An Adaptive and Personalized In-Vehicle Human-Machine-Interface for an Improved User Experience

Guillermo Reyes
guillermo.reyes@dfki.de
German Research Center for Artificial Intelligence (DFKI)
Germany

ABSTRACT

Human Machine Interfaces (HMIs) enable the communication between humans and machines. In the automotive domain, all in-vehicle systems used to be independent. Today they are more and more interconnected and interdependent. However, they still don't act in unison to help drivers achieve their individual goals. More specifically, even though, some current HMIs provide a certain degree of personalization, they don't adapt dynamically to the situation and don't learn driver-specific nuances in order to improve the driver's user experience.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; • **Computing methodologies → Artificial intelligence**; • **Social and professional topics →** *User characteristics.*

KEYWORDS

Adaptive Interfaces; Continuous Learning; Incremental Learning

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1 INTRODUCTION

An Human-Machine-Interface (HMI) is the part of a system which enables the communication between a user and a machine. It provides the user with access to control elements and all information necessary for a user to complete a task. In the automotive domain, an HMI refers to the elements necessary to perform the primary task, like the pedals and steering wheel, but also to the elements that control the infotainment systems for secondary and tertiary tasks. HMIs play a very important role in the driver's behavior. They are responsible for providing the driver and the passengers information about the vehicle's condition and the environment. Driving is one of the most complex actions humans perform. Drivers' behaviour can be influenced by influenced by external (weather, traffic, street conditions, etc.) and internal (age, experience, psychological state, etc.) factors. Since everyone is different and situations can strongly vary, a single HMI design that fits everyone's needs and every situation is perhaps not possible. It is thus necessary that the HMI continuously adapts itself to the driver and the situation.

As long as vehicles are not fully autonomous, the design of an appropriate HMI is is critical safety issue. An active driver should not get distracted from the main task of driving the vehicle. When autonomous driving is engaged, the design of the HMI is even more critical. Today, most autonomous vehicles have a level three of autonomy, defined by the SAE. This means the there are situations in which the passive driver will have to take control of the vehicle again. In this situations it is additionally of utmost importance that the driver understands why taking the control was necessary. On the other hand the HMI should also be aware of the current state of the driver and estimate whether or not the driver can take take over the control and in which way.

The objective of this dissertation topic is the development of an adaptive and personalized HMI for vehicles which improves the user experience of the driver. As aforementioned, driver behavior can be influenced by both internal and external factors. The HMI should, therefore, adapt itself to the personal driver's characteristics and these external factors. The external input could come from four sources: the environment, the vehicle, media and other passengers.

An understanding of how the input from these different sources influence the driver and the interaction with the vehicle and how the HMI should be adapted is one of the main goals of this research project. Internal factors are equally important. Some internal factors like the age, gender or some preferences can easily obtained from e.g. a smartphone or user profile. However, it is also worth researching which other internal factors can also influence the driver. There are also dynamic internal factors like emotions or the drivers attention that are ever changing. These factors can also influence the way the driver interacts with the HMI, but cannot be read from a smartphone. The HMI should, thus, constantly monitor the driver for these changes.

One of the main research questions of this research project is: how do internal and external factors influence driver interaction with the vehicle and how should the HMI adapt to these factors? The driver can interact with the vehicle in two ways: explicitly and implicitly. Explicitly, the driver could steer the wheel, manipulate the main console, perform hand gestures, or give speech commands. Implicit interaction refers to the driver's behavior and actions which don't trigger a specific action. This includes natural driver movement like eye gaze, emotions and facial expressions, hand movement, use of other devices, interaction with other passengers, etc. Both explicit and implicit interactions are influenced by internal and external factors, but they can also be monitored in order to understand the psychological state of the driver and

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other internal factors. Current vehicle HMIs include elements with which drivers can interact. These include multimedia functions like the radio, but also the navigation assistant, phone, air conditioner, social media and many vehicle settings. Understanding how different internal and external factors influence the driver can provide some insight on how to adapt these vehicle functions. Another question is which expectations users have from an intelligent and adaptive HMI. The main goal of of this research project is to develop an algorithm that combines symbolic and subsymbolic data and which considers the aforementioned internal and external factors to support the driver and increase the user experience.

2 RELATED WORK

While vehicles started being purely mechanical machines, today they have complex software and hardware systems. This is of course also reflected in their HMIs. Although these used to be different independent systems inside the vehicle, today they are interconnected and interdependent systems. Some vehicles offer some options for personalization, like the definition of user profiles with driver preferred widgets and themes. However, these user profiles are mostly static and configured by the users themselves and don't provide suggestions based on the emotional state and they don't adapt to the environmental situation. Project AIDE [1] (Adaptive Integrated Driver/Vehicle Interface) had the goal of generating knowledge and methods for the efficient integration of ADAS (Advanced Driver Assistance Systems), IVIS (In-Vehicle Information Systems) and mobile devices with the driving environment. Although at the time this work was written smartphones and many technological advances in artificial intelligence, gesture recognition and autonomous driving had not yet been developed, it was successful in foreseeing many of these developments. To enable the real time adaptivity, this work defined five monitoring modules. A Driver's Charactiristics Module defined drivers profiles and was in charge of driver identification; an Availabilty of the Driver Estimation Module analyses the primary activity (driving); a Cockpit Activity Assesment Module focuses on the secondary activity of the driver to determine if he is distracted. a Driver State Degradation Module detected if the driver showed signs of tiredness; finally a Traffic and Environmental Assessment Module monitored traffic and the environment and estimates the overall risk.

A generic concept to adapt the HMIs of automatic systems was presented in [3]. The purpose of this adaptation was to improve the the usability. The authors used rule-base logic to adapt the HMI to the context of use, which consisted of the user profile, the tasks, roles and the environment. Another example of an adaptive interface can be seen in the context of mobile applications [4]. The authors created a UI for mobile phones, in particular for Android, which used machine learning to learn from experience and adapt itself to the user. They suggested a framework available to all applications capable of learning during usage by clustering types of of users.

3 APPROACH

In order to approach this research topic it is first necessary to do a comprehensive literature research to compile a list of internal and external factors which affect the driver and how the driver is affected. Based on this, new hypotheses can then be suggested on how the HMI should be adapted. Several user studies and questionnaires should support these hypotheses and adaptations. Next, new adaptation methods should be developed to fuse information from different sources. The HMI take into account three types of aspects: External factors, internal factors and personal driver preferences which can be inferred from external sources. Based on this the HMI should be adapted in three ways. (1) Static adaptation: consists primarily on user and group preferences. Although they can be changed, they remain for the most part static. (2) Dynamic adaptation: They are changes in the UI which are triggered by a certain situation in run-time. (3) Continuous adaptation: similar to dynamic situation that are triggered by certain situations, however these changes are mostly based on user habits which are learned by the system through continuous use. These methods should support the drivers by understanding by first understanding their goals and preferences and then by integrating symbolic and subsymbolic data form the different sources in order to understand the current situation and reacting accordingly to achieve such goal. For this, propositional logic, baysian networks, machine learning and deep learning will be essential.

4 RESULTS

So far we have worked on personalizing gesture recognition to particular drivers in so far unpublished results. We were able to generate label hypotheses for new training samples during runtime. These could then be used to further train the recognition module. We studied the stability-plasticity dilemma and how often and with how much new data the model should be updated to avoid the problem of catastrophic forgetting [2]. This work, while part of the HMI adaptation to improve user experience, does not take into account the user goals. Nevertheless, it is still a good starting point for the development of incremental algorithms that learn individual user differences and could prove useful in the future.

5 NEXT STEPS

The next step is study which factors influence drivers and how, in order to better understand how the HMI should be adapted. Then, an adaptation algorithm that takes into account these factors will be developed, so that the HMI is adapted in the way described in section 3.

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