Vibrotactile Patterns for Smartphone Based ADAS Warnings

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Abstract. A large number of researches show that various driver distractions considerably increase the probability of causing an accident. Advanced Driver Assistance Systems (ADAS) can be used to prevent dangerous driving conditions by monitoring the environment and warn the user in situations like collision, lane departure or speed infractions. In most cases of using the ADAS systems, the driver is warned by visual indicators or audio signals. This paper investigates the design of a device that can be integrated in the driver's seat which allows the issue of dynamic vibrotactile warnings received from a smartphone based ADAS system.

Keywords: Advanced Driver Assisted Systems · Vibrotactile patterns
Driver distraction

1 Introduction

In recent years, numerous studies have been conducted on the development of advanced driver assistance systems (ADAS) in order to prevent accidents from happening [4, 9]. These systems rely mainly on visual indicators or audio signals for warning the driver in different dangerous situations. Visual warnings consist in presenting various messages in different types of displays, but can be missed by the driver if he/she is not paying attention to the device that issues the alert. Also audio warnings can be ignored when listening to music. An innovative method of warning the driver is by using vibrotactile cues.

Vibrotactile represents a haptic feedback that is intuitive and easy to interpret and learn. This technology can be used in many domains such as navigation systems, warning systems. ADAS that implement vibrotactile impulses as a warning method present numerous advantages because the sense of touch is not as involved as other senses, such as sight and hearing, in the driving process. Vibrotactile warning is the optimal solution in noisy environment with heavy traffic [7].

One of the main advantages of vibrotactile warnings is the fact that it is noticed only by the driver, especially when alerting a taxi or truck driver regarding his/her degree of fatigue. But this method of warning may lose its efficiency in winter when the clothes worn by the driver are thicker [8].

Vibrotactile warnings can be used to refocus the driver's attention when he/she is following a car and needs to maintain a safe distance from it, as presented in [6]. The

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three vibrotactile stimuli were placed in a Velcro belt fastened around the driver's belly area and generated a triple cue, each for 100 ms.

In [1] is studied the reduction of the driver's braking reaction time in the event of an imminent collision by using vibrotactile warnings. The vibrotactile stimuli were placed on the driver's back in a square layout with stimuli in the center. The breaking reaction to impeding collision was also analyzed in [2], but in this research the driver was alerted by both audio and vibrotactile warnings. The vibrotactile impulses were generated by two motors driven by a 250 Hz sinusoidal signal and were placed on the driver's hands.

Warning and directional cues can be represented by static patterns such as vibrotactile stimuli on a specific area on the human body or by dynamic patterns that consist in a succession of vibrotactile stimuli in different areas of the body situated in close proximity. Dynamic patterns situated on the driver's torso cause a faster response than the ones situated on other areas of the human body or the usage of static patterns [10].

Dynamic vibrotactile patterns have been used only in take-over situations, as presented in [12] where 47 vibrotactile motors have been distributed in the driver's seat, 25 along the back, 16 in the seat area and 3 on the sides. The input voltage for the vibrotactile motors was 1.6 V, creating a vibration frequency of 140 Hz.

This paper investigates the design of a device that can be integrated in the driver's seat which allows the issue of dynamic vibrotactile warnings received from a smartphone based ADAS system.

2 Development of the Vibrotactile Patterns for Smartphone Based ADAS Warnings

2.1 Smartphone Based ADAS System

The developed smartphone dual camera ADAS solution, also presented in a previous research [3] is running on the Android OS system, allowing to improve safety within the vehicle and traffic. The smartphone used (HTC One M9) for the ADAS application installation has the following specifications: Qualcomm Snapdragon 810 processor at 2 GHz, Adreno 430 GPU, 3 GB RAM, a primary camera of 20 MP, f/2.2, 28 mm, a secondary camera of 4 MP, f/2.0, 27 mm. The advantage of this smartphone is that it simultaneously allows the receiving and analyzing of images from both cameras.

The main camera of the smartphone is used for acquiring the traffic scene images which are processed by the ADAS applications in order to identify different dangerous situations such as: vehicle crossing the solid/dashed line, vehicle/pedestrian front collision and speed infractions (Fig. 1). The second camera is used to identify distracting activities performed by the driver. The developed ADAS system can be used in real traffic scene scenarios or offline ones by providing the Android application with a video stream input, previously recorded.

Fig. 1. Lane positioning vibrotactile cue.

2.2 Vibrotactile Display Patterns

The developed vibrotactile display provides vibrations that the driver interprets, by using actuators located on the driver seat. A set of dynamic vibrotactile patterns are proposed to signal the following warnings received from ADAS based smartphone: lane positioning, speed infraction and front collision.

The dynamic patterns are implemented by positioning several stimuli (vibration motors) in different locations of the seat in order to simulate a movement felt on the driver's back, by activating them in a precise order. There are four dimensions for coding vibrotactile information: frequency, amplitude, location, and timing (moving pattern) [11].

Fig. 2. Vibrotactile motors matrix positioned on the driver's seat and smartphone based ADAS system integrated in a vehicle simulation test bench.

The vibrotactile warnings are obtained by using 3 × 4 motors matrix which can be attached to the driver seat. The motors were mounted on a 25 × 20 mm piece of foam material (Fig. 2). The motor matrix was positioned on the back rest of the driver's seat in order to have firm contact to the driver. In [5] is reported that the distance of 40 mm is too small and can confuse the driver. Therefore, the distance between the motors rows is set at the minimum distance of 50 mm. For this matrix were used Shaftless Vibration Motors, type Pololu, dimensions: 10 × 2.0 mm. Based on manufacturer recommendations and test performed in the university laboratory, the input voltage was set at 3 V. The motors vibrated at about 200 Hz frequency and 0.75 G amplitude.

The control of the motors matrix, in order for it to issue the ADAS warnings, was realized through the use of a Teensy microcontroller. The communication between the developed smartphone based ADAS system and vibrotactile warning device was realized through Bluetooth wireless technology.

The lane positioning warning was implemented by activate the motor columns for 300 ms from the left to the right and is perceived by the driver as a horizontal movement on his/her back. The speed infraction warning was implemented by activate subsequently several adjacent motor for 200 ms which allows the creation of a circular pattern and the driver feels a circular movement on his/her back (Fig. 3).

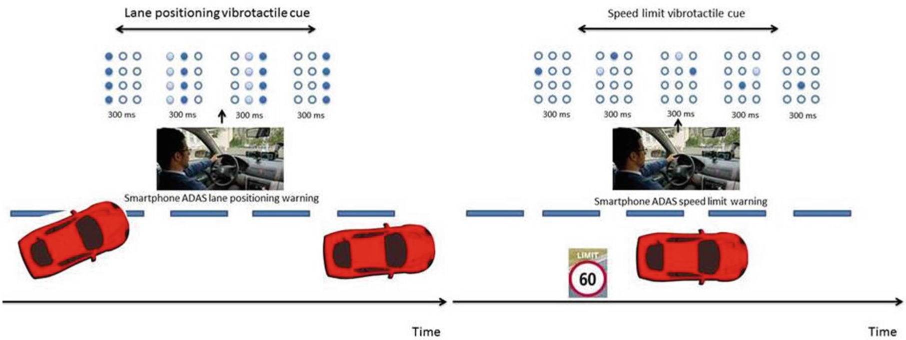

Fig. 3. Lane positioning vibrotactile cue and speed limit vibrotactile cue.

The front collision warning was implemented by activate the motor rows for 300 ms from the lowers to the top of the motor matrix and the driver perceivers a movement from the lumbar to the cervical area of his/her spine (Fig. 4).

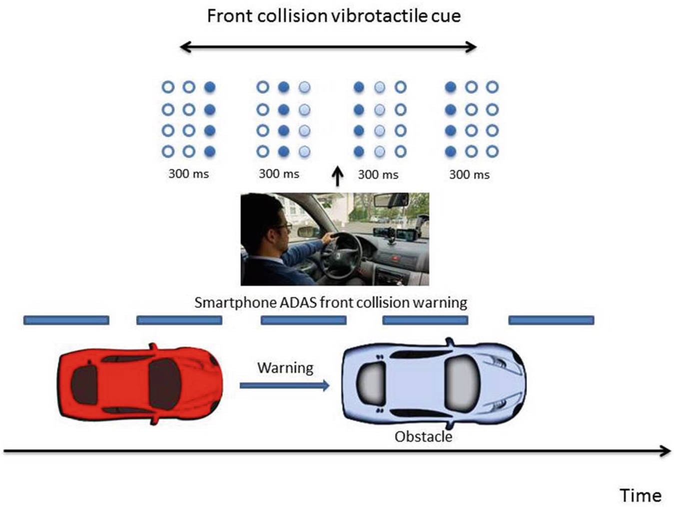

Fig. 4. Front collision vibrotactile cue.

3 Conclusions

Advances in the development of ADAS systems present the potential to warn and assist the driver in various dangerous situations. The paper presents the development of a set of dynamic vibrotactile patterns that can be used to signal the lane positioning, speed infraction and front collision warnings received from an ADAS based smartphone. The warnings are issued by using a 3 × 4 vibrotactile motors matrix which can be attached to the driver seat. The developed dynamic vibrotactile pattern shows a promising potential which allows the improvement of alerting the driver in dangerous situations through ADAS system warnings. The limitations of the proposed system consist in the sensibility of perceiving the vibrotactile warnings. Future studies will investigate the effects of developed ADAS system on driver behavior in real driving condition.

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References

1. Ahtamad, M., Spence, C., Ho, C., Gray, R.: Warning drivers about impending collisions using vibrotactile flow. IEEE Trans. Haptics **9**(1), 134–141 (2016)
2. Biondi, F., Strayer, D.L., Rossi, R., Gastaldi, M., Mulatti, C.: Advanced driver assistance systems: using multimodal redundant warnings to enhance road safety. Appl. Ergono. **58**, 238–244 (2017)

3. Duguleană, M., Dumitru, A., Postelnicu, C., Mogan, G.: Video-based evaluation of driver's visual attention using smartphones. In: Proceedings of 6th International Conference on Information, Intelligence, Systems and Applications (IISA), Corfu, Greece, pp. 1–5 (2015)
4. Dumitru, A.I., Girbacia, T., Boboc, R.G., Postelnicu, C.C., Mogan, G.L.: Effects of smartphone based advanced driver assistance system on distracted driving behavior: a simulator study. Comput. Hum. Behav. **83**, 1–7 (2018)
5. Fitch, G.M: Driver comprehension of integrated collision avoidance system alerts presented through a haptic driver seat. Diss. Virginia Tech (2008)
6. Ho, C., Tan, H.Z., Spence, C.: Using spatial vibrotactile cues to direct visual attention in driving scenes. Transp. Res. Part F: Traffic Psychol. Behav. **8**(6), 397–412 (2005)
7. Li, Y., Jeon, W.R., Nam, C.S.: Navigation by vibration: effects of vibrotactile feedback on a navigation task. Int. J. Ind. Ergon. **46**, 76–84 (2015)
8. Meng, F., Li, S., Cao, L., Peng, Q., Li, M., Wang, C., Zhang, W.: Designing fatigue warning systems: the perspective of professional drivers. Appl. Ergon. **53**, 122–130 (2016)
9. Pantea, A., Girbacia, F., Girbacia, T.: Development of an advanced driver assistance system using RGB-D camera. In: Chiru, A., Ispas, N. (eds.) International Congress of Automotive and Transport Engineering, CONAT 2016, pp. 746–75 Springer, Cham (2017)
10. Petermeijer, S.M., Cieler, S., De Winter, J.C.F.: Comparing spatially static and dynamic vibrotactile take-over requests in the driver seat. Accid. Anal. Prev. **99**, 218–227 (2017)
11. Petermeijer, S.M., De Winter, J.C.F., Bengler, K.J.: Vibrotactile displays: a survey with a view on highly automated driving. IEEE Trans. Intell. Transp. Syst. **17**(4), 897–907 (2016)
12. Schwalk, M., Kalogerakis, N., Maier, T.: Driver support by a vibrotactile seat matrix—recognition, adequacy and workload of tactile patterns in take-over scenarios during automated driving. Procedia Manuf. **3**, 2466–2473 (2015)