Advanced Vehicle Sonification Applications

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AutomotiveUI '14 Adjunt, Sep 17-19 2014, Seattle, WA, USA
ACM 978-1-4503-0725-3/14/09.
http://dx.doi.org/10.1145/2667239.2667284

Abstract
Visual displays are still mainly used in the in-vehicle context, but they may be problematic for providing timely, appropriate feedback to drivers. To compensate for the drawbacks of visual displays, multimodal displays have been developed, but applied to limited areas (e.g., collision warning sounds). The present paper introduces advanced vehicle sonification applications: Two of our on-going projects (fuel efficiency sonification and driver emotion sonification) and a plausible future project (nearby traffic sonification). In addition, applicable sonification techniques and solutions are provided. Sonification applications to these areas can be an effective, unobtrusive means to increase drivers' situation awareness and engagement with driving, which will lead to road safety. To successfully implement these applications, iterative and intensive assessment of driver needs, effectiveness of the application, and its impact on driver distraction and road safety should be conducted.

Author Keywords
Auditory display; connected autonomous vehicles; driver affective state; emotion; fuel efficiency; sonification; traffic flow

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces – interaction styles, Sound and Music Computing – methodologies and techniques.

General Terms

Design; Human Factors

Introduction

Given that vision is heavily occupied during drive, research on in-vehicle use of auditory displays and sonification has been intensively conducted [for review, see 1]. Current applications of in-vehicle auditory displays include the traditional collision warning sounds for driving task [2], voice and beeps for personal navigation devices [3], and diverse sounds for in-vehicle infotainment systems [4]. Multiple resources theory [5] predicts benefits of the use of auditory displays for the driving context and much research has supported it. Leveraging those successful applications of auditory displays and sonification to the vehicle situation, the present paper tries to extend the application areas and outline plausible scenarios and sonification techniques.

Application I: Fuel Efficiency Sonification

Although research has established that feedback from fuel efficiency driver interfaces (FEDIs) can have a positive impact on driver behaviors associated with fuel economy, the impact of FEDIs on driver distraction has not been established. It is precisely during fuel-consuming behaviors that drivers should not divert their attention away from the driving task. Thus, visual displays may be problematic for providing this feedback. Auditory displays, however, can offer a viable alternative to visual displays for communicating information about fuel economy to the driver without introducing visual distraction. For example, speech-based auditory displays have been prototyped for use in FEDIs; the system offered spoken alerts and advice to improve fuel economy [6]. Speech offers an advantage in that the intended message requires no explanation and the system does not require a learning phase. However, speech might interfere with concurrent conversation and create annoyance in the form of a virtual backseat driver. Fairly recently, our research team has been trying to prototype FEDIs using non-speech sounds and sonification techniques [7]. We have developed an app that can extract all the driving performance data (speed, lane deviation, torque, steering wheel angle, pedal pressure, crash, etc.) from our simulator (NADS miniSim). All these data can be mapped onto sound parameters. In the actual vehicle, the fuel consumption data obtained via communication with CAN (Controller Area Network) bus can be used to trigger sound feedback or translated into sound/music parameters. Concrete examples of sonification are described in Technique sections below.

Application II: Driver Emotion Sonification

Even though there have been several attempts to develop an in-vehicle affect detection system [e.g., 8, 9], little research has focused on implementation of a mitigation system, which is the necessary step for safe driving. Literature provides only simple ideas, such as changing a font size of the display [10], blocking emails [11], or making a conversation with the in-vehicle agent [12]. From this background, we aim to build and test intervention techniques using interactive sonification. We attempt to integrate multiple data, including physiological measures (ECG, respiration, skin conductance response), bodily reactions (facial expression, fEMG, eye-tracking), and brain waves (EEG). These real-time data will be combined and further processed to be used as inputs for interactive sonification. The driver emotion sonification system could monitor all parameters and sonify in real-time a driver's affective states and driving behaviors, and adapt sound scapes depending on those data patterns. The intervention effects will be assessed again with a driver's physiological data (i.e., regulation of the affective state per se) and driving behavior data (i.e., mitigation of affective effects on behaviors).

Application III: Nearby Traffic Sonification

The previous two projects describe an individual driver level application, whereas it is also possible to apply sonification techniques to the drivers' collective awareness level [13]. Recently, research on connected autonomous vehicles has proliferated and big data from those vehicles have high potential to be used to manage traffic flow. Thanks to autonomous vehicles, drivers' overall tasks and workload might decrease, but simultaneously their controllability and situation awareness can also decrease. Traffic sonification can enhance drivers' controllability, situation awareness, risk perception, and subjective satisfaction; it can also reduce workload. For example, we can create a new radio channel, dedicated to real-time traffic sonification based on nearby traffic data (e.g., overall speed, flow in each lane, accidents, etc. see Figure 1). We can easily try to translate the information from the current traffic broadcasting, such as XM (the US) or RDS (Europe) into sound parameters. If well implemented, traffic sonification can yield comparable trust level and driving performance as speech-based traffic broadcasting, while it can unobtrusively increase drivers' situation awareness and engagement with driving, which will lead to road safety.

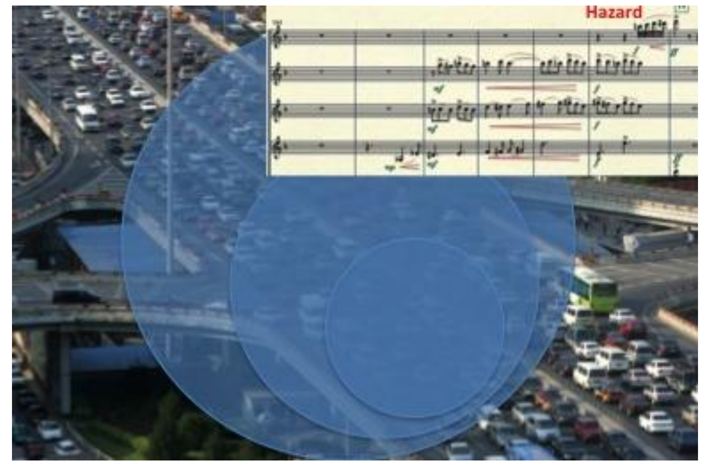

Figure 1. A conceptual diagram of traffic sonification. Using a car stereo system, drivers can monitor traffic flow and real-time warnings by listening to spatial music algorithmically improvised based on traffic data. Drivers can configure a range of traffic, type of variables, etc.

Technique I: Intermittent Sonification

A couple of sonification approaches can be used to implement these advanced vehicle sonification applications. Discrete sounds can be generated as an alarm, warning or feedback (e.g., using earcons [14], auditory icons [15], spearcons [16], or lyricons [17]). For example, if the fuel efficiency or driver's affective state is optimal for a certain amount of time, the sonification system can generate positive sounds as reinforcement [18]. On the other hand, if the driver exceeds a certain threshold (e.g., fuel consumption or angry level abruptly increases), the system can provide a direct warning signal.

Technique II: Continuous Sonification

Another approach is using a continuous soundscape based on parameter sonification [19]. The sound can be generated as a state monitoring, but multiple sound streams can also provide a behavioral guidance. The discrete sonification can provide a more direct message, whereas the continuous sonification can serve as a subliminal cue [20]. Each aspect should be empirically evaluated with drivers. It can also be considered to integrate both approaches appropriately. For example, the sound scapes are usually generated using the holistic mappings (e.g., driving performance, fuel efficiency, and driver's affective state influence music tempo and rhythm with differentiated weights), and warning signals can be generated based on one-on-one mappings (e.g., frequent lane deviation instances trigger a warning sound). This sonification can also be used for novice drivers during driving training sessions. Depending on their affective states and driving behaviors, the difficulty level of driving scenarios can be dynamically changed.

Conclusion and Future Work

As an alternative of visual displays, auditory displays and sonification have been applied to the in-vehicle context. The present paper lays out more enhanced version of vehicle sonification applications. Auditory displays of the same information may allow drivers to adjust their behaviors for more eco-friendly and safer driving and also allow them to keep their eyes on the road. With electric vehicles being pervasive, this type of multimodal in-vehicle system is expected to improve driver situation awareness and road safety even more. Our research program seeks to provide evidence for best use of auditory displays and sonification in the in-vehicle context by investigating their effectiveness and feasibility, considering customization and aesthetics.

References

[1] Nees, M. A. and Walker, B. N. Auditory displays for in-vehicle technologies. In P. DeLucia (Ed.), *Reviews of Human Factors and Ergonomics*, 7, 1 (pp. 58-99). Santa Monica, CA: Human Factors and Ergonomics Society. 2011.

[2] Belz, S. M., Robinson, G. S. and Casali, J. G. A new class of auditory warning signals for complex systems: Auditory icons. *Human Factors*, 41, 4, 1999, 608-618.

[3] Jeon, M., Park, J., Heo, U. and Yun, J. Enhanced turning point displays facilitate drivers' interaction with navigation devices. In *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactice Vehicular Applications (AutomotiveUI09)* (Essen, Germany, 2009).

[4] Jeon, M., Gable, T. M., Davison, B. K., Nees, M., Wilson, J. and Walker, B. N. Menu navigation with in-vehicle technologies: Auditory menu cues improve dual task performance, preference, and workload. *International Journal of Human-Computer Interaction, published online,* 2014.

[5] Wickens, C. D. Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*, 3, 2002, 159-177.

[6] Meschtscherjakov, A., Wilfinger, D., Scherndl, T. and Tscheligi, M. Acceptance of future persuasive in-car interfaces towards a more economic driving behaviour, In *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactice Vehicular Applications (AutomotiveUI09)* (Essen, Germany, 2009), pp. 81–88.

[7] Nees, M. A., Gable, T., Jeon, M. and Walker, B. N. Prototype auditory displays for a fuel efficiency driver

interface In *Proceedings of the 20th International Conference on Auditory Display (ICAD2014)* (NY, USA, 2014).
[8] Lisetti, C. L. and Nasoz, F. Affective intelligent car interfaces with emotion recognition. In *Proceedings of the 11th International Conference on Human Computer Interaction* (Las Vegas, NV, USA, 2005).
[9] Healey, J. *Wearable and automotive systems for affect recognition from physiology*. PhD Dissertation, Massachusetts Institute of Technology, Boston, MA, 2000.
[10] Hudlicka, E. and McNeese, M. D. Assessment of user affective and belief states for interface adaptation: Application to an air force pilot task. *User Modeling and User-Adapted Interaction*, 12, 2002, 1-47.
[11] Eyben, F., Wollmer, M., Poitschke, T., Schuller, B., Blaschke, C., Farber, B. and Nguyen-Thien, N. Emotion on the road-Necessity, acceptance, and feasibility of affective computing in the car. *Advances in Human-Computer Interaction*, 2010, ID 263593 2010, 1-17.
[12] Harris, F. H. *Emotion regulation for drivers: An exploration of variables that promote positive emotional states and safe driving*. PhD Dissertation, Stanford University, Stanford, CA, 2011.
[13] Riener, A., Jeon, M. and Ferscha, A. Human-car confluence: Socially-inspired driving mechanisms, in A. Gaggioli (Ed.), Human-computer confluence: Advancing our understanding of the emerging symbiotic relation between humans and computing devices, in press.
[14] Blattner, M. M., Sumikawa, D. A. and Greenberg, R. M. Earcons and icons: Their structure and common design principles. *Human-Computer Interaction*, 4, 1989, 11-44.
[15] Gaver, W. W. Auditory icons: Using sound in computer interfaces. *Human-Computer Interaction*, 2, 1986, 167-177.
[16] Walker, B. N., Lindsay, J., Nance, A., Nakano, Y., Palladino, D. K., Dingler, T. and Jeon, M. Spearcons (Speech-based earcons) improve navigation performance in advanced auditory menus. *Human Factors*, 55, 1, 2013, 157-182.
[17] Jeon, M. Lyricons (Lyrics + Earcons): Designing a new auditory cue combining speech and sounds. In C. Stephanidis (Ed.), *Posters, Part I, HCII 2013, CCIS 373,* pp. 342-346. Heidelberg: Springer. 2013.
[18] Jeon, M., Roberts, J., Raman, P., Yim, J.-B. and Walker, B. N. Participatory design process for an in-vehicle affect detection and regulation system for various drivers. In *Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'11)* (Dundee, Scotland,2011).
[19] Hermann, T. *Taxonomy and definitions for sonification and auditory display*. In *Proceedings of the 14th Internatinal Conference on Auditory Display (ICAD2008)* (Paris, France, 2008).
[20] Riener, A. and Jeon, M. The role of subliminal perception in vehicular interfaces. In *Proceedings of the 14th ACM International Conference on Ubiquitous Computing (UbiComp'12)* (Pittsburgh, USA, 2012).