Tutorial: How Does Your HMI Design Affect the Visual Attention of the Driver

Sebastian Feuerstack
OFFIS
Oldenburg, Germany
feuerstack@uol.de

Bertram Wortelen
University of Oldenburg
Bertram.wortelen1@uol.de

AutomotiveUI '17 Adjunct, September 24–27, 2017, Oldenburg, Germany

ACM ISBN 978-1-4503-5151-5/17/09…$15.00
https://doi.org/10.1145/3131726.3131727

Abstract

The consideration of driver's visual attention for Human Machine Interface (HMI) design is critical to ensure fast reaction times in unexpected situations and to promote situation awareness in hand-over situations. The effect of an HMI to the attention distribution of the driver can be measured by performing eye-tracking studies in a driving simulator. Performing eye-tracking studies requires functional HMI prototypes but give no insights on the underlying mechanisms for the measured behavior. In the tutorial we introduce a tool-driven and model-based approach to visual attention prediction, which can be performed already based on early HMI mockup ideas and with less effort compared to eye-tracking studies. The tutorial starts with an introduction to the theories of model-based visual attention prediction. Thereafter, participants are invited to either predict the visual attention for their own HMI design ideas or conduct an evaluation of an exemplary use case with the software tools that the participants can install on their computers or use in our lab.

Author Keywords

Visual Attention; Monitoring; Human Factors.

CCS Concepts

• Human-centered computing~Visualization design and evaluation methods • *Human-*

centered computing~User models • *Human-centered computing~Systems and tools for interaction design* • Computing methodologies~Modeling methodologies

Introduction

The US National Highway Traffic Safety Administration (NHTSA) reported that 10 percent of fatal crashes, 18 percent of injury crashes, and 16 percent of all motor vehicle traffic crashes in 2014 involved one or more distracted drivers. Visual-manual interaction is considered as one of the main causes of distractions The NHTSA therefore recommends interaction designs that ensure that drivers spent less than 2 seconds with single glance and in a total sum not longer than 12 seconds away from the road away [5].

Eye-tracking studies in driving simulators are a common approach to the analysis of car drivers' visual attention. However, they require complex study setups. The machine interface (e.g. an automotive assistance system) and its environment (e.g. the driving situation) need to be realistically simulated to produce valid data. Furthermore effort needs to be spent on data analysis in order to match the eye-tracking recording to the dynamic traffic situation. Such data enables to estimate drivers' reaction times and absolute numbers on for how long drivers are required to shift their attention to interacting with an HMI. But the actual reasons for the measured behavior remain unknown.

In the tutorial we present a model-based attention prediction approach. It offers a low-cost and low-effort alternative to eye-tracking studies and is specifically targeted to a very early HMI design phase. In that phase, designs are elaborated based on sketches and non-functional HMI mockups. Driven by the idea of continuous testing in computer science where software being in development is continuously tested for each modification to e.g. measure its impact to the overall software performance or source code quality, we argue that a continuous evaluation of the HMI design impact to drivers' visual attention ends up in HMIs that can be efficiently monitored.

Model-based visual attention prediction also offers insights into how people understand and therefore use and monitor an HMI. This can be of benefit for HMI designers in two scenarios: First, if drivers predict their visual attention themselves it can improve designers understanding of drivers using the proposed HMI. Second, if data is collected within a design team, it can reveal differences in understanding of the HMI and prior hidden assumptions about how drivers will use the HMI within the team to foster discussion.

Benefit and Outcome

In this tutorial the participants learn the basic mechanisms of how humans tune their visual attention to monitor automated systems. We introduce the participants to basic models from psychology, which are selected and discussed based on their applicability for concrete human factor issues in manual and automated driving. With the theoretical foundations of visual attention in mind, we present the current state of the art techniques and tools that support modeling and analyzing how humans spent and tune their attention while driving. Finally, participants get the chance to apply what they have learned as part of the tutorial either based on their own use cases or on exemplary ones that we offer along with a software tool that participants can take with them back home to further

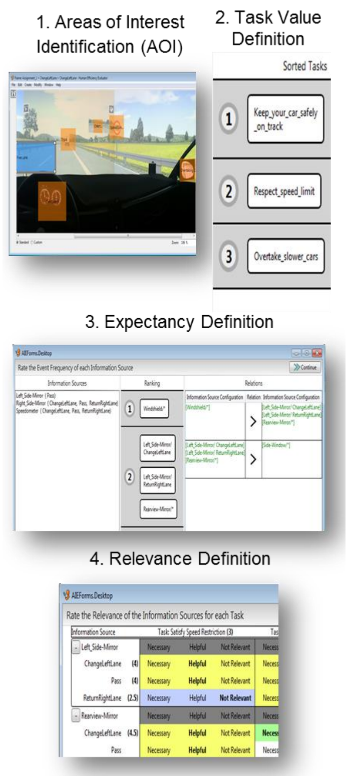

Figure 1: Visual attention modeling process with the HEE.

analyze how their can improve the visual attention allocation and reaction times of drivers for their HMI designs.

Content

This half-day tutorial is composed of three parts. We will begin with a lecture on modeling and prediction of visual attention, then ask participants to model attention with the offered techniques and tools on an individual basis and finally collect results in small groups that then present the overall outcome to all participants of the tutorial.

In the first part we introduce the participants to the approach of simulating human behavior based on psychological and physiological plausible models. Such model-based prediction methods have been applied for a wide variety of tasks: e.g. to evaluate drivers' monitoring behavior while approaching intersections [1], to explore how characteristics of the in-vehicle tasks impact visual scanning behavior [4], or to explore the impact of different urban Advanced Cruise Control (ACC) assistance system HMI designs [3] to the visual attention allocation of drivers. In the lecture we focus specifically on the SEEV model [6] and the AIE model [7]. The SEEV (Saliency, Effort, Expectancy, and Value) model of human attention allocation proposed by Wickens et al. [6] predicts human attention prediction based on four influencing factors. Two of these factors are task-related, top-down factors Expectancy and Value and are the main drivers of attention while driving a car [4]. Determining the SEEV model's expectancy and value parameters is difficult and requires expertise in cognitive modelling and the application domain. Techniques, like the lowest-ordinal heuristic and tools like the Human Efficiency Evaluator (HEE) [2] have been proposed recently to ease the creation of SEEV models based on these top down factors. Figure 1 illustrates the four principle steps for attention modeling.

In the second part of the tutorial, the participants are introduced to the HEE[1] and have the chance to model a driver's monitoring behavior for their own use case, exemplary ones and those of the other participants.

Finally, in the last part of the tutorial we guide the participants through the driver monitoring simulation and aggregate the predictions from participants that modeled the same use cases. In small groups the results are then explored, summarized andfinally presented to the entire audience of the tutorial. Figure 2 shows an exemplary result: a heatmap illustrating a driver's attention allocation. Figure 3 illustrates exemplary visualizations for further model explorations, like e.g. graphs depicting prediction differences between modelers that reveal differences in understanding of a situation in that an HMI is aimed to support the driver.

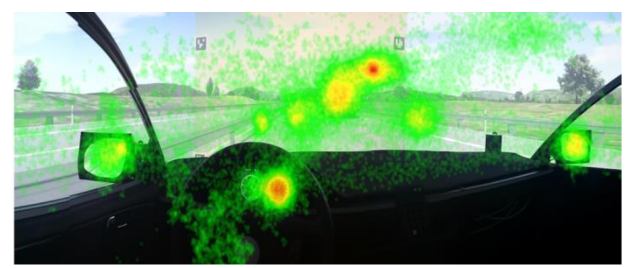

Figure 2: An exemplary attention prediction result: a heatmap depicting the visual attention allocation of a driver.

[1] http://hee.multi-access.de, last checked 06/14/17

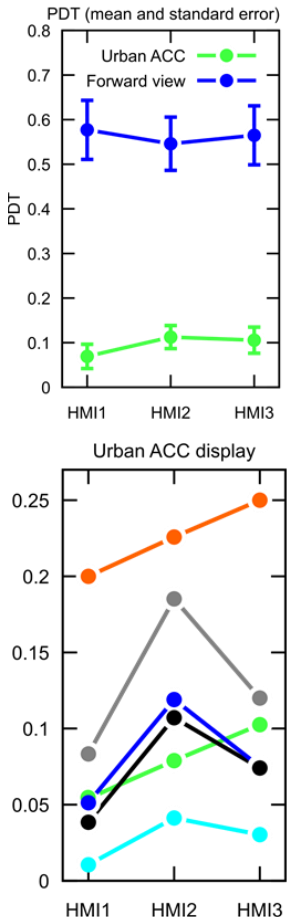

Figure 3: Exemplary prediction results: Percentage Dwell Time (PDT) distribution between an ACC and the frontal view (top) and expectancy rating difference between raters for different HMI versions (below) taken from [3].

Targeted Audience and Prerequisites

The tutorial is targeted to those that are interested in visual HMI or assistant system integration in vehicles. Ideally participants have designed or implemented in-car HMIs before or have an idea in mind for a future HMI that they then might use as an application example for visual attention modeling for the hands-on practical tutorial session. No specific further prerequisites are required and graduate students up to experienced researchers and practitioners from the industry are invited. Those with a notebook running on windows can install the required software beforehand. But we also offer computers with the software preinstalled in our lab.

Presentation Format and Tutorial Style

The tutorial will start with a lecture on the foundations of human visual attention, relevant basic psychological models, methods and tools. Thereafter, those participants that brought along their own use case are asked to briefly present their idea based on 5 mins and "1 slide" presentations. For all others, we offer an exemplary use case. Each participant is then invited to individually model a driver's visual attention for at least two use cases to practice the modeling. The evaluation results are then first discussed in in small groups of participants that analyzed the same use cases and finally presented to the audience.

Organization

The tutorial involves a hands-on session at a lab space (e.g. room U104) and therefore we intent to limit the space to a maximum of 14 participants.

Schedule

1. Lecture (60 min)
2. Use case presentations (30 min)
3. Hands-on modelling session (90 min)
4. Results discussion and presentation (45min)

Acknowledgements

The authors acknowledge the financial support by the European Commission (H2020-MG-2014-2015) in the interest of the project AutoMate (http://www.automate-project.eu/) – Grant Agreement 690705 and the funding initiative Niedersächsisches Vorab of the Volkswagen Foundation and the Ministry of Science and Culture of Lower Saxony as a part of the Interdisciplinary Research Centre on Critical Systems Engineering for Socio-Technical Systems.

Instructor Background

Sebastian Feuerstack is a senior researcher from the human-centered design group at the OFFIS-Institute for Information Technology. There, he is investigating in methods and tools for the early model-based evaluation of safety critical systems such as airplane cockpits, car assistance systems or complex clinical setups. He is an invited lecturer at the University of Oldenburg where he lectures about cognitive engineering and human factors. Currently he is working in the AutoMate EU H2020 project. It implements a novel driver-automation interaction and cooperation concept based on viewing and designing the automation as the driver's transparent and comprehensible cooperative teammate. Furthermore he is part of the research center "Critical Systems Engineering for Socio-technical Systems" in which he focuses on modeling and evaluating standardized processes of prehospital resuscitation.

Bertram Wortelen is doing research in the area of cognitive modeling for safety-critical applications with a strong focus on model-based attention prediction at the cognitive psychology lab of the University of Oldenburg. As part of his PhD work, he has developed a simulation model of the Human attention distribution, with which human machine interfaces for the monitoring of automation systems can be analyzed. After completing his PhD he is now working in the research center "Critical Systems Engineering for Socio-technical Systems" at the University of Oldenburg to make the simulation models applicable to practice.

References

1. Alexander J. Bos, Daniele Ruscio, Nicholas D. Cassavaugh, Justin Lach, Pujitha Gunaratne, and Richard W. Backs. Comparison of novice and experienced drivers using the seev model to predict attention allocation at intersections during simulated driving. In *Proceedings of the Eighth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, June 2015.
2. Sebastian Feuerstack and Bertram Wortelen. A model-driven tool for getting insights into car drivers' monitoring behavior. In *Proceedings of the IEEE Intelligent Vehicles Symposium (IV'17) (in press)*, 2017.
3. Sebastian Feuerstack, Bertram Wortelen, Carmen Kettwich, and Anna Schieben. Theater-system technique and model-based attention prediction for the early automotive hmi design evaluation. In *Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 2016.
4. William J. Horrey, Christopher D. Wickens, and Kyle P. Consalus. Modeling drivers' visual attention allocation while interacting with in-vehicle technologies. *Journal of Experimental Psychology: Applied*, 12(2):67–78, 2006.
5. NHTSA. Visual-manual driver distraction guidelines for portable and aftermarket devices. Technical Report ID: NHTSA-2013-0137-0059, National Highway Traffic Safety Administration, 2016.
6. Christopher D. Wickens, John Helleberg, Juliana Goh, Xidong Xu, and William J. Horrey. Pilot task management: Testing an attentional expected value model of visual scanning. Technical report, NASA Ames Research Center Moffett Field, CA, 2001.
7. Bertram Wortelen, Martin Baumann, and Andreas Lüdtke. Dynamic simulation and prediction of drivers' attention distribution. *Transportation research part F: traffic psychology and behaviour*, 21:278–294, 2013.