Towards A Generic Adaptability Framework for Automotive HMI

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Abstract: Reduction of mental workload of the driver in dangerous traffic situations requires adaptive systems. Furthermore, the functional and informational complexity of driver information and -assistance systems today cannot longer be handled by the driver alone without employing adaptability. Cultural adaptive systems automatically adapt the Human Machine Interaction (HMI) to the needs of user groups, exposing a certain HMI behavior that depends on cultural background. A shift from cultural to individual adaptability in HMI will be presented employing a generic adaptability framework (GAF).

1 Cultural Adaptive Automotive HMI

The mental workload of the driver has to be as low as possible for the sake of preventing accidents in traffic. However, today, driver information and -assistance systems are very complex both in functionality and in usage and therefore tend to need much mental power of the driver. Hence, when the driver is in danger to be mentally overloaded, the characteristics of the interaction between the system and the driver must be adapted automatically to reduce mental workload and to prevent mental overload (Piechulla et. al. 2003). Therefore, it is necessary to make driver information and –assistance systems adaptive: in dangerous traffic situations the driver does not have enough time to change settings for HMI manually (e.g. blocking a phone call when approaching an intersection). Besides, culture influences the individual interaction of the user with the system because of the movement of the user in a cultural surrounding (Röse 2002). To be able to design user interfaces that can adapt to the cultural and individual needs of the user automatically, the first step is to find out the differences in the needs of the users and hence the differences in HMI on all levels of HMI localization (surface, functionality, and interaction) (Röse et. al 2001). Thereby, areas like presentation of information and language or dialog design as well as interaction design are concerned. One promising method to accomplish this task is to observe and analyze the interaction behavior of different users with the system by an appropriate automated analysis tool to determine (mainly quantitatively) different interaction patterns according to the preferences of the users (Heimgärtner 2005).

A study using this tool revealed different interaction patterns according to the cultural background of the users regarding e.g. design (ample vs. simple), information density (high vs. low), menu structure (high breath vs. high depth), personalization (high vs. low), language (symbols vs. characters) and interaction devices (Heimgärtner 2006). These results have been also confirmed qualitatively e.g. by Lewandowitz et al. 2006. From this, a cross-cultural usability metric trace model (UMTM) has been derived, which can be used for the design of adaptive HMI containing e.g. mouse clicks and interaction breaks (cf. Heimgärtner 2007). Moreover, cultural adaptability does not only concern the look and feel of the user interface, but also the interaction devices as well as the number and the kind of system functions (Röse et al. 2001) that can be changed dynamically according to driver preferences, driver situation and driving situation (Heimgärtner & Holzinger 2005). Furthermore, constantly increasing functions (e.g. Advanced Driver Assistant Systems, Autonomous Driving) combined with a large number of nomadic devices (e.g. MP3 player, personal navigation systems, mobile phones) are requiring flexible, safe and adaptable HMI solutions for the world market. However, stronger interactive invasive changes require more complex systems. Therefore, the design of future driver information and assistance systems will take into account more strongly the culturally influenced individual preferences and needs of the drivers using methods of adaptability to broaden universal access. In this sense, infotainment solutions for cars will change dramatically in the near future.

2 From Cultural to Generic Adaptive HMI

The postulated principle for cross-cultural adaptive HMI (CCAHMI) in Heimgärtner 2005, partly in accordance with Savidis & Stephanidis 2001, Malbury 2001, Baumgartner 2003, and Leuchter & Urbas 2004, represents a feedback control system which allows the deduction of the values of the cultural dimensions by analyzing the monitored user interaction behavior and by retrieving associated cultural parameters stored in database (cf. figure 1).

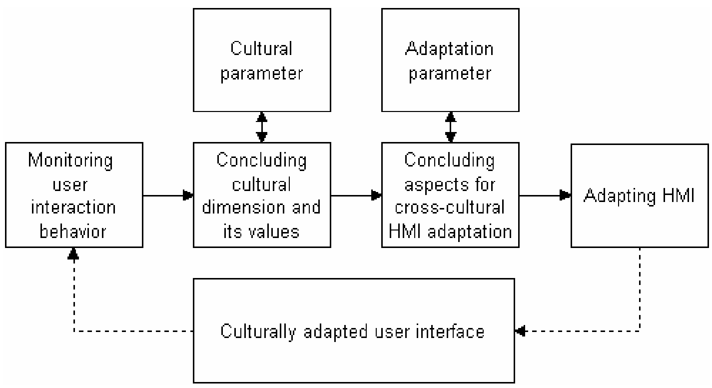

Figure 1: Principle for Cross-Cultural Adaptive HMI

The system monitors and records the user interaction behavior with the system. Then the system analyses this data using cultural interaction criteria to determine the cultural characteristics of the user. Finally, the system adapts the HMI according to the cultural preferences of the user employing HMI design guidelines for intercultural interface design either after asking the user or automatically if expectance conformity is not hurt or an emergency situation enforces to do so. Based on two cross-cultural studies, the principle of CCAHMI could have been optimized (cf. Heimgärtner 2007). Figure 2 shows the revised principle for CCAHMI derived by these studies (marked in contrast to the former assumed principle in figure 1).

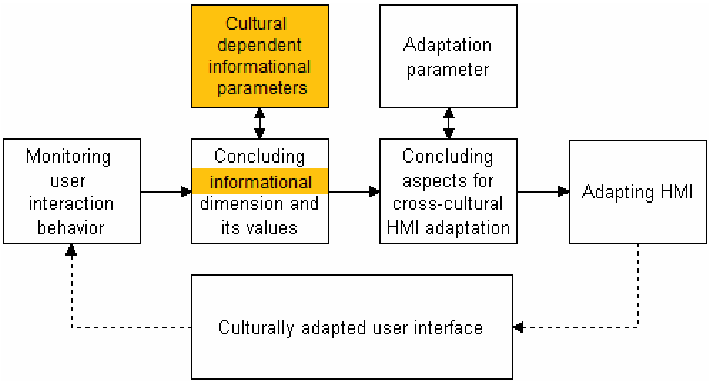

Figure 2: Revised Principle for Cross-Cultural Adaptive HMI

No cultural dimension (describing the behavior of the members of a group with the same cultural imprint) will be used anymore to relate the interaction behavior of the user with the system to a certain culture. Only the interaction behavior itself will be classified according to the informational dimensions whose peculiarities depend on the cultural background and imprint of the single user. Hence, it is not necessary to classify the user to a certain culture, but to a certain interaction behavior from which is known, what cultural settings the user presumably prefers. E.g., if the user interacts very frequently and fast with the system, it can be assumed that either the user is very experienced or he belongs to a cultural group which is highly relationship oriented like China or France without saying that the user has Chinese or French nationality. From knowing the default values of the variables of the informational dimensions determined for different cultures in the design phase, the system can compare those values with the actual ones initiated by the user interacting currently with the system. The best matching patterns allow the system to deduce the cultural adaptation parameters for adapting the HMI with the highest probability to cope with the cultural user needs.

Furthermore, there are target user groups of drivers which have their own characteristics of using driver information or -assistance systems in vehicles depending on their individual preferences (e.g. driving beginners vs. experienced drivers, old vs. young people, female vs. male users) that are imprinted by their primary culture (Honold 2000).

Hence, the meaning of the concept of "culture" as ethnical determined can be extended to the "individual culture" of the user (e.g. driving, communicating, using the user interface etc.). Therefore, it is necessary to extend the principle of cultural adaptive HMI to a general principle of adaptability to cover cultural *and* individual as well as HMI specific aspects of adaptability in HMI (like general widget usage concerning layout and interaction design). In this sense, the revised principle of CCAHMI (as seen in figure 2) has to be extended to a general principle of adaptive HMI by widening the cultural to individual and general aspects (marked in figure 3).

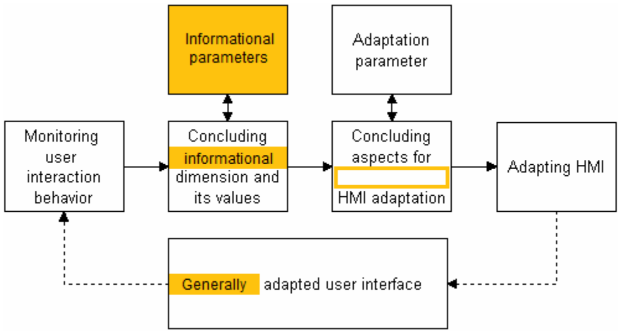

Figure 3: General Principle of Adaptive HMI

The basic principle of adaptability consists of observing the behavior of the user with the system generating a user model by the system and automatically adapting the system to the user (cf. Mandl, Schudnagis & Womser 2003, and Brusilovsky & Maybury 2002). To demonstrate the principle of general adaptive HMI, the deduced UMTM can be implemented as "intercultural adaptive interface agent architecture" (IAIAA) within a generic adaptability framework, which monitors, analyzes, and adapts HMI according to the user preferences. The general principle of adaptive HMI is represented within an abstract overview of a general adaptability framework (GAF) as shown in figure 4.

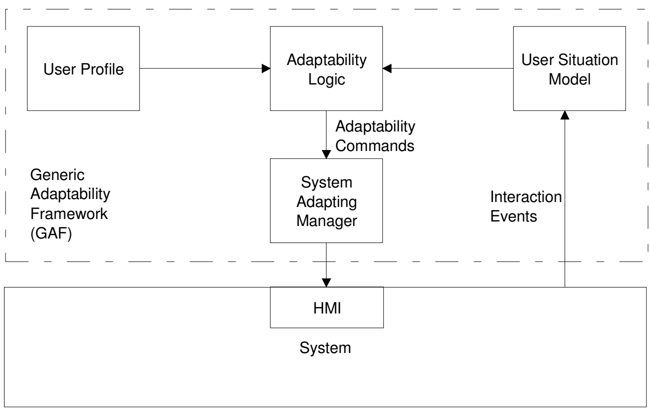

Figure 4: Abstract Overview of a Generic Adaptability Framework (GAF)

The GAF contains the most important modules of generic adaptability: the user profile, the adaptability logic, the user situation model as well as the system adaptation manager. All relevant events in the system are sent to the framework to be modeled by the adaptability logic in the user situation model which provides information containing what has to be adapted and when by the system adaptation manager depending on the user profiles.

3 Designing a Generic Adaptability Architecture for Automotive HMI

Developing automotive adaptive HMI contains additional tasks to ensure driving security: in automotive context, the actual driving situation has to be taken into account (e.g. by a driving situation model). Basic to automotive adaptive HMI is to analyze and to integrate the driver's cognitive states influenced by preferences, situation and workload into respective models (cf. figure 5).

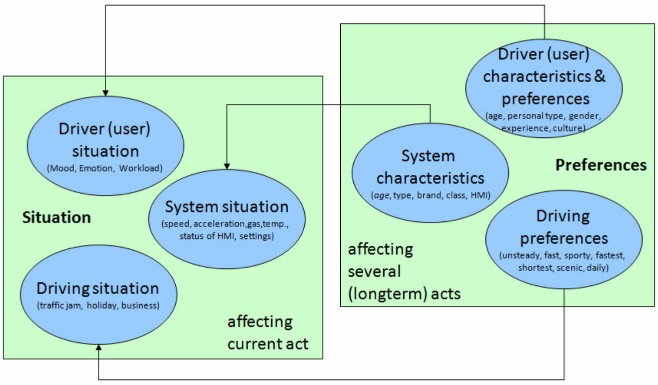

Figure 5: Influencing Aspects within Adaptive Automotive HMI

If a driver information or -assistance system knows the culturally imprinted but individual preferences of the user, it can adapt its behavior to the expectations of the user to reduce mental workload, to prevent mental distress and to increase driving security as well as joy of use and comfort. Therefore, the system has to know the different cognitive models of all drivers using the vehicle. Hence, cognitive modeling and system adaptability play a decisive role for a generic adaptability framework for Automotive HMI. However, adaptability may not surprise the user but must be in accordance with the mental model of the user (Kobsa 1990). Therefore, the system has to analyze the interaction behavior of the user, to find out interaction patterns and to behave similar as the user does. This means to reach the acceptance of the dialog partner by unobtrusive imitation of the behavior of the dialog partner attaining to be on the same wavelength and to bring to reconcile the cognitive models of the system and the user (cf. "principle of charity" according to Davidson 1984). The models should show the relationships of those cognitive states as wells as its relations to HMI adaptation. This ensures a certain basic acceptance as well as a fundamental benevolence of the user with regard to the system.

Furthermore, this increases the possibility that the user will buy a device from the same producer again, presupposed that system usability, functionality and politeness are sufficient enough. In addition, data from car, history logging, emotion recognition, and driver verification have to be used. After evaluating and computing the adaptive HMI commands by considering priority control and driver-load controlled information flow, presentation of preferences and sensitive information have to be calculated. Hence, many data from several models and sources (like driving situation, intention, and interaction model as well as driving history and vehicle data) have to be integrated since driving behavior includes aspects such as fast, stressed, hectic, sporty, or curvy driving and depends on the experience of the driver (beginner, intermediate, professional, expert), or gender and especially on the cultural background (using bumpers for parking, buzzer frequency, interaction times, interaction frequencies, etc. cf. e.g. Xie & Parker 2003). The history of the driving tours contains important information about the preferences of the driver: the preferred type of routes, average speed, default tours, short or long tours, along rivers or hills, etc. Moreover the interaction styles can vary strongly (e.g. reasonable, rational, arbitrary, sequentially, fast, well considered, haptic, visual, auditory, linguistic, etc.). Hereby, also the relationship of secondary tasks to driver workload has to be considered which finally leads to workload optimization. E.g., there can be developed a layer approach for intelligent services which compromises the architecture and the priorities of the data oriented models. The data-oriented driving situation model describes the current driving situation which is defined by the values of the variables of the vehicle such as speed, lateral and longitudinal acceleration as well as the position of the vehicle (traffic jam, highway, parking place etc.) or the reason for driving (business, spare time, race etc.) and so on. The driver workload model contains information about the mental or physical stress of the driver indicated by variables such as heart rate, galvanic skin response values or error clicks and task failures. It can be an extension e.g. of de Waard's model by "sleepy" state to include drowsiness detection (micro sleep) (cf. de Waard & Brookhuis 1997). However, fine grained research must deliver further information to enable the development of these models in more detail and to generate an integrated adaptive HMI model.

3 Conclusion and Outlook

Adaptability in driver information and assistance systems is necessary: the functional and informational complexity of automotive systems today cannot longer be handled by the driver alone without employing adaptability. There are many different groups of drivers, which exhibit their own “culture” whether regarding groups at international level (e.g. countries), at the national level (e.g. social, ethnic, or driver groups), or even at individual level (e.g. driving style). A generic adaptability framework (GAF) for Automotive HMI takes into account cultural as well as individual aspects and should help to reduce programming effort because of being necessary only once for all possible applications using a generic adaptability interface. However, there are still some disadvantages to use GAF, which have to be researched like high consumption of system resources, influencing the design of the system architecture by the requirements of a generic adaptability module interface, as well as unknown adaptability settings, parameters and consequences.

Therefore, the near-term objective is to think about and to design the generic adaptability framework in detail to get the scope and the problems of GAF and to be able to answer e.g. the following questions: How many dynamic changes are optimal for and will be accepted by the user? When does a "hidden" adaptation occur? How can this be prevented? How much does the user trust the adaptive system? The mid-term objective is to implement a well designed GAF into a separate DLL providing an API to be able to be used by every application fulfilling the requirements of the generic adaptability interface. Thereby, a complete development kit for a HMI adaptability module could appear in the future to support and speed up R&D processes. Qualitative evaluation using intercultural usability tests with different users and under mental stress should reveal the acceptance of the generic adaptability framework by the users as well as the degree of the reduction of the driver's mental workload. Even, it is pretty clear, that much research and work has still to be done, it is also clear, that the necessary idea of a generic adaptability framework (GAF) for Automotive HMI has been born and must be pursued in future.

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