strives towards goals and can interfere with the others on goals, resources, procedures, etc. Interference can take several forms, for example precondition, etc. If there is no interference, coordination is prebuilt and is not questioned during task execution; thus, the agents' activities are independent; (ii) each tries to manage interference to facilitate the individual activities and/or the common task when it exists ((Hoc, 2000). Therefore, the cooperation happens when humans and machines execute tasks together, use resources together, interact with each other in a dynamic environment and make autonomous decisions. So, the cooperation is not only a matter of task distribution, since it concerns also a perceptual and decisional level. This concept, based on the Hoc model of cooperation shown in **Errore. L'origine riferimento non è stata trovata.** (Hoc, 2009) has been exploited and extended in the project's framework, and it will be will be described in the next chapter.

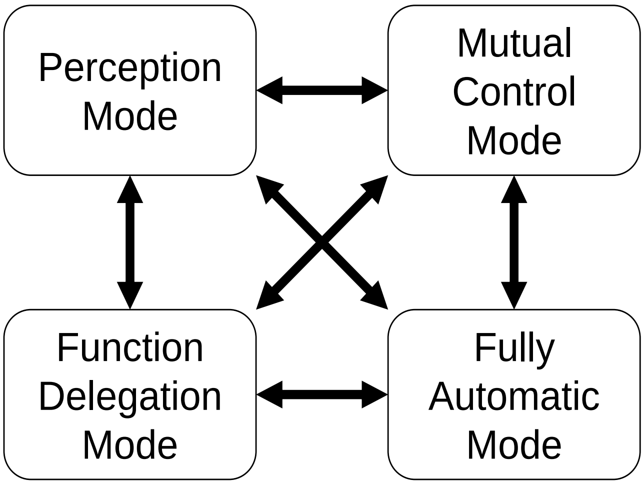

Figure 2: Modes of Cooperation

The success of more complex and more automated vehicles in the future will depend on how well they interact, communicate and cooperate with humans both inside and outside the vehicle. The quality of cooperation and communication will strongly determine the driver's trust in the automated systems. And in order to leverage the introduction of highly automated vehicles to the market and to fully exploit the automation potential to improve traffic safety and efficiency, these systems need to be trusted by the driver appropriately.

In terms of communication between humans and highly automated vehicles different solutions have been developed in the last years. For example, a novel and relevant solution implies multimodal communication. Multimodality in vehicle's HMI can be considered from two different points of view, namely, multimodal input and multimodal output. A multimodal input describes the driver-to-vehicle information flux; whereas, a multimodal output describes vehicle-to-driver one. Multimodal elements help to reduce the complexity of car’s cockpit. Nonetheless, each single interaction modality has advantages and drawbacks. These solutions that combine audio, visual interaction and sophisticated images, have been implemented in the TeamMate HMI. The paper aims at evaluating the concept of human-automation interaction based on cooperation. In particular, the technical enablers developed in this project have the scope to suggest an innovative interaction paradigm to overcome the concept of “driverless” approach to suggest a “*driver-more*” approach, i.e. to increase the role of the driver in the driving task instead of reducing it. In this way, the human and the automation will be seen as members of the team, and the cooperation is the means to compensate the reciprocal limits. It concerns mainly a different and unconventional use of technological supports to exploit the complementarity between human and technological agents.

This new approach implies the need to consider Human Factors implications related to the interaction with highly automated systems. For this reason, one of the scopes of this study is to understand if the greater involvement required to the driver compared to traditional systems is likely to increase the workload and affect his/her feelings, e.g. increasing frustration.

3 PROJECT CONCEPT

The top-level objective of AutoMate is to develop, evaluate and demonstrate the “TeamMate Car” concept as a major enabler of highly automated vehicles. This concept consists of considering the driver and the automation as members of one team that understand and support each other in pursuing cooperatively the goal of driving safely, efficiently and comfortably from A to B. In order to describe how the cooperation is actually implemented, it is important to briefly explain why the cooperation is needed, and how the human and the automation can support each other to create a safe, efficient and comfortable driving experience. Both the human and the automation have **limits** that can negatively affect the safety as well as the efficiency, the comfort, the trust and the acceptance of the autonomous driving. For the human, the limits are often related to his/her driving performance: they are likely to affect the safety, and cause accidents. For the automation, the limits, mostly at perception and decision level, may affect the efficiency and the comfort of the trip, and then, in turn, the acceptance of the automation. AutoMate goes beyond the simplistic concept of trusted automation by proposing a much more sophisticated approach to create trusted human-automation teams based on a new concept of cooperation. The AutoMate approach is based on the mutual complementarity between the driver and the automation: this support is achieved through the cooperation, between the team members.

While the Automation to Human Cooperation (A2H) is used to complement the human limits, the Human to Automation Cooperation (H2A) is implemented to allow the driver to support the automation to overcome its limits. The complementarity between the driver and the automation is the conceptual solution to compensate the reciprocal limitations. while the cooperation is how the complementarity is implemented. Figure 3 shows how both the A2H and the H2A cooperation can be implemented in perception (state A and B) and in action (state C and D).

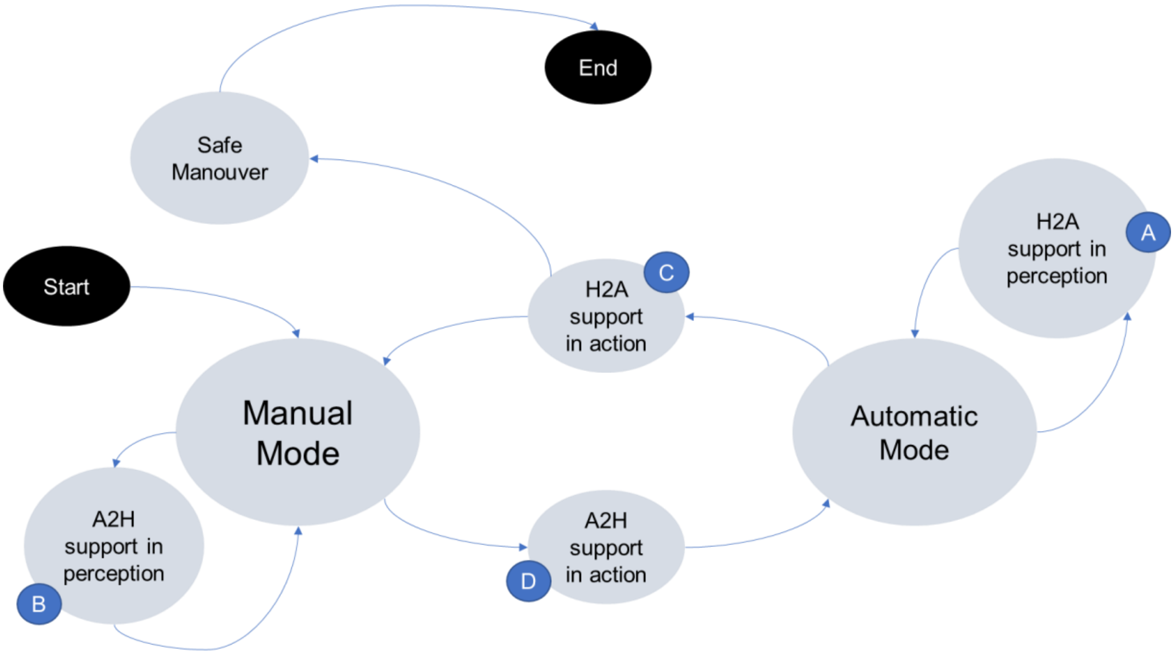

Figure 3 - State machine that shows how the cooperation is implemented

To implement this disruptive concept, a shift of paradigm in the role of the driver is required. The technology should not decreasing the human element, yet it must support the driver to have a new role: he/she must be involved with a different role in the driving strategy. What is this new role? While increasing the levels of automation, the role of the driver shifts from driving tasks to decision-making tasks to complement the limits of the automation. In this scenario, the HMI is the key enabler to implement the innovative cooperative concept: a new concept of interaction has been designed to allow the automation to involve the driver in the driving strategy to deal with the complexity of the real world. The archetypal interaction paradigm, that is warning-based, is still used to suggest critical situations, but when the situation is not safety-critical the interaction is negotiation-based.

So, the HMI developed in Automate is innovative in terms of concept, since it introduces a new interaction paradigm, but is also disruptive in terms of implementation. The success of this strategies relies less on extraordinary intelligence and more on sophisticated negotiation of changing context and subsequent behaviour. For this reason, we used a 3D video to deeply explain the cause of the request of support and the expected behaviour. Both in terms of concept and implementation the most disruptive part is the H2A in perception because it allows to reduce the number of requests of takeover (a well-known safety critical condition in the driver-automation interaction)

4 TEST METHODOLOGY AND RESULTS

A test to evaluate the HMI was performed on the instrument cluster, since it can be considered as the main tool in which the cooperation happens. The study was preliminary and a small sample of users were involved. The number of participants selected for the test was 9. The gender of the subjects was balanced to avoid possible biases: 5 males and 4 females were recruited. The average age of participants was 29,44 years (Range=39-23; σ=4,55).

Research questions for the specific H2A support (in perception compared to the support in action, i.e. the request of takeover from the vehicle to the driver) were:

I. Does the driver understand that the automation is asking for a support *only* in perception?

II. Does the driver understand that he/she has *only* to use his/her perception (in place of the sensors of the automation) and provide a feedback, instead of taking back the control of the vehicle?

III. Is the support in perception able to reduce the cognitive workload and the frustration related to the disengagement?

The participants were asked to interact with the HMI in a static experiment; they were invited to examine the HMI’s behaviour in different use case’s scenarios, and then to answer some questions to measure the level of comprehension of the message. The message was display in a digital instrument cluster and reinforced with audio, i.e. vocal communication in natural language from the vehicle to the driver, to adapt the communication to the complexity of the scenario. In order to measure the workload, the NASA-TLX questionnaire was administered after each scenario. This tool is used to measure different levels of workload, including mental, physical and temporal demand (Hart et al., 1986). It is a self-reported measure, widely considered as a solid technique to quantify the workload. It has been used in different domains, including aviation (Zheng et al., 2011), and automotive (Pauzie and Manzano, 2007), including autonomous vehicle research (Schipani, 2003),

The research questions (I) and (II) were stated as requirements to validate the HMI: results show that 96,3% of answers about the type of support needed were correct (success criteria: > 90%); (I) moreover, the message was correctly understood by the users, i.e. we’re able to understand that only a perceptual help was request by the vehicle (results: 96,3% - success criteria: > 90%).

The results of the NASA TLX questionnaire show that the support in perception is considered as less demanding then the support in action, confirming the hypothesis and giving strength to the approach established in the concept. In fact, the overall workload perceived by the users was lower for the support in perception than the support in action (Δ = 0,73). In particular, the support in perception proved to be effective in improving the perceived performance (Δ = 1,05), reduce the effort (Δ = 0,88), and reduce the frustration (Δ = 1,25). Although the HMI for H2A support in perception (negotiation-based) is more complex than the warning-based HMI (to adapt the amount of

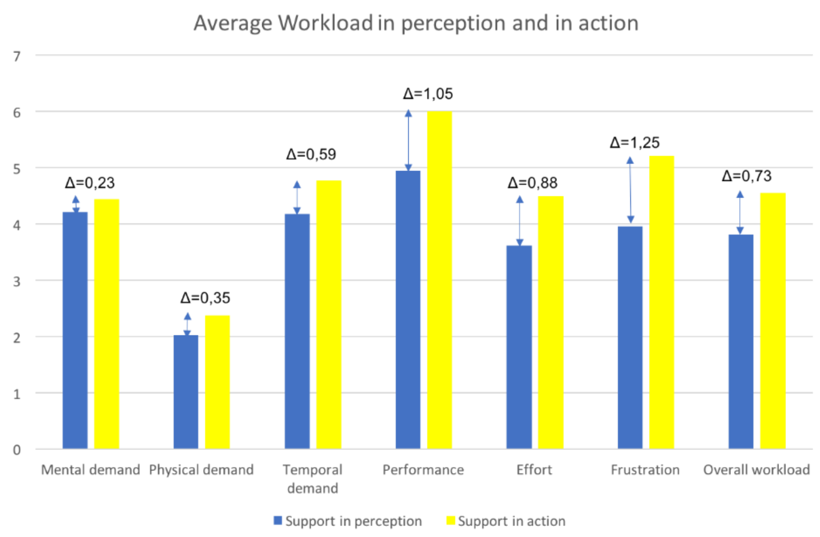

Figure 4: Average workload in perception and in action

information to the complexity of the situation), the users perceive less effort when the cause of the need (i.e. the limit) of cooperation is explained.

5 CONCLUSIONS AND EXPECTED IMPACT

This paper describes the concept of cooperation developed in AutoMate project, how it has been implemented through the HMI and tested to assess its consistence. In particular, the concept of cooperation, as an implementation of the complementarity between the human and the automation, has proved to be a promising solution to increase both safety and acceptability issues arising from the increasing vehicle automation. The results of the experiment suggest that the most innovative direction of support (i.e. H2A, when the automation requests a support to the driver) is well understood and accepted by the users. Moreover, the H2A support in perception has been measured to be less demanding then the support in action (the transition of control). Although this study is preliminary and has several limitations due to the small sample size and the lack of statistical analysis, this pointing can be considered a promising outcome. In fact, although the HMI for H2A support in perception (negotiation-based) is more complex than the A2H warning-based HMI (i.e. the archetypal paradigm used in automotive HMI industry and research), the users have proven to be able to understand it and to perceive correctly the reduced requested effort compared to the H2A support in action (i.e. the request of takeover). The findings emerged during this study are likely to be used as a basis to design effective Human Machine Interfaces for highly automated vehicles. This concept and its implementation can be considered an innovative solution that is likely to be implemented in a short-term period, before the adoption of fully automated vehicles. AutoMate project follows an iterative path; the next steps foresee to test this concept in more complex scenarios with a larger sample of users, in driving simulators and real cars.

So, why “driver-more”? Because to increase the involvement of the driver it means to foresee a near future of cooperation that does not weaken the driver, rather it empowers him/her, reinforcing the role of the human.

As stated by Ju, “future adopted automation systems will not wrestle control with the human: the team will negotiate activities, communicate and reconcile disparate perceptions of the environment and anticipate actions with explicit and implicit interactions” (Ju, 2015).

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