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MINARGUS: Test tool for User Experience measurement and parameter modification within ADAS simulation

Maik Auricht[a]*, Rainer Stark[a] *

a Technische Universität Berlin, Pascalstraße 8-9, 10587 Berlin, Germany

* Corresponding author. Tel.: +49 030 39006 111; maik.auricht@tu-berlin.de

Abstract

Advanced Driver Assistance Systems play a leading role in the revolution of vehicles; it has become a high priority for automotive industry and meanwhile is used in all automotive segments. In this paper, a tool is introduced, which allows capturing User Experience (UX) on the Model-in-the-Loop level (where only abstract models exist): MINARGUS. This solution allows direct feedback to other partners in the development process and, hence, allows a more efficient work relationship between system development engineers and test & validation engineers. The tool allows a connection between a simulation model and the measurement of physiological data in one environment. The Traffic Jam Assist system is used as an ADAS example in this paper.

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Keywords: Advanced Driver Assistance Systems; Validation; User Experience

1. Introduction

„Digital networking is a revolution around the car and the entire transport system. Communication and information are becoming increasingly important.

The exchange of information of all road users to each other and networking with the internet are major steps forward towards resource and time-saving traffic of the future." [1]

Advanced Driver Assistance Systems are important in this revolution; it has become a high priority for the automotive industry. Current systems still lack robustness and error free capabilities which negatively influence customer satisfaction. The errors vary from either compatibility problems between different systems to general runtime errors. However, one can also recognize dissatisfaction within different assistance systems. It may influence usability or even User Experience (UX) for various reasons (e.g. symbolic aspects, subjective feelings, habits). Within the development of Advanced Driver Assistance Systems, these motivations are tested continuously. The validation starts with a model-in-the-Loop (MiL), and ends with the Vehicle-in-the-loop (ViL), shortly after the physical testing process begins (driving tests, field tests, etc.). In this paper, a tool is to be introduced, which allows to capture the UX already on MiL level to be fed back directly into the development process. This tool allows for a more efficient work relationship between system development engineers and test & validation engineers.

Moreover, within the last 10 years, product development processes have changed significantly. The time-to-market has been decreased [2], the number of functionalities of a product has been raised, the portfolio of companies has been changed in terms of more variants [3] and with that, the complexity of the development has been increased [4]. In the end, the product has to satisfy customer demands. There are several validation cycles within the development process to make sure, the right product is being developed in terms of intended purposes of the customer. Beyond that, there are also verification cycles to make sure the requirements of the customer are fulfilled. The user experience needs to be taken seriously in order to fulfill the customer requirements.

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2. 2. State of the Art

2.1. Advanced Driver Assistance Systems

The driver's primary task, relating to road transport, is to have control over the car while safely navigating the road. Due to the increasing complexity of the resulting tasks, the driver can quickly reach physical and mental limits. From these factors, the most important functions can be derived to ensure the safety of the people inside (driver, passengers) and outside (pedestrians) the car. In this case the human being is the biggest and most unpredictable risk factor in itself. As a result the human being is also a main focus of the development of Advanced Driver Assistance Systems. Especially driver performance relative to driving a car relating to road transport must be considered as a starting point. In this perspective the driver is viewed not as a single factor but represents a dynamic factor embedded in the overall system and the environment.

The basic system configuration is the same for all Advanced Driver Assistance Systems and corresponds to a typical mechatronic system. The basis is always its mode of action, which can be: pneumatic, hydraulic, mechanical or electromechanical. In the first place the system receives state variables of a certain part of the system, which is realized by a physical or virtual sensor. In addition to the vehicle-related variables, sensors are used to record certain information from the environment. With a control unit the information is processed and evaluated. The actuators are then set to the desired change in the previously recorded state variable.

Between these components there are certain transport mechanisms, information, energy and mass transfer flow by which the communication takes place. The basic system provides information about all three flow types. The contact between the sensors and actuators are connected digitally via an information processing module, accordingly, there is only one flow of information. The information processing element is often still associated with information processing elements of other Advanced Driver Assistance Systems over a digital communication interface. Thus, different information can be worn together and included for the proper response of the actuator.

The Traffic Jam Assist is an intelligent form of cruise control that slows down and speeds up automatically to keep pace with the car in front of the own, especially in traffic jam. The Traffic Jam Assist consists of a longitudinal and a transverse guide assistant. The longitudinal component of the Traffic Jam Assist system consists of an automatic distance control and an automatic stop & go system. It has basically the same system limits as the two single systems. Therefore the Traffic Jam Assist cannot provide automatic driving in every situation. In certain situations, the driver receives a takeover prompt. Also, the driver must confirm the setting off from standstill. As an extension to the ACC Stop & Go is the assumption that large stationary targets can be detected by sensors. The transverse component of the Traffic Jam Assist system is to be limited to the low-speed range. In order not to provide the functionality of an autonomous city vehicle to the driver, the lateral control is available only under 40 km/h. In addition, the maximum steering angle is limited. If the situation requires a higher steering wheel angle, the driver receives a take-over prompt [5]. Figure 1 shows the basic functionality of the system including the different sensors such as camera, ultrasonic and lane keeping assist.

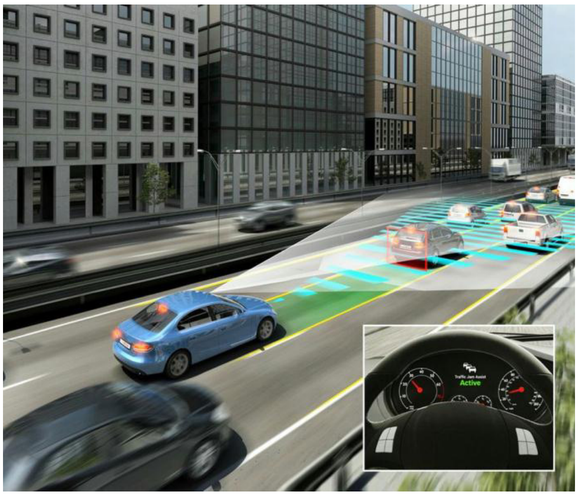

Figure 1: Traffic Jam Assist [6]

2.2. Validation methods for ADAS

Validation is the central activity of the product development process and therefore has a high relevance [7]. Mostly used in early phases are virtual prototypes such as Digital Mock-ups (DMU's). A limitation of the virtual environment, however, is the lack of tactile feedback. An object in the virtual world cannot be compared with the feeling of a real feedback in combination with the hand-eye coordination [8].

Only in the advanced phases of the product development process physical prototypes are built. As the overall integration and validation takes place predominantly at this late stage, the rectification of errors is usually associated with high costs and high effort [9].

The combination of digital prototypes with physical elements to realize real-time force feedback interaction is relatively new. There are different approaches within this field. Bordegoni et.al. for example, describe a framework for applications using mixed prototyping and Mixed Reality techniques. Therefore the Virtual Reality environment is enriched with physical elements (switches, buttons or other mock-ups). Hereby it is possible to evaluate for instance the ease of use, sensorial feedback or accessibility [10].

Within the development of Advanced Driver Assistance Systems there are different validation methods. The Model-in-the-loop (MiL) test is one of the first validation methods which will be conducted. MiL allows tests without the investment of hardware. MiL refers to a process in which an embedded system connects via its inputs and outputs to a matched counterpart system. In this case, tests can be conducted any number of times with different parameters. Also the use of data from real tests will be applied in practice. In later stages Software-in-the-loop (SiL), Processor-in-the-loop (PiL) and Hardware-in-the-loop (HiL) tests are used. During the SiL, the model of the MiL test is converted into C-code and will be tested in an environment.

In the early testing phases driving simulators are used in some cases. The maturity of the simulator (in terms of degrees of freedom, visualization, haptics, sound etc.) increases with the maturity of the model which needs to be tested. Within MiL, the models are mostly tested in a simple environment with basic controls such as a steering wheel, pedals and a monitor. Nevertheless most tests are only plausibility checks without a driver in the loop. In the ending phases, sophisticated simulators are in operation, which are able to reproduce G-forces.

2.3. User Experience

The haptic perception together with visual perception is an important part in building a mental model of the product to the user [11]. The tangible interaction with the prototype is a part of the User Experience (UX) concept. This can be understood as an umbrella term for various design and usability disciplines [12].

"By "experience" we mean all the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it." [13].

Research has shown that factors such as particular emotions (e.g. subjective feelings, physiological reactions), usability (e.g. effectiveness, learnability) and aesthetic aspects (e.g. visual, haptic) are playing a major role in the evaluation of products and product characteristics [14]. UX methods are usually used in the later phases. The integration in early phases is not being used yet. Where the classic usability refers to the objectivity of the user, the UX expands this approach. One tool for measuring the UX is the questionnaire AttrakDiff. The questionnaire goes beyond usability and considers aspects such as job satisfaction, attractiveness or the hedonic quality (stimulation, identity).

2.4. Driving simulators

Static driving simulators are suitable when the subjective impressions of the dynamics are not important. They are usually low cost and compact in dimensions. They are used for studies in which the dynamics play a subordinate role. The Usability Research Simulator (URS) at the Chemnitz University for example is a modular, portable static driving simulator. In addition to a 180 degree vision system, it consists of an aluminum profile structure for simulating the passenger compartment, which is changeable in its dimensions. The research focus is directed on the product development and manufacturing process, focusing particularly on the user-centered product design and improvement of the interface between humans and technology [15]. Due to their low purchase price, static driving simulators can be quickly assembled and disassembled in order to ensure a fast evaluation depending on the application requirements. A major disadvantage of static driving simulator is the so-called simulator sickness. The simulator sickness occurs in about 20-40 % of all users. It is very similar to the motion sickness [16].

Dynamic simulators also reproduce vehicle acceleration, rotations as well as other movements. Therefore motion systems are used (e.g. hexapod systems). The dynamic driving simulator of Daimler AG in Sindelfingen for example started its operations in October 2011 and is now one of the most advanced of its kind and consists of a dome with 360 ° visualization by both mock-ups and a complete vehicle that can be installed. The dome and the motion platform are mounted on a twelve-meter long rail for translational motion simulation that moves the system with up to 12 meters per second [17].

In the early phases the static simulators are often used because of the operation costs and because they are appropriate for most of the testing purposes. Figure 2 shows different driving simulators of Automotive OEM as well as from suppliers and Research Institutes.

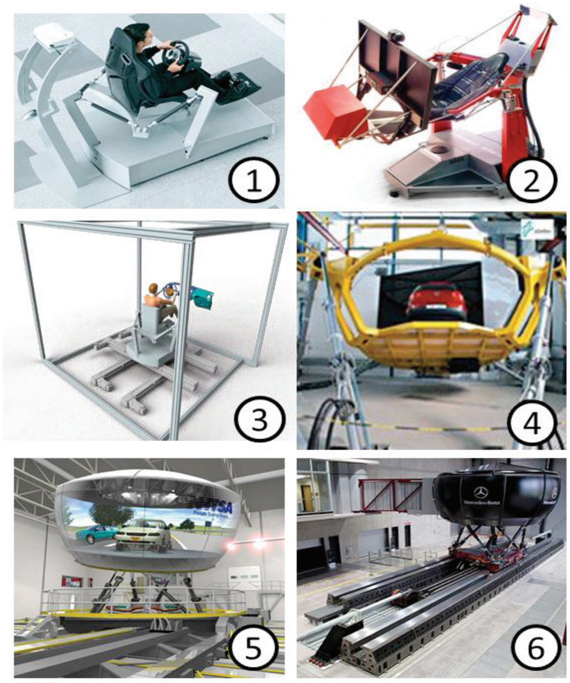

Figure 2: 1: Festo Airmotion Ride [18]; 2: Force Dynamics 401 [19]; 3: Digital Cube Test Center (Technische Universität Berlin) [20]; 4: DLR Dynamic Driving Simulator [21]; 5: Toyota Driving Simulator [22]; 6: Daimler Driving Simulator [17]

3. Motivation

The increase of computer technology in recent years facilitates more virtual testing. The human as a test object is integrated too late in the development process. The variety and quantity of assistance systems in a car lead to new problems which not only consist of Usability issues but also of UX. Thus, there must be a change in the development of mechatronic systems especially to consider UX in early phases of the development process. To support the change of the development process the Information Technology needs to provide innovative tools.

4. MINARGUS*: A new tool to measure User Experience online

Within experiments during a validation cycle (see chapter 2.2. Validation methods for ADAS) the user performs different tasks through a virtual world and experiences the movements, visualization and sounds from the simulation via suitable output channels (hexapod seat, 3D projection, and surround sound). The driver will be tracked through various channels: pulse, ECG, EEG, eye tracking, cameras, sound, input devices, etc. In order to track all changes and its effects directly, a new tool will be developed: MINARGUS (see Figure 3). On the one hand MINARGUS allows the visualization of all measured data and on the other hand it allows the direct parameter sweep. Therefore, the tool is directly connected to the simulation model. If the developer makes changes to certain pre-defined parameters, the effect can be viewed directly in MINARGUS. The advantage over individual tests with questionnaires is that several changes can be made within one experiment. Now the developer can draw direct conclusions and can optimize the parameter.

The tool is developed in Matlab/Simulink and therefore allows a direct connection via Matlab to the simulation environment (see Figure 3 (1)) such as dSpace Automotive Simulation Models (ASM) [23], IPG Carmaker [24], Dymola and others. The connection can be realized either via Matlab or the FMI Standard (Functional Mockup Interface [25]). On the other side, the tool is connected to the User Tracking Environment (2). This environment consists of a psychological measurement system (PAR-Port (3)) with several inputs such as EEG, EKG, EOG, ECG, Pulse. The system interacts via Matlab with MINARGUS. Furthermore it has a connection to different streams (video from the Eye-Tracking system and cameras, audio) as well as the satisfaction buttons which are located on the steering wheel. During a test, the operator requests the user to press either the "satisfied" button or the "dissatisfied" button on the steering wheel which are supposed to indicate the users experience in different situations. Those are tracked in MINARGUS.

Within the tool the user can choose between those different channels, depending on the test case (e.g. EEG, Satisfaction buttons, pulse) (4). Aside from the fact that the tool has the standard functionalities (save, open, jump to times, etc.) (5,6), it allows the direct parameter change within MINARGUS (7). Thus, the user doesn't need to switch between tools and simulation environments. By changing parameters (for example the starting delay) the user can see the influences via the different channels.

Developers, test persons and experimental designer are now working very closely together, to minimize the number of iteration cycles and time. The development environment has to become a test environment and vice versa. The new working areas need to be flexible, small and inexpensive, so that many tests can be performed. In industry driving simulators are usually both very large and expensive to purchase and operate and usually fully booked. Such a new working area is currently being built up at the Technische Universität Berlin under the title DCTC: Digital Cube Test Center. For this purpose a test center is built, which is an environment for both developers and experimental designer. The attempt of the test center is to be small, flexible and inexpensive. The core is an active driving simulator (hexapod system + motion platform for 6 degrees of freedom), a 360° active stereo visualization and a surround audio system [26].

5. Conclusion and Outlook

The proposed tool and its sub-projects (such as the development of a robust process and methods for the application) are currently being developed. The tool shall be validated at the end with a study consisting of > 30 participants. Hereby the test persons will drive a defined test scenario. During the test the operator changes parameters (such as starting acceleration or the starting delay (see chapter Advanced Driver Assistance Systems) on the fly. The measured data (such as EEG, ECG, pulse, etc.) can then be evaluated in real-time to optimize the parameters. Therefore two different sets of parameters will be compared to each other by using also questionnaires (e.g. AttrakDiff, meCue). The results will be published at the end of 2015.

Furthermore the interfaces of the tool shall be extended. One example is the Functional Mockup Interface (FMI).

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* MINARGUS = Minerva (Roman goddes of wisdom) + Argus Panoptes (Greek mythology: 100-eyed giant)

Figure 3: The GUI of MINARGUS (work in progress)

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