Integrating User Experience Validation into a New Engineering Development Process for Advanced Driver Assistance Systems

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AutomotiveUI '14 Adjunct, September 17 - 19 2014, Seattle, WA, USA

ACM 978-1-4503-0725-3/14/09…$15.00
http://dx.doi.org/10.1145/2667239.2667270

Abstract

Advanced Driver Assistance Systems play a leading role in the revolution of cars; it has become a high priority for the automotive industry and now is no longer reserved for only premium cars. In this paper, a process is to be introduced, which allows to capture the User Experience (UX) already on the Model-in-the-Loop level (where only abstract models exist) to be fed back directly into the development process. This process allows for a more efficient work relationship between system development engineers and test & validation engineers. Furthermore the work in progress of a new tool is shown: MINARGUS. It allows a connection between a simulation model and the measurement of physiological data in one environment. The Advanced Active Cruise Control (Advanced ACC) system is used as a continuous example to support the paper.

Author Keywords

User Experience, UX, Validation, Advanced Driver Assistance Systems, Model-in-the-Loop

ACM Classification Keywords

Design, Human Factors, Experimentation, Verification

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 play a leading role in this revolution; it has become a high priority for the automotive industry and now is no longer reserved for only premium cars. An example is the Ford Focus, which in the compact class currently has the most assistance systems on board. Today’s systems, however, 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 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 process is to be introduced, which allows to capture the UX already on MiL level to be fed back directly into the development process. This process allows for a more efficient work relationship between system development engineers and test & validation engineers. The Advanced Active Cruise Control (Advanced ACC) system is used as a continuous example to support the paper.

State of the art

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 Advanced ACC 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 Advanced ACC consist of a longitudinal and a transverse guide assistant. The longitudinal component of the Advanced ACC 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 Advanced ACC 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 Advanced ACC 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 [2].

Validation methods for ADAS
Within the development of Advanced Driver Assistance Systems there are a number of different validation methods. Validation is the central activity of the product development process and therefore has a high relevance [3]. 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.

User Experience
The haptic perception together with visual perception is an important part in building a mental model of the product to the user [4]. The tangible interaction with the prototype is a part of the UX concept. This can be understood as an umbrella term for various design and usability disciplines [5].
“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.” [6].
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 [7]. 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. Other tools which measure the UX are Affect Grid, mDES, VisAwi, ISO-NORM or Mano and Davis.

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

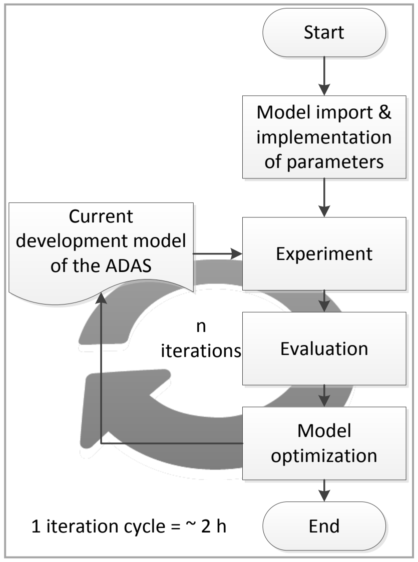

Figure 1: The old process

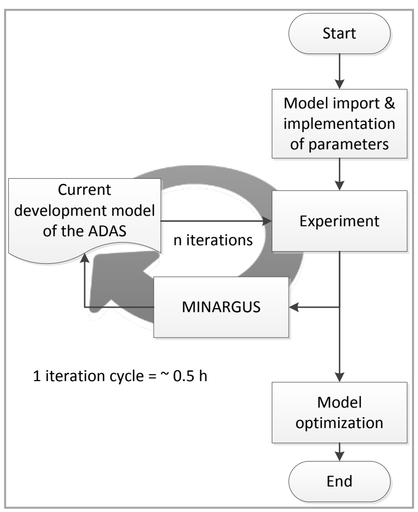

Figure 2: The new process

development process. The limitation of the running development processes for mechatronic systems are:

- Interactive prototypes, such as driving simulators, are used too late [8]
- Emotions, which are important for the acceptance of a mechatronic system [8] are not fully covered in the validation of the system
- The influence of parameter changes in the ADAS model are not directly visible

The proposed sub-process shall decrease these limitations.

Introducing a new sup-process to ensure proper UX-integration

Figure 1 shows the current process including the iteration cycle for the testing and optimization of parameters. Figure 2 shows the new sub process. The suggested process can be integrated in existing development processes. The new process should be embedded as early as possible. The sooner the human is involved in the development process, the more errors can be identified. Therefore it is recommended to embed the process when the logical models are developed. These models are usually developed in software tools like Matlab Simulink, Vector, dSpace, IPG Carmaker and so on. Those models need to be tested first, to make sure, the higher-level logic and behavior is correct. Only when this test is correct, it is suitable for further investigation. It follows a decision making process to be examined whether the system is relevant to a UX test or not. Not for all systems a complex UX test is necessary. For this, a method is developed which supports the decision making. This can be a (Excel-based) tool, which proposes a decision with the help of categorized questions and awarded grades. If this decision is positive in terms of a necessity of a UX test, the model needs to be exported. Generally it should be noted that for this purpose the Functional Mockup Interface (FMI) standard is suitable. The intention of the Functional Mockup Interface is a modeling environment that can generate C-code from a (dynamic) system model and can be exported to other simulation and development environments. The developer then defines the test and the parameters, which need to be optimized. Using the example of Advanced ACC, defined parameters can be the starting acceleration or the starting delay. Both parameters are highly important for the UX: A high starting acceleration and a short delay indicate an aggressive driving behavior of the system and could cause discomfort. Whereas a small starting acceleration and a long delay could cause discomfort in terms of being forced to interact because of the behind driving cars. These parameters are defined together with the experimental designer. The experimental designer now builds up the UX test with all its constraints (test procedure, test design, questionnaires, etc.). After defining the parameters, they are then integrated in the simulation model. The model and the simulation environment must allow real-time simulation because of adjustments to the parameters. In most cases there is a complete model of the car and the environment (streets, other cars, etc.). In this stage testing can be conducted. The test subject drives a virtual car in a simulator, which ideally covers all important sense areas (see chapter *User Experience*). The chapter *Online Parameter Sweep and Emotion Detection* shows the iteration between the experiment and the current development model in detail. Once the test has been performed, the results can be evaluated. The model optimization is the final step.

Online Parameter Sweep and Emotion detection

Within the experiment 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). MINARGUS stands for Minerva and Argus (Minerva was

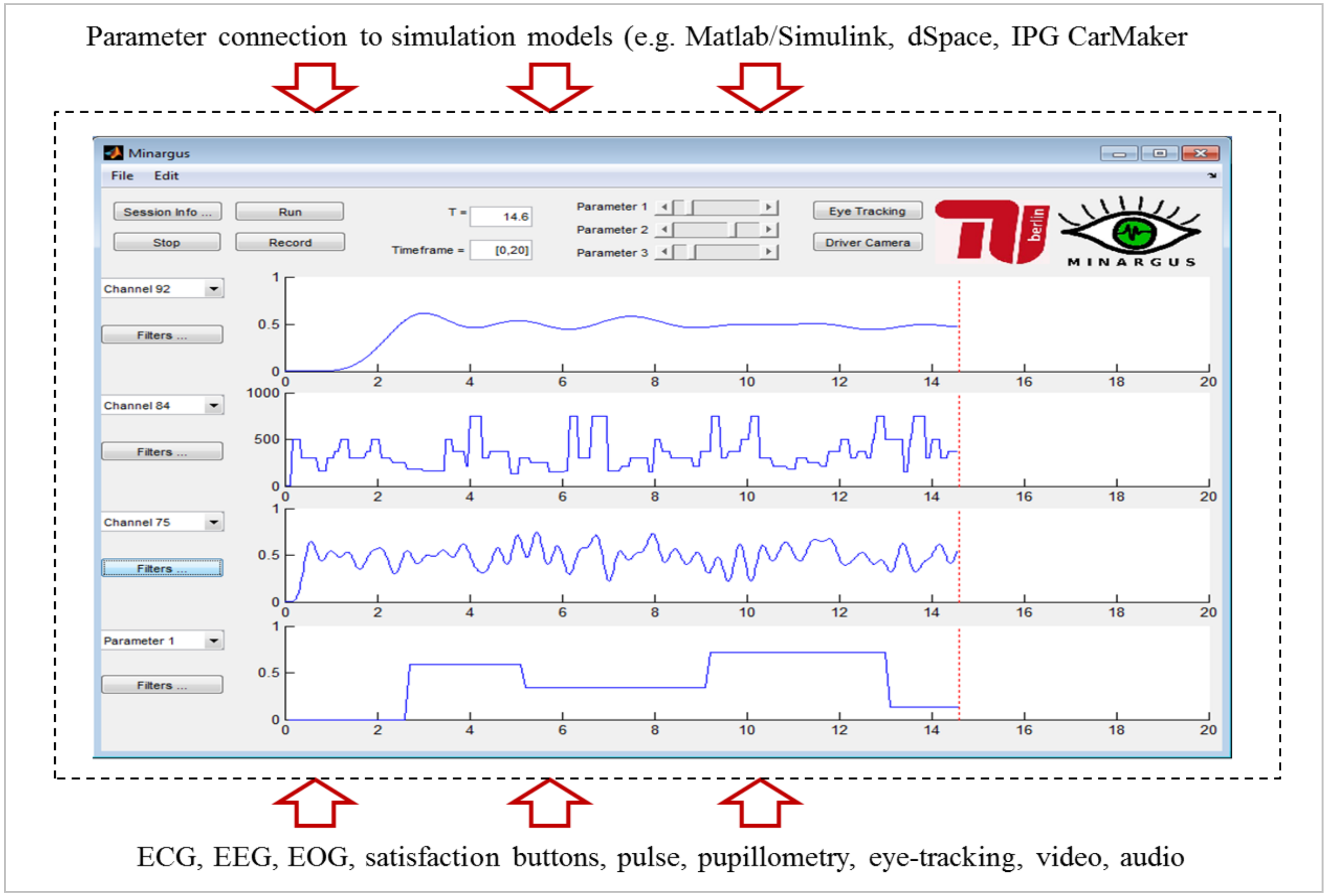

Figure 3: GUI of MINARGUS (work in progress)

the Roman goddess of wisdom and Argus is the name of the 100-eyed giant in the Greek mythology). 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.

Outlook

The proposed process and its sub-projects (such as the development of methods for each step) are currently being developed. The process 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 UX, 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).

Acknowledgments

The authors thank the European Regional Development Fund (EFRE) for supporting the research project FORUM "Forschungs- und Anwendungszentrum für Füge- und Beschichtungstechnik".

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