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Acceptance of Tactile Belts for Directional Information Representation in Automobiles

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ABSTRACT

Tactile belts are an alternative display to present directional information in automobiles. We conducted a user evaluation in a controlled environment to investigate the acceptability of tactile belts for that purpose and circumstances. A tactile belt, consisting of six vibrators was used for continuous direction presentation in a driving simulation. The simulation consisted of a video clip showing a recorded drive from the driver's viewpoint. This was synchronized with a tactile track providing tactile presentations of upcoming turns through a tactile belt. Information regarding front direction, right or left turns was presented on participants' waist by activating appropriate vibrator(s). Factors of the Technology Acceptance Model (TAM)[1] have been evaluated with the help of questionnaires afterwards. The results show that tactile belts are acceptable by drivers for directional information.

Categories and Subject Descriptors

D.2.8 [**Human Machine Interaction**]

General Terms

Measurement, Experimentation, and Human Factors

Keywords

Tactile user interfaces, Automobiles, Acceptability

1. MOTIVATION AND HYPOTHESIS

Todays car navigation systems use mainly visual and auditory interfaces to display directional information, e.g. for navigation support. Since the visual and auditory senses are already used for driving or communicating, they cause additional distraction, irritation, and cognitive workload. With respect to the Multiple Resource Theory [2], tactile stimulation as an additional channel could support driving without using the visual or auditory sense. We have evaluated the acceptability of tactile belts as one example of tactile user interfaces, for presenting directions using the TAM. In particular the factors *Perceived Usefulness* (PU) and *Perceived Ease of Use* (PEoU) have been determined.

2. EXPERIMENT

We have used a tactile belt with six vibrators to present front, right and left directions in the driving simulation. The front direction was presented by simultaneous activation of two vibrators situated in the front-left and front-right of the belt. The stimulation on right and left side represent upcoming right and left turns respectively. Front, right and left vibrators continuously display directions until a crossing is reached. Duration of right and left vibration is calculated as: on small routes a vibrator is activated 50 meters in advance and on main routes 200 meters in advance. In the experiment a video of 267 seconds of a pre-recorded route was presented to the participant and synchronized with the tactile stimulation indicating the turns. The route was composed of different turns on smaller streets and main roads of a city. In the end of evaluation participants asked to fill a questionnaire, which is designed according to scale proposed by Davis [1]. Fourteen participants belonging to 18 to 40 years age group have taken part in experiment.

3. RESULTS AND DISCUSSION

According to the calculated mean of responses, all factors of PU and PEoU fall on scale of 'Quite Likely', this shows participants' acceptability to tactile belt for directional information presentation in automobiles. Results show learning, usage, and interaction of tactile belt are more acceptable factors among all. According to oral responses of participants, they prefer to use tactile belt as an integrated feature for directional information over visual and auditory interfaces, but demanded to provide visual map for showing full route. Participants feel irritated with continuous direction information, especially for longer trips. They desired to have vibration of tactile belt as controllable feature because probability of messing vibration information with the vibration of the car. Distinct information need to present with different frequencies patterns.

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Collision-avoidance system using auditory and haptic feedback

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ABSTRACT

Human performance and inattention while driving a vehicle are themes that call the scientific community attention in the area of human factors. Several researches have been focusing the ways drivers interact with the vehicle, seeking to comprehend the influence that the modern technological devices have over the errors committed by drivers. According to DNIT [1], the National Department of Transportation Infra-structure, more than 9% of the accidents in Brazilian roads in the year 2008 are resultant of lateral obstruction, when one vehicle blocks another's path. From this kind of accident, more than 50% results in wound or loss of life, what suggests that technological aid could improve safety in such situation.

In this work, we develop a driver assistance system to warn the driver that a lateral collision with other vehicle may be imminent, when the rear mirror observation is insufficient or the driver is distracted. The system is composed by an activation module and a warning module. The activation module detects the dangerous condition by sensors placed around the vehicle and on the identification of a lane departure tendency.

This paper focuses on the warning module, which proposes the usage of tridimensional sound together with vibration stimulus. The selection of the warning combined with auditory and haptic is based on studies that suggest the usage of more than one perceptual channel as a mean the reduce reaction time [2]. Additionally, the high visual demand of the driver indicates that other perceptual channels should support the functions of the vision.

The proposed device aims to optimize the variables determinant for the reaction time in the selection of an action to be taken: stimulus modality, intensity, expectation and compatibility between stimulus and action [3]. The proposed interaction modalities, auditory and haptic, are used because the auditory stimulus is processed significantly faster than the visual one and the haptic stimulus strengthen the auditory one guiding the human motor system to an action to be taken. Besides calling the driver attention, system makes available earlier the information that the vehicle is in collision path with another vehicle. We expect that once the confidence in the system is built, the driver will reduce time to action instead of looking for environment cues to understand the surrounding situation.

A simulation environment is proposed to reproduce in laboratory the environment where the driver actuates. In this environment, the subject is requested to play a driving game projected in the frontal wall using a steering wheel, pedals to accelerate and brake and a gear shift. The seat is equipped with the vibration and auditory stimuli generator elements. While the driver conducts the vehicle over the game route, the stimuli are activated.

Experiments are done in the environment described above to justify the usage of the proposed system. First, the kind of action which the driver takes when the vehicle is about to collide laterally is evaluated. The intention is to understand the behavior pattern regarding braking and trajectory change when such situation is identified. Second, reaction times in the execution of the identified action in the first part of the experiment are measured, when the subject is submitted to different stimuli. This way, the reaction time measurements are registered, allowing a comprehension of the influence of each kind of stimulus in the driver performance. Subjects are also inquired about the utility and annoyance of the applied stimuli, as qualitative evaluation of the experience with the system. Since this is a work in progress, quantitative and qualitative data from the experiments are not yet available.

Keywords
Multimodality, warning design, automotive interfaces, driver-vehicle interaction, driver assistance system.

Acknowledgement
Authors thank Continental do Brasil and Universidade de São Paulo for the support in this work.

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UML for automotive multi–modal HCI

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ABSTRACT

Multi–modality can help to ease operation and avoid driver distraction, but is hard to specify and in turn makes specification more complex. Existing HCI modeling approaches lack compatibility to the Unified Modeling Language standard. They neither follow formal semantics nor provide methods addressing multi–modality. We base our approach on a formal semantics resolving ambiguities of the UML. We introduce new stereotypes for multi–modality and present a modeling method and tool support, both following our semantics. Proof of concept is given by an automotive multi–modal dialogue specification.

1. BACKGROUND

Up to now, no standard method for modeling complex multi–modal Human–Computer Interactions (HCIs) in the car exists . There are two major fields of studies addressing multi–modal dialogue specifications. First, the research community provides transformation–based approaches using Task Trees for HCI modeling, usually for multi–modal web applications. This method is not adequate for task–specific HCI models, where task–specific dialogues differ for each modality depending on the given context. Second, important contributions deal with modeling dialogue flows in Unified Modeling Language (UML)[3]. Existing methods integrate multi–modal aspects by non–UML extensions and lack of formal described semantics as requested by Broy[1].

2. MODELING APPROACH

Our work is based on a UML state machine semantics using Abstract State Machines (ASM)[2]. This semantics description resolves semantic ambiguities of state machines and gives a formal description of their behavior execution. The modeling method comprises three main steps: modeling the system components, operations and data using class diagrams, describing the task model in a hierarchical manner and modeling the multi-modal HCI behavior using state machines. The class diagrams define the context for the behavior models and assure a consistent design process. We decompose the HCI using task models and derive user operations and user triggered events from those models. These operations and events are added to the class diagrams to extend the behavior execution context. The integration of modality–specific content in a UML conform way requires enriching the UML. Our modeling method uses stereotype definitions for specific semantic constructs: speech recognition grammar, prompt and description of the graphical user interface. These stereotypes collect specific attributes for each semantic construct. While modeling, they can be assigned to any state in any combination, e.g. prompt and speech grammar.
We provide tool support for graphical modeling, verification and simulation of multi–modal state machine models. We specified multi–modal in–car dialogues to prove our approach. We conclude that a UML–conform specification of in–car HCI is possible and adequate regarding multi–modality.

3. CONTRIBUTIONS

Our work is based on a formal semantics so that we provide a clearly defined base for modeling as well as support automatic processing of our models, e.g. code generation. We ensure UML compatibility also for our multi–modal extensions. This encourages reuse of UML–based methods for verification and validation of HCI models. Our tool follows the ASM semantics and supports simulation of multi–modal UML models, which enables validation and comparisons of different HCI concepts already in an early stage of design. We proved our modeling concept by specification of multi–modal in–car HCIs including tool–based verification and validation by simulation.

4. FUTURE WORK

We will further validate our method by case studies. We plan to introduce enhancements like model–based dialogue quality measurement using model checking to offer support for development and test of multi–modal in–car HCIs.

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A Multifunctional Tool for Designing the HMI of Mechatronic Products

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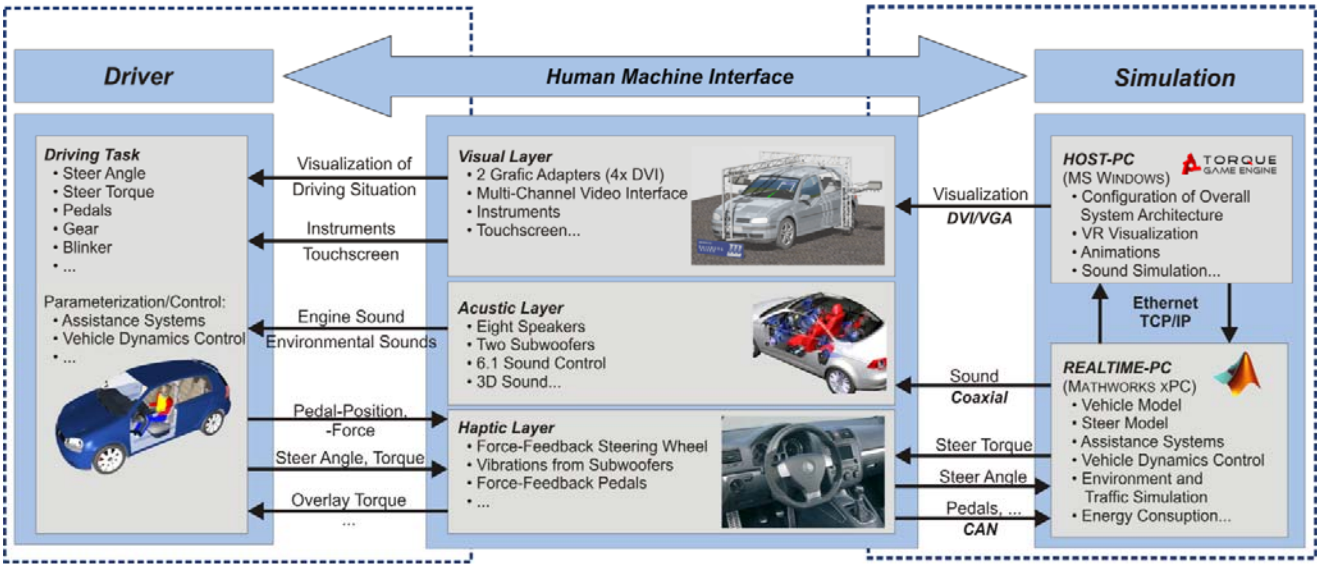

Figure 1: Simulator Struture of the DRIVASSIST Simulators

1. INTRODUCTION

Human centred mechatronic systems, such as modern driver assistance systems, are designed to simplify the use of complex systems or make them more secure. During their development there are two major issues: In addition to the technical function, the human centred characteristics of the system have to be engineered [1]. The driving simulators of the DRIVASSIST project provide the engineer with a tool to address both and make use of an advanced simulation concept provided by the mercatronics GmbH.

2. SIMULATOR STRUCTURE

The DRIVASSIST simulators work on a Matlab/Simulink basis. All vehicle models and assistance-systems were build at the Chair of Mechatronics. The user ist provided with open source code. This allows a fast implementation of new systems into the simulation environment. The open source code enables a maximum of felxibility for simulator investigations.

2.1 REAL TIME ENVIRONMENT

The models are computed in real-time by using a xPC target (Mathworks), which is both easy to use and fairly inexpensive. The real-time simulation coupled to a force-feedback steering wheel gives the driver a realistic feeling to operate a vehicle. This is essential for studies of HMI concepts.

2.2 HUMAN MACHINE INTERFACE

The HMI is the object of investigation, but it also is an important part for any realistic driving simulator. The intention of these standard HMI is to make the driver feel sitting in a real vehicle. Therefore, the DRIVASSIST simulators are designed with different visual, acoustical and haptical elements that can be used as HMI. New set-ups that are to be tested can be added easily.

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Intuitively usable user-interface concepts – Safety and reliability for usage of new functions and systems

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ABSTRACT
In this contribution we present an overview of our research results on psychological concepts and methodology for the intuitive use of technology. We focus on the special relevance of concepts of intuitive use for mobile systems and safety systems. Comfort aspects are also considered.

As central and initial theoretical research result the concept '*intuitive use*' will be defined and characterized. The theoretical assumptions then lead to two means for practical application, one of which includes principles for interface design, and the other one comprises criteria for prototype and product evaluation.

Categories and Subject Descriptors
H.1.2 [**Models and Principles**]: User/Machine Systems – *Human factors, Human information processing, Software psychology*

H.5.2 [**Information Interfaces & Presentation**]:User Interfaces – *Theory and Methods, User-centered Design, Graphical user interfaces (GUI) Evaluation / methodology*

D.2.2 [**Software Engineering**]: Design Tools and Techniques – *User interfaces*

General Terms
Human Factors, Theory, Performance, Design, Measurement, Safety, Reliability, Experimentation, Verification

Keywords
intuitive use, intuitiveness, human machine interaction, interface design, usability engineering, attention

1. INTRODUCTION
In times of short product cycles and increasing product functionality users and manufacturers are searching for usability solutions which provide spontaneous "easy" and correct use, probably while solving some other tasks like, for example, driving a car. A common approach to give the user a feeling of easy use is to design interfaces for *intuitive* use. But what does 'intuitive use' exactly mean – especially as a scientific term?

2. DEFINITION OF INTUITIVE USE
Intuitive use is a widely applied term even though there is no clear, consistent, or detailed understanding of the concept's meaning nor a complete equivalent already exists in other usage concepts. – On the Basis of literature review, expert workshops, user surveys and observations as well as analysis of relevant processes of usage the following definition has been elaborated:

> **'Intuitive use' is an interaction event of a user with an unknown or sporadically used system or object, which happens by spontaneous application of unconsciously transferred and adapted knowledge and thus is accompanied by a feeling of very low mental effort.**

Additional we found a characteristic usage concept, holding – compared to other concepts, e.g. familiarity – characteristic features for special demands or requirements regarding the human-technology interaction and therewith proves to be particularly suitable for the respective applications. Furthermore there are special usage situations and usage contexts in which intuitive use provides appropriate support and moreover increases the safety of individuals. Intuitively usable interfaces are highly supportive and facilitate the mental relief in multiple-tasks situations while an effective task processing is still given or even enhanced. This is of special importance when interacting with one of the numerous assistance systems while driving.

3. DESIGN AND EVALUATION MEANS
The theoretical characterization of the construct differentiates clearly between the process description *intuitive use* and the system feature *intuitive usability*. This separation offers the possibility to regard, define, characterise, and substantiate both aspects independently for their particular application. The evaluation criteria are separated in subjective and objective criteria. The design principles combines necessary and supporting principles.

Based on the theoretical results and the criteria for design and evaluation methodological suggestions with respecting tools regarding the integration of aspects of intuitive use in all major phases of a product development cycle have been developed.

4. ACKNOWLEDGMENTS
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Reaction Time Differences in Real and Simulated Driving

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ABSTRACT

The poster shows initial results at the question to what extent driving simulators can be used to serve as cheap and easy realizable environments for simulating on-the-road behavior. We have conducted two studies comparing the driver's reaction time in real and simulated settings with the aim to provide a metric for the differences in reaction time. The events were triggered trace-driven (simulation) or manually by the experimentor (real driving study) and notifications were forwarded to the driver using the modalities vision, hearing, and touch. We have found that (i) both settings provide similar results for the order of average response using the three modalities and (ii) the simulator experiment performed better, most likely by reason of the simpler setup of the driving simulator compared to the real world setting.

Keywords

Driving experiments, Driver-vehicle interaction (DVI), Feedback modalities, Performance evaluation.

1. MOTIVATION AND APPROACH

The car domain is requested to shorter and shorter time-to-market cycles, with at the same time driver assistance systems and control instruments catching on more and more into the dashboard. To cope with decreasing production cycles, simulation has been successfully applied, for instance to crash or wind tunnel tests. But for user interface evaluation, particularly for experiments measuring reaction times in driver-vehicle communication, simulation has been rarely used to date, e. g. by Santos *et al.* [4] or Panerai *et al.* [2], probably due to the complexity of person behavior representation. Nevertheless, performance and/or usability evaluation of user interfaces for new generations of vehicles in on-the-road experiments is often infeasible – beside economical reasons and the danger for road participants mostly due to the fact of long preparation and execution times.

Our goal was to provide a metric for the difference in response times between simulation and the real world to be used as a conversion table when replacing future on-the-road studies with simulation experiments. This solution can be assumed promising, as it has been shown for the automotive domain that simulation is a useful approach for data collection and driver behavior analysis, e. g. by Adler *et al.* [1] or Baujon *et al.* [3].

To provide evidence, we conducted two studies measuring the reaction time for notifications via the three sensory modalities vision, hearing or touch in both a simulated and a real-world driving experiment.

Conclusion and Future Work

Initial findings have shown that the reaction times in real world driving are higher (in the range 4.41% to 27.41%, depending on the stimulation modality); however, the simulation has only been done using a simple setting (a car in a garage and a video of the track). In the next experiments a more sophisticated simulator, providing an immersive environment (road vibrations, engine noise, etc.), will be used. With such simulators it should be feasible to analyze the increase in reaction time given the three modalities when transferring settings from the simulation to the real world.

Attribute	Reaction time *(ms)* $\overline{x_{TD}}$	$\overline{x_R}$	Diff. *(%)* $\overline{x_{TD \to R}}$	Order $_{TD,\ R}$
CI 5% [752 trace-driven (TD), 353 real (R) datasets]				
Combined	889.2	1,003.2	12.82	-, -
Visual	784.3	978.7	24.79	2, 2
Auditory	1,129.6	1,179.5	4.41	3, 3
Vibro-tactile	690.6	879.9	27.41	1, 1

Acknowledgements

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Advisory Cruise Control Device for an Intelligent Vehicle-Highway System

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ABSTRACT
The Intelligent Vehicle-Highway System in this paper is built for a Cooperative Adaptive Cruise Control system. In this system, vehicles communicate with each other through wireless means, where they coordinate each other's speed for better traffic flow. In this paper, we describe the design and evaluation of the interface between vehicle and driver, where the system takes an *advisory* role. The interface was developed into two prototypes where one has guidance mode and the other has explanation mode. We conducted a test on a driving simulator using both prototypes, in order to find which prototype is preferred and why.

Categories and Subject Descriptors
H.5.2 [**Information Systems**]: User Interfaces – *Evaluation/methodology, Prototyping, Screen design, User-centered design.*

General Terms
Management, Measurement, Performance, Design, Experimentation, Human Factors, Verification.

Keywords
Multimodal interface, Automotive, Cooperative Cruise Control

1. INTRODUCTION
Cooperative Adaptive Cruise Control (CACC) is the next generation of Adaptive Cruise Control (ACC), where there is a communication between vehicles in addition to sensor capabilities of each vehicle to adapt speed to other vehicles in order to make a smooth traffic flow and optimize traffic throughput. This speed adaptation is automatic, i.e. done by the cruise control system of each vehicle. In addition to the automatic system, we also proposed an advisory system: Cooperative Cruise Control (CCC). This device is intended to be built as an aftermarket device, which will have better market penetration thus increasing the number of users in the traffic.

According to a survey on Advanced Driver Assistance System (ADAS) [1], more than 42% of the respondents liked to be supported during congestion driving in motorways, and more than 90% of the respondents wanted to be warned for upcoming traffic conditions e.g. congestion and road works. We focus on speed for guidance, because according to a survey on speed choice [2], drivers' reasons to obey speed limit are safety and avoiding fine. Unintentionally 15% of drivers exceed the speed limit.

A preliminary study through two focus groups of 10 and 11 participants showed a preference for advisory over automatic systems. Moreover, participants considered information about traffic jams, unavailable roads, traffic density, environment (speed limit, safety level, traffic regulation, etc) as important. In the case of an advisory system, participants wanted to know the reasons for the system's advice. Participants strongly disliked intrusive auditory signals, so visual feedback was considered. To increase multitasking ability [3], the visual feedback should be glanceable.

2. PROTOTYPES
In order to answer the question of what, how, and when to present advices from a CCC device, several prototypes were developed and tested. Preliminary study and several visual and audio design iterations resulted in two prototypes. They both inform users about speed choice in three states {Too Fast, Appropriate, Too Slow}. In the Guidance prototype, users are only presented with colors, numbers, and sounds. In the Explanation prototype, additionally users are presented with icons and can interact with buttons for more information (explanation/consequences).

Each of 24 test participants was asked to do 10 to 15 minute driving using both prototypes (one at a time) on a driving simulator. They were asked to rate each interface element of the prototypes through a questionnaire, asked to express their understanding on the icons, and interviewed to get forced preference of prototypes, modalities, and elaboration on questionnaire results.

The results show that people liked the extra information for triggering action and sensing high urgency. They judged the color changes presented in the periphery of the visual field as more action triggering than audio signals.

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Speech and sound for in-car infotainment systems

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ABSTRACT
In a hands-busy and eyes-busy activity such as driving, spoken language technology is an important component of the multimodal human-machine interface (HMI) of an in-car infotainment system. Adding speech to the HMI introduces two distinct challenges: accurately acquiring the user's speech in a noisy car environment, and creating a spoken dialog system that does not require the driver's full attention.

Categories and Subject Descriptors
H.5.2. [**User Interfaces**]: Natural language, Voice I/O, Interaction styles, Prototyping.

General Terms
Algorithms, Design, Human Factors.

Keywords
Speech interfaces, in-car infotainment, multimodal UI.

1. INTRODUCTION
Voice-enabled dialog systems are among the most attractive features of in-car infotainment systems, since speech is the only wideband communication channel not significantly engaged during driving. Such systems first began to appear in high end cars, but recently found their way to mass production cars, such as Ford and Fiat. Currently they are in transition from being a cool gadget to an integral part of the modern automobile. Speech interfaces are being integrated into a growing number of applications, ranging from control of the radio and other equipment in the car, to the use of external devices such as mobile phones, portable media players, and navigation systems.

2. SOUND CAPTURE SYSTEM
Environmental noise is the major challenge for sound capture in cars. The in-car system typically has a speech enhancement block that attempts to remove environmental noise, followed by a chain of several encoder/decoders (Bluetooth, GSM, G711). Another challenge is to make the sound capture system suitable for both human-human communication and speech recognition (both in-car and server-based). To maximize the perceptual sound quality and speech recognition results end-to-end optimization of the system can be performed. The sound capture can be further improved by adding more microphones to form a microphone array [5].

3. NATURAL LANGUAGE INPUT
Most conventional in-car speech systems work with a fixed grammar, i.e. a set of commands that the driver has to remember. For improving the system usability, we propose using a more flexible system that replaces the grammar with a statistical language model (LM). For added robustness to system and user errors, the recognizer output is then post-processed using information retrieval techniques commonly used in web search, such as TF-IDF. This combination of LM-based speech recognition and search techniques enables the system can find the most relevant match for the user's request even when the input query is not exact. Using this approach, we have designed applications for selecting music from a media player [3][4], replying to text messages [2] and searching the car owner's manual.

Speech is a very useful and efficient input modality when selecting an item from a long list, e.g. 5K songs. However, the usability and efficiency of speech decreases if the list length is small, e.g. selecting the exact song from the top four hypotheses. In these situations, when the driver can see all four candidates by just glancing at the screen of the in-car system, touch or button may be a preferred input modality. A multimodal user interface that appropriately combines the strengths of speech, graphics, button, and touch is less distracting and more convenient than a user interface that relies exclusively on any one single modality.

4. CONCLUSIONS
A successful human-machine interface for in-car applications is one that allows drivers to perform non-essential infotainment tasks without adversely affecting driving performance. Along with touch, buttons, and graphical displays, speech is a key modality that enables the design of user interfaces that can improve usability and reduce distraction for drivers. More information and videos of our prototype can be found on our project web page [1].

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Evaluating Design Language for Vehicle Instrument Clusters

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ABSTRACT

The fields of Human-Computer Interaction and interface design have been expanded from a narrow focus on usability to more broadly consider the human experience and aesthetic response to design. Tools and methods developed to evaluate the relationship between perceived usability and interface aesthetics have revealed that overall preference for an interface is highly correlated to positive aesthetic response, and that positive aesthetic response is elicited through use of positive symbolism, incorporation of classical aesthetic elements and creating an interface that is typical (expected) and attractive. While symbolism can be a representation of sentiments, such as family or the environment, or cherished memories, such as one's youth or achievements, in product design, the container for symbolism is often the brand and is expressed through the brand or design language (DL). In large multidisciplinary product design organizations the DL is more often created by marketing and/or brand management organizations to position the brand and control the product statement, and the DL is conveyed formally to the designers using image boards, inspiration videos and other media to infuse the language into those whom will make decisions that affect product brand expression. Since there currently is no formal method for assessing how well products convey the design/brand language, we used, and present here, the methodology for aesthetics-usability assessment to assess brand language expression. Our intent is to create a tool that can be used as part of an iterative design-refinement cycle to help designers hone designs to crisply convey the intended messages. To do so, we created 24 designs of automotive instrument clusters, which were variations of 8 different basis designs. 5 of the 8 basis designs were inspired by adjectives from the Cadillac DL and 3 were inspired by that of Chevrolet. The seven adjectives/terms – daring, dramatic, attitude, groundbreaking, impressive, intricate and precise – were used to convey the Cadillac brand. Similarly, the 7 adjectives/terms – clean, pure, straightforward, strong, bold, solid and confident – were used to express the Chevrolet brand. The basis designs differed through their exploration of the design trades between simplicity and complexity, symmetry and asymmetry and openness and closedness. In a structured three phase experimental protocol, 50 respondents evaluated the 24 designs for overall attractiveness, overall preference and how well the designs communicated the terms of the two different DLs. Detail analysis of respondent data revealed that both of the DL are comprised of two dimensions. The Cadillac DL (as expressed via the stimuli in this research) is comprised of two factors, one that includes (F1) daring, dramatic, attitude, groundbreaking and impressive, and a weaker factor that includes (F2) intricate and precise. One of the two strong factors that comprise the Chevrolet DL has the grouping – (F3) clean, pure and straight forward and the other factors contains the terms (F4) bold, solid, confident and strong. Attractiveness and preference ratings revealed that not only were the designs considered quite attractive with average values of 5.85 and 5.18, respectively (1-10 rating scale), but that there was fairly high correlation (0.7) between attractiveness and preference. This correlation indicates, as was found in previous research, that the brief exposure of the respondents to the design (500 ms) is sufficient to elicit aesthetic impression. Assessment of how well each of the designs expressed the Chevrolet and the Cadillac design languages revealed that the goal of expressing the DL of Cadillac is more challenging than that for Chevrolet. Only one of the Cadillac designs received a high score in expressing the Cadillac DL, and the second highest score was received by a design inspired by the Chevrolet DL. On the contrary, with the exception of one design (a Chevrolet DL inspired design) that scored low for both design languages, all of the design adequately expressed the Chevrolet design language. These results indicate that the DL adjectives/ terms were not semantically orthogonal. For instance, bold (Chevrolet) & daring (Cadillac) are not semantically distinct terms and clean (Chevrolet) & precise (Cadillac) are not completely distinct. While the designers had less success in their goal of expressing the Cadillac design language than they did for expressing the Chevrolet DL (for instance, none of the designs adequately conveyed 'precise' or 'intricate'), they did uncover design directions that could be leveraged in additional design cycles. Design features such as filled area indicators seem to convey Cadillac whereas traditional needle-in-dial indicators score higher for expressing Chevrolet than Cadillac. These design threads and this analysis methodology is being pursued in follow-on iterative design/ evaluation research to create instrument clusters that truly convey the brand intent.

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