Testing Human-Machine Interfaces with a Low-Cost Modular System

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Abstract for demonstration

Abstract—**Automatized systems have become progressively widespread on roads, still machines have not yet taken control of vehicles from humans. This paper introduces a new low-cost modular sensor and data collector system that provides information for analyzing human driver behavior in different traffic situations while using various user interfaces.**

I. Introduction

Individual transportation is constantly changing. Transformation of automated, semi-autonomous and autonomous vehicles plays a big role in this change and as a result user interfaces (UI) are also developing. As new safety critical active functions or integrated self-driving modes are implemented in cars, a special UI design approach is needed to keep user experience (UX) sustainable. It has been confirmed that at higher SAE levels [1] the number of Non-driving Related Tasks (NDRTs) increase, road-based vigilance tasks are reduced [2]. The aim of this study is to test whether present Human-Machine Interfaces (HMI) are suitable to manage proper communication and support the required safety level which is promised by Advanced Driver-assistance Systems (ADAS). Cognitive infocommunications (CogInfoCom) investigates the link between the research areas of infocommunications and cognitive sciences, as well as the various engineering applications which have emerged as a synergic combination of these sciences [3]. Therefore the elements of the above systems can actually be identified as Human Computer Interaction (HCI) and based on this, we can examine it as a CogInfoCom System [4]. This paper outlines the design of a modular, low-cost test system which supports psychological, UI development investigation and research. Since our study is presented in Demo Paper, the article do not include results, as further measurements are necessary.

II. Theoretical Background

We still use automobiles to get from one place to another, but the need for our senses, cognitive focus and physical activity to drive vehicles is decreasing seemingly and significantly with the advent of increasing integration of technologies into these vehicles. Drivers have to control the vehicle largely manually, and also operate semi-automated or automated and autonomous systems, capable of reacting to many traffic situations [5]. Present HMIs are built on the foundation of previous generations of fully manually driven cars. Automation is still only on SAE level 2 for the masses, which means that vehicles available for consumers are equipped with ADAS. In spite of this, most vehicles have fundamentally unchanged UI concepts, focusing on safety and ergonomics. UX is evolving through the introduction of touch screens, haptic feedback, voice recognition and motion sensing [6]. Hence, multiple controllable functions and system elements have added a larger demand for competence and attention – cognitive workload – for driving [7]. To evaluate HMI, we have to consider three factors: 1. Attributes of Human-Machine Cooperation; 2. Human trust in Automatic Machines; 3. Human need for transparency of system operation.

A. Attributes of Human-Machine Cooperation

HMI is the tool for the cooperation of humans and machines. Human Machine Cooperation (HMC) research is described in various ways and points of view. On the one hand, CogInfoCom deals with combinations of artificial and natural cognitive systems. It aims to find and investigate new blended combinations of artificial and natural cognitive capabilities instead of focusing on the interaction between the artificial and natural cognitive capabilities. On the other hand, it describes several other disciplines: some focus on psychological mechanisms with cooperative activities, others try to determine tools and human-computer interfaces which support these cooperative activities [8]. „Cooperation" in this sense stands for a situation where a human and a computer – operator and machine – work on the same task and perform actions together, which need to exchange information. As we consider the specific HMI subarea we have studied as a part of CogInfoCom, we used cognitive methods for examination. From this perspective, the focus of our analysis is actually on the intercognitive communication: the information transfer between a human and an artificial cognitive system.

B. Human Trust in Automated Machines

A multi-layered conceptual model was constructed for examining trust and reliance [9]. Complexity of trust was simplified to three layers: dispositional trust, situational trust, and learned trust. The different factors in each layer affect e.g. the operator's perceptions, the situation or trusting tendencies of the system. Providing appropriate and permanent feedback about automated system reliability and performance to users generate higher levels of trust. As interpersonal relationships are

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based on reliability, dependability and faith, trust in automation is a specific form of interpersonal trust which follows the same stages, but in an opposite way [10].

C. Human need for transparency in system operation

Humans combine several heuristics and even think in meta-heuristic procedures in order to make right decisions [11]. This process is even more complex if an HCI also. The intentional model of Lyons [12] presents that it is important for the user to identify the main functions of an autonomous system in order to fully understand its purpose. Based on a Cognitive Work Analysis model the driver should know the maximum level of a vehicle's autonomy, what the autonomous system can perform, and how prioritization is managed [8]. In autonomous mode, the driver must be informed of what the system does, when and how he/she can interrupt a task. The driver should clearly see decision making processes and know vehicle sensor boundaries. The driver must be able to know the current mode of automation and be able to switch between modes.

III. Proposed Model for Evaluating HMI

The design concept of the test system is to integrate a modular sensor and a data collection system which is able to provide information to analyze human driver behavior in different traffic situations while using diverse UI/UXs. Our research focuses on HMC, trust, and transparency on different levels of automation. The measuring system examines the driver in specific traffic situations and scenarios according to the following aspects: Investigation of driver behavior under ADAS operation (SAE level 0-3); Investigation of driver behavior in an autonomous vehicle (SAE level 4-5); In Vehicle Information System cognitive load test; Investigation of driver behavior and reaction under the influence of NDRTs; Investigation of vehicle-to-human interaction as a function of UI/UX design. The measurement system collects three main data groups: physiological data, vehicle data and stimulus generated by HMI. As a new approach, the data listed above are collected in a ROS-based system. ROS is an open source, flexible and scalable (modular) framework that enables the interconnection and communication of heterogeneous hardware elements. The operation of the hardware components organized in the network are independent of each other, but the information is exchanged in the form of ROS bag. The ROS Central Data Acquisition Unit (ROS Master) can provide processing solutions for incoming data packets (such as image processing). Using a similar concept, an ROS-based measurement system was used during human-robot interaction studies [13]. All physiological sensors are made system compatible by using appropriate drivers and transmitting bags to the ROS Master. Vehicle data is obtained from ROS-compatible system components of an experimental vehicle (in real world or simulated environment) [14]. Active stimulus implementation requires the design and programming of Graphical User Interfaces (GUIs) when using multi-purpose touch sensitive displays. In order to simulate physical buttons or knobs multifunctional and programmable demonstration panel(s) can be used. Auditory signals, distracting or entertaining acoustic effects and intervention of voice-based communication systems are also a part of the multimodal stimuli unit. For data collection, Nvidia Jetson development hardware is used. The synchronization of recorded data set is solved with timestamped data packets suitable for subsequent playback and evaluation. Several researchers pointed out how unbiased approaches of true human cognition can improve HCI design [4]. This merging and extension of cognitive capabilities are targeted towards engineering applications in which artificial and/or natural cognitive systems are enabled to work together more effectively [15]. One of CogInfoCom's goals is to focus on engineering applications in which artificial and/or natural cognitive systems can interact more effectively. Accepting this view, we argue, that better understanding of human behavior leads to the design of better machines. We hope that our measurement results will contribute to this process.

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References

[1] SAE International, „Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles," J3016, April 2021.

[2] E. Greenlee, P. DeLucia, D. Newton, "Driver Vigilance in Automated Vehicles: Hazard Detection Failures Are a Matter of Time", *Human Factors,* vol. 60, issue 4, pp. 465-467, 2018, doi: 10.1177/0018720818761711

[3] P. Baranyi, A. Csapo, "Definicion and Synergies of Cognitive Infocommunications," *Acta Polytechnica*, vol. 9, no. 1, pp. 67-83, 2012.

[4] P. Baranyi, A. Csapo, G. Sallai, "Cognitive Infocommunications (CogInfoCom)," *Springer International Publishing*, 208 pages p. 48, 2015, doi: 10.1007/978-3-319-19608-4.

[5] G. Kovacs, A, Hogye-Nagy, Gy, Kurucz, "Human Factor Aspects of Situation Awarness in Autonomous Cars – An Overview of Psychological Approaches," *Acta Polytechnica Hungarica,* vol. 18, no. 7, pp. 7-24, 2021.

[6] G. Meixner, C. Häcker, B. Decker el al., "Retrospective and Future Automotive Infotainment Systems—100 Years of User Interface Evolution," *Automotive User Interfaces. Human–Computer Interaction Series,* chapter 1, pp. 3-53, 2017, doi: 10.1007/978-3-319-49448-7_1

[7] K. M. Wilson, S. Yang, T. Roady, J. Kuo, and M. G. Lenné, "Driver trust & mode confusion in an on-road study of level-2 automated vehicle technology," *Safety Science*, vol. 130, no. January, p. 104845, 2020, doi: 10.1016/j.ssci.2020.104845

[8] S. Debernard, C. Chauvin, R.Pokam, S. Langlois, "Designing Human-Machine Interface for Autonomous Vehicles," *IFAC-PapersOnLine,* vol. 49-19, pp. 609–614, 2016, doi: 10.1016/j.ifacol.2016.10.629

[9] K. A. Hoff, M. Bashir, "Trust in Automation: Integrating Empirical Evidence on Factors That Influence Trust," *Human Factors,* vol. 57-3, pp. 407-434, 2015, doi: 10.1177/0018720814547570.

[10] J. D. Lee, K. A. See, "Trust in Automation: Designing for Appropriate Reliance," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 46(1), pp. 50–80, 2004, doi: 10.1518/hfes.46.1.50_30392

[11] J. Vallderdu, V. C. Müller, "Blended Cognition, The Robotic Challenge," *Springer Series in Cognitive and Neural Systems*, vol. 12, pp. 3-21, 2019.

[12] J. Lyons, "Being transparent about transparency: A model for human-robot interaction," *AAAI Spring Symposium - Technical Report*, vol. SS-13-07, pp. 48-53, 2013.

[13] W. Jo, S. S. Kannan, G. E. Cha, A. Lee, and B. C. Min, "A ROS-based Framework for Monitoring Human and Robot Conditions in a Human-Multi-robot Team," arXiv, 2020.

[14] Pablo M, Ahmed H, David M, and Arturo de la Escalera, „Complete ROS-based Architecture for Intelligent Vehicles," Advances in Intelligent Systems and Computing, vol. 694, pp 499-510, 2018, doi: 10.1007/978-3-319-70836-2_41

[15] P. Baranyi, "Special Issue on Cognitive Infocommunications Theory and Applications – Guest Editorial" *Infocommunication Journal*, vol. 12, no. 1, p. 1, 2020.