Towards Cultural Adaptability to Broaden Universal Access in Future Interfaces of Driver Information Systems

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Abstract. This paper elucidates and discusses some aspects of cultural adaptability which aid usability and universal access. We describe the concept, influence and Use Cases of cultural adaptability in driver information and assistance systems exemplified by a portable navigation system. Thereby, the reasons, advantages and problems of using adaptability regarding the driving safety and the driver preferences will be addressed. Differences in the amount of information for map display and in interaction behavior which depend on the *cultural* background of the users (e.g. attitude, preference, skill etc.). We explain how cultural adaptability can improve usability and how it has a share in universal access. Finally, a short outlook into the future of adaptive driver information and assistance systems closes our reflections.

Keywords: cultural adaptability, cultural user interface design, adaptive HMI (Human Machine Interaction/Interface), driver navigation systems, driver information systems, driver assistance systems.

1 Necessity and Benefit of Cultural Adaptability

Today driver information and assistance systems are very complex both in functionality and in usage. Generally, the design and development of user interfaces for vehicles includes manifold aspects e.g. information visualization, haptic technology etc. which are challenges to HMI designers and software developers. Driver information and assistance systems have to integrate a lot of data from several models and sources such as driving situation model, driver preference model, driver intention model and driving history as well as vehicle data [4]. Within the infotainment systems of a car, alongside other components – including radio, telephone, CD or DVD player and telematics unit – especially the car navigation system demands many highly interactive activities from the driver. Furthermore, it also provides many important and calculated pieces of information together with vehicle data to other devices (e.g. data about the driving situation). In this sense, the driver navigation system plays a prominent role of intersection within the round dance

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of driver information and assistance systems. Therefore, it will be used as an exemplary system in this paper to elucidate cultural adaptability.

In order to calculate for example the optimal route, it is necessary to take into account all factors relating to the driver: preferences, mental and physical state as well as outside aspects such as weather, road conditions etc. Interaction between the driver and the system takes place not only before travel, e.g. when the destination is entered, but also whilst driving. This interaction includes the observation and reaction to the maneuver guidance and making decisions about a desired alternative route in the case of traffic jams. However, in addition to the traditional human factors, the cultural diversity and the corresponding emotional appeal include one inescapable factor: the configuration of the interface between the driver and the navigation system must prevent the driver experiencing an excessive mental workload [11]. The information presented to the driver needs to be suitable for the specific driving situation, the driver workload as well as the cultural driver preferences (e.g. to reduce information complexity).

In this case, adaptability is an appropriate solution because the driver does not have the opportunity to manually adapt the setup of the information presentation according to the special requirements depending on the situation. Especially for stressful situations, the HMI of the driver information system has to be adaptive to reduce the mental workload of the driver [12], depending on the driver's cultural background [14]. According to the principle of cross-cultural adaptation of HMI, the culturally dependent behavior of the driver has to be measured and recorded over time in order to obtain information about the parameters necessary to be able to culturally adapt the HMI [2]. Either the system suggests the adequate form of information presentation to the driver (Computer Supported Adaptation) or it adapts it automatically (Automatic Adaptation) whilst the driver is actually concentrating on driving [8]. E.g. difficult routes with high rate of accidents can be avoided most notably for beginners by analyzing the routes as well as the driving behavior and by adapting the route calculation and the information presentation according to the recognized facts.

The concept of adaptability is found in the HMI roadmaps of most automobile manufacturers nowadays: the basic concepts of adaptability for future projects have to be developed anyway. Moreover, the engineering process necessary to obtain adaptability, promotes the usability of the devices. To achieve cultural adaptability at all, i.e. to be able to perform adaptation by the initiative of the system according to the cultural differences in HMI dependent on the user needs, the cultural differences must be determined by intercultural usability engineering [6]. Including such methods from the beginning of HMI design and development also reduces costs in future developing and planning for product (regional) variants as well as increases usability [5].

Furthermore, adaptability will go along with good usability [7] by adapted user and system models, shorter training times by fast adaptation to the driver as well as in less distraction from traffic and mental workload by automatically optimizing and adapting the HMI according to the current driving situation to increase driving safety [12]. The acceptance of intercultural adaptive intelligent user interfaces is guaranteed, when the user is aware of the changes in the user interface driven by the system or when the changes are very small and happen over a long period of time so that the driver does not recognize them because he is familiarized slowly (except in dangerous situations where the system must adapt immediately and automatically according to driving situation). The resulting effect of improved usability by cultural adaptability is that many more drivers are able to use the same systems in the car more easily and with contentment which contributes to universal access.

To make driver information and assistance systems culturally adaptive, at least the following steps are necessary:

Step 1: The cultural differences in using the systems have to be determined during the analyzing phase of the product development process. This gives first insight into the different user preferences and system requirements for markets with different cultures (cultural preferences).

Step 2: The results have to be taken into account in the design phase for new products and the system architecture has to be modified and extended according to the adaptations necessary to support the cultural needs of the user for existing products. This allows the end-user to manually adapt the system according to individual cultural preferences (personalization).

Step 3: At runtime, the system has to detect the user preferences during operating and controlling the system in different driving situations in order to determine the tendency of the cultural attitudes of the driver and to adapt the HMI accordingly and automatically (adaptability).

Integrating all the three steps emerges as the most potent effect to help broadening universal access because the system is able to adapt itself to the special needs of *many more users* than those who would be covered by driver information and assistance systems that only dispose default parameters (without cultural adaptability).

1.1 Cultural HMI Patterns (Step 1)

To be able to adapt a system manually by personalization or automatically by adaptability to the cultural needs of the user, the first step is to investigate what must be adapted, i.e. to find out the differences in the cultural needs of the users as well as the cultural differences in HMI on all levels of HMI localization (user interface, functionality, and interaction) concerning Look & Feel. In this context, topics such as presentation of information (e.g. colors, time and date format, icons, font size) and language (e.g. font, writing direction, naming) or dialog design (e.g. menu structure and complexity, dialog form, layout, widget positions) as well as interaction design (e.g. navigation concept, system structure, interaction path, interaction speed) are affected [13].

One promising method to accomplish this task is to observe and analyze the interaction of users, from different cultures, with the system by an appropriate automated analysis tool [2]. From this, cross-cultural usability metrics can be derived, which can be used for cultural adaptability. The "Intercultural Interaction Analysis" tool (IIA tool) was developed to automatically obtain quantitative data regarding cultural differences in HMI by simulating use cases of navigation systems [3]. The main objective was to observe and analyze the interaction behavior of users from different cultures with a computer system to determine different interaction patterns according to the cultural background of the users (if any).[1] A quantitative study using

[1] For detailed information about the IIA tool, please refer to [2].

this online tool has shown that there are different *cultural interaction patterns* that can be measured quantitatively by a computer system using *cultural interaction indicators* that depend on the interaction behavior imprinted by the culture of the user. The cultural differences, which were found, are *statistically discriminating enough* to enable computer systems to detect different cultural interaction patterns automatically and to relate users to a certain culture behavior, which in turn makes *cultural adaptability possible* in the first place. The most classifying interaction indicators regarding the cultural preferences of the users can be summarized in the following categories: number of tasks, time period between display of information, display time of the presented information, number of mouse clicks and key presses, number of acknowledged system messages, number of refused system messages, number of list entries, time to finish task cases, number of mouse moves, number of interaction breaks, number of initiated functions, number of interactions, interaction times.[2]

This preparatory work contributes to the first step to broaden universal access in future driver information and assistance systems: now we have first knowledge about the cultural differences in the interaction behavior of the user with the system.

1.2 Scope of Cultural Adaptability (Step 2)

The interaction strategies within in-car devices/systems are connected to their main functions and divided into primary functions such as driving, navigating and secondary functions e.g. listening, talking, phoning, entertaining etc. All these are interacting.

Use Cases, which need massive interaction, are e.g. destination input, map interpretation and maneuver guidance [2]. According to the Use Cases, there are several areas in driver information and assistance systems where adaptability is reasonable, e.g. maneuver generation, voice guidance (instructions and timing), guidance pictograms, map display, dynamic routing / traffic message data handling (e.g. by TMC), multimedia / multimodal HMI in general, destination input, speech recognition, help concept controlled by speech, interaction management and dialog management. Therefore, cultural adaptability does not only concern the look and feel of the user interface, but also the interaction devices (e.g. *EasyCo*, a HMI concept based on touch pad and handwriting recognition [10]) as well as the number and the kind of system functions that can dynamically change according to the driver preferences, the driver state and the driving situation. To be able to take into account these complex information structures simultaneously and to let the driver's mental workload be as low as possible at the same time, it is necessary to employ cultural adaptability additionally to cultural pre-settings or profiles. Automatic adaptation affects country-specific aspects including format, modality, menu structure, content of menu, alternative routes (scenic, sporty, short, fast…), guidance, map display, language, advice for beginners or experts, number of messages, length of texts, number of hints, degree of entertainment or ratio of information to entertainment, etc.

[2] For a description of the results and the test setting in more detail, please refer to [3].

Special Use Cases, which can be solved by cultural adaptability, are the following:

- Adapting the scrolling speed of list boxes according to the speed of the touch drive usage
- Showing the right information (relevance) and the right amount of information (quantity) according to driving conditions
- Knowing the characteristics of the road in advance (virtual horizon) supports driving with foresight: the driver is warned by getting information in good time (anticipative driving)
- Changing the lower-beam headlamp such that the light automatically falls into the direction of the curve
- Using intelligent automatic gearing (especially on mountain roads)
- Calculating routes according to the driver preferences e.g. differences in gender
- Computing destination time and optimizing computation of routes according to fast or slow drivers
- Automatically showing of lanes and/or guidance information in the head-up-display.

Knowing those Use Cases for cultural adaptability enables to extend the architecture of such systems by the parameters and values as well as the adaptability algorithms to enable adaptability according to the needs of the driver to fulfill the step 2 on the way to universal access.

1.3 Demonstration of Cultural Adaptability (Step 3)

To demonstrate worldwide cultural adaptability, the first prerequisite is to manage that the adaptive HMI supports international fonts (e.g. Unicode). Furthermore, it is necessary for the design of a cultural adaptive system to take into account the differences of the desired cultures where the product will be sold. Tables consisting of the differences between the desired *cultures* (countries, ethnic groups, dialects, gender, age, preferences etc.) must be created. The results need to be integrated into the mental driver model and implemented in prototypes. The represented cognitive models of the user (driver) have to be adjusted according to the desired country.

The results of the online study using the IIA tool have been implemented in this way in a mobile navigation system based on Windows CE building a cultural adaptive HMI demonstrator to proof the concept of cultural adaptability of the HMI. In Figure 1 you can see the map display of this demonstrator exemplifying information density and information coding for Chinese (left picture) and for German (right picture) users. It is possible to adjust the number of POI according to the needs of the users: reducing disturbing or increasing information as needed. Moreover, colors can be adapted to the recognized culture of the user to provide familiarity and to avoid confusion: according to the interaction of the user with the demonstrator, the number of POI (many vs. few) as well as the color design is changed, e.g. main roads (yellow vs. white), highways (green vs. blue), calculated route (red vs. yellow). Further research should deliver more specific information to enable the development of these models in greater detail and to generate a sophisticated future adaptive HMI concept. Now, tests are done to verify the adaptive algorithm and to get the level of user acceptance and the usability of adaptive HMI to fulfill step 3 on the way to universal access.

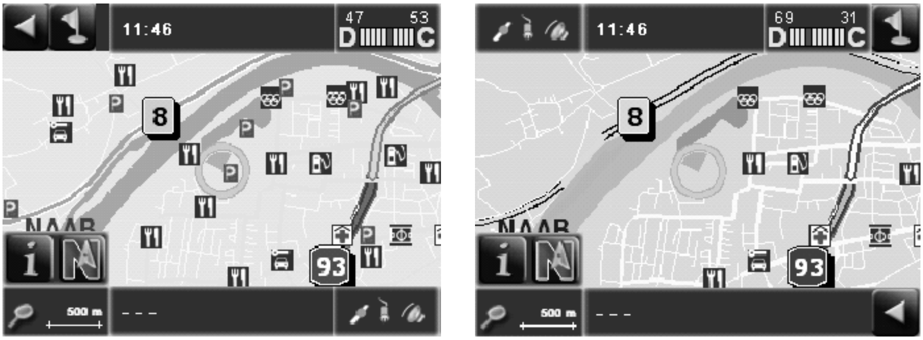

Fig. 1. Different number of POI and colors according to different needs of information density and information coding between Chinese and German users

2 Broadening Universal Access (Integration of Steps 1-3)

The objective of cultural adaptive HMI in driver information and assistance systems is the situation-referential adaptation of cultural aspects of the Graphical User Interface (GUI) and Speech User Interface (SUI). For cultural adaptive HMI user models are employed, which are averaged over all users of a cultural group (e.g. information dimming or multi-modal dialogs according to the different requirements in China and Germany respectively, according to the current situation and context). Additionally, there are some target user groups of drivers that have their own characteristics or "culture" of using such systems in the vehicle e.g. driving beginners vs. experienced drivers, old vs. young people, female vs. male users, HMI developer vs. HMI user drivers, vehicle of brand A vs. vehicle of brand B drivers (regarding HMI paradigm and motto), professional vs. hobby drivers, vehicle type A (e.g. truck) vs. vehicle type B (e.g. car) drivers, vehicles with or without cargo loading / trailers, drivers with handicaps, cheap vs. expensive car drivers, pragmatic vs. hedonic drivers and drivers of different countries and nationality.

These items are connected to the culture of the driver. However, in this sense, the meaning of the usual conception of *culture* as ethnical determined is extended to the *individual culture* of the driver (e.g. individualistic but culturally influenced style of eating, driving, interacting, using a device etc.). The individual driving behavior including aspects such as fast, stressed, hectic, sporty, or unsteady driving depends on the kind of cultural imprinting of the driver related to the group he belongs to (beginners, intermediates, professionals, experts), or gender and on the cultural background (using bumpers for parking, buzzer frequency, interaction times, interaction frequencies, etc. cf. e.g. [14]). The data collected about driving contains important information about the preferences of the driver such as 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.). By associating these aspects with the cultural models, implications can be made to culturally adapt the HMI and the functionality of such systems. For example, accidents are caused statistically by very young as well as very old drivers because they are not so experienced or need more time to interact with the system and to react in the right way according to dangerous events during driving (partly because of lacking technological knowledge and partly because of physical handicaps and lower mental flexibility) respectively. Here the interaction differences of old vs. young drivers have to be regarded depending on their cultural imprinting. Another aspect concerns the differences in the amount of information to display as well as the differences in interaction behavior which depend on the culture of the users (e.g. at country level like Chinese vs. German drivers).

Therefore, the "culture" of special driver groups has to be considered in the design of driver information and assistance systems. If such a system "knows" those cultural preferences of the driver, it can adapt itself to the cultural expectations of the driver regarding the driver behavior. In this sense, cultural adaptability broadens universal access, because many more users (even physically handicapped or mentally less flexible people) can use the same device (than without using cultural adaptability).

3 Discussion

It is problematic that an automatic adaptation (adaptability) depends on maximum data when observing new users: the system needs more data in order to be able to release information about the user as well as to be able to infer the characteristics of the user regarding information presentation, interaction and dialogs. Furthermore, the knowledge gathered about the user can be *misleading* or simply false. Hence, the reliability of assumptions can be a problem [9]. The behavior of the system has to be in accordance with the beliefs of the user to prevent unexpected situations. Another problem is that legal restrictions also have to be taken into account. Only the effects of driver actions are allowed to be permanently stored, but not the log file of the personalized driving sessions themselves [1]. As long as no solution is available, which can achieve meaningful adoptions from minimum data automatically; it remains necessary to investigate standard parameters and their values very early in the development process, long before runtime, in order to integrate them into the system. Therefore, it is necessary that the system already has corresponding user-knowledge (standard parameters) before the user's first contact with the system occurs. Before using the system for the first time, it must be adjusted e.g. to the nationality of the user (which indicates the main affiliation of the user to a cultural group) and the corresponding cultural parameters can be placed simultaneously as standard parameters for the desired country. Furthermore, the adaptive system also obtains adequate characteristics of the user more quickly at runtime, because there is "more time" to collect the culture-specific data for the user, since a basic adaptation to the most important user preferences has already been performed before runtime (by putting the standard parameters into the system). Thus, designing an appropriate system according to the user in the design phase helps to avoid the problems rising from adaptability. Additionally, there are many open questions that have to be addressed very carefully: 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? E.g., adaptability should not surprise the user but it must be in accordance with his mental model.

Therefore, sudden changing must be prevented or space limits for the automatic enlargement of buttons for handicapped users have to be taken into account during the design process. Nevertheless, even if answering those questions demand higher development costs or increased effort, this is no argument against adaptive automotive systems since adaptability is necessary and beneficial (cf. chapter 1).

4 Conclusion

It is necessary to apply adaptability in driver information and assistance systems because:

- It is hard for the driver to handle the functional and informational complexity of such systems in extreme driving situations: the mental workload, which is caused by all possible senses (i.e. resulting from visible, audible, haptical, etc. information), simply exceeds the mental capacity of the driver.
- The mental workload should be held in acceptable limits in dangerous driving situations if the system adapts the information flow with the user automatically. Due to this fact, adaptability has also to take into account external input sources (e.g. from pre-crash sensors).
- The output modality has to be adapted automatically to achieve the lowest workload (e.g. using of different displays).

It is also necessary to *adapt culturally* in driver information and assistance systems because

- The driver preferences have to be considered and covered, which depend on the cultural background of the driver.
- The cultural background of the driver also determines the behavior in certain (especially dangerous) driving situations.
- There are many different groups of drivers, which exhibit their own “culture” (e.g. interaction behavior cf. [2]) whether regarding groups at international level (e.g. countries) or within the national level (e.g. social, ethnic, or driver groups).
- The local market for cars has changed more and more to a worldwide market, future infotainment systems have to handle the demands of various drivers and various cultures. This aspect can only be covered within a single system, if this system is adaptable and configurable.

The cultural differences in HMI found using *special combinations of cultural interaction indicators* are *statistically discriminating enough* to enable computer systems to detect different cultural interaction patterns automatically and to relate users to a certain culture behavior, which in turn makes *cultural adaptability possible* in the first place.

To design cultural adaptive systems some formation principles in the vehicle context have to be taken into account:

- The distraction potential (the mental, visual and audio workload) of the driver must be held as low as possible.
- The HMI must be simple and safe in order not to reduce the driving security.

- The reason for the adaptation (e.g. the current driving situation) and the kind of adaptation (e.g. structuring menus or renaming soft keys etc.) must be comprehensible for the driver at all times. Therefore, the frame of reference is not allowed to be altered too strongly.
- The frequency of the adaptation has to be kept as low as possible.
- Multi-modal dialog design requires that the driver can choose the modality freely anytime.
- The possibility that all haptically usable interaction elements can be accompanied by verbal output has to be guaranteed in following the motto "speak what you see".
- The interruption and resumption of dialogs and interactions has to be possible.

Using methods of artificial intelligence help to fulfill the steps to get cultural adaptability to broaden universal access applying the cross-cultural adaptive HMI principles [2] such as learning the differences in the interaction of the users of different culture, classifying interaction patterns according to culture, determining the user preferences according to culture, adapting HMI according to the user preferences, learning user preferences by observation of HMI over time and integrating knowledge from observation into the system's user model.

5 Future Outlook

The examples of cultural differences in the map display according to information density and color-coding (as shown in 1.3) are first realizations on the way to cultural adaptability in HMI. However, stronger interactive invasive changes require more complex systems. A layer approach for intelligent services, comprising the architecture and the priorities of at least two models must be employed. 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. Thus, infotainment solutions for cars will change dramatically in the near future. 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. Therefore, the design of future driver information and assistance systems will take into account more strongly the culturally influenced personal preferences and needs of the drivers using methods of cultural adaptability to broaden universal access.

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