In-Vehicle Natural Interaction Based on Electromyography

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ABSTRACT
In this paper, we describe a natural interface based on microgestures performed on a steering wheel and recognized through the driver's electrical muscular activity. This approach is based on a wearable paradigm of interaction, in which the sensors are placed on the user's arm. The wearable system communicates with the infotainment system of our prototype through Bluetooth. We designed the gesture vocabulary in order to facilitate the driver interaction with the infotainment system while holding the steering wheel with both hands. We tested our approach with eight users showing the possibility to recognize four microgestures with an average accuracy of 94.55%.

Categories and Subject Descriptors
H [**Information Systems**]: H.5 Information Interfaces and Presentation—*H.5.2 User Interfaces;*

General Terms
Experimentation, Human Factors.

Keywords
Electromyography; Microgestures; In-Vehicle Interaction.

1. INTRODUCTION
Nowadays, In-Vehicle Information and communication Systems (IVISs) provide increasing entertainment and communication opportunities while driving. Most IVISs are placed in the central console of the car, allowing both driver and passenger to control it. Unfortunately, these systems may distract the driver, which has to shift the eye gaze and attention from the road and to move one hand from the steering wheel. In fact, many IVISs include buttons around a central display as well as multifunctional controllers or touch displays for controlling secondary tasks. The result of this approach consists in the user being overwhelmed by a plethora of controllers on his/her dashboard. The impact on the driving task of such IVIS has been studied by Bach et al. and compared to a gestural interface in [1]. The research community agrees on considering the gestural interaction for the driver as safer than using controllers that are distributed on the dashboard. Indeed, Riener stated that "in-vehicle gestural interfaces are easy to use and increase safety by reducing visual demand on the driver" [6]. Similarly, Döring et al. assessed that the driver's visual demand is reduced significantly by using gestural interaction on the multi-touch steering wheel that they developed and presented in [4].

The main contribution of this work is a natural interface based on microgestures focusing on the driver interaction with an IVIS. This system adopts the wearable paradigm that consists in placing the sensors on the user. These sensors capture the electromyographic (EMG) signals generated by the electrical muscles activity. The wearable system sends these data to the IVIS. Finally, the IVIS interprets these data as commands. In the next section we describe the system architecture, the gestures design with relative anatomic details for the sensors placement and the first tests we conducted in order to validate this approach.

2. APPROACH
Developing an interface to interact with the IVIS of a car typically requires integrating physical interfaces in the vehicle. This can be problematic since a change in the hardware involves a significant modification in the production chain of a car. In this paper, we propose an approach based on a wearable paradigm, which has the advantage of separating the technology on the user and the technology on the car. The onboard system has to receive and interpret the signals from the wearable component. Acquiring data from wearable sensors, the interaction can be done on the entire surface of the steering wheel external ring.

Designing our gesture vocabulary (see Figure 1), we limit our research on interactions that are not demanding for the driver. The interface should not distract the user from his/her primary task: driving. In addition, we chose to focus on gestures supporting the driver interaction even while holding the steering wheel with both hands. For instance, the driver can control the IVIS without moving the gaze from the road conserving the safety of the driving.

Microgestures, if correctly designed, allow executing a secondary task without interrupting or interfering with the primary task. Wolf et al. [7] studied the design of gestures in a car having the driving as primary task. The authors proposed a list of optimal microgestures in terms of feasibility, attention and risk of confusion. Extending their research, we defined the simple microgestures vocabulary depicted in Figure 1.

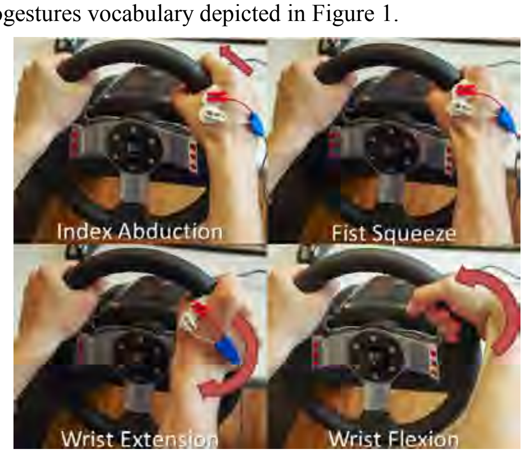

Figure 1. The four gestures used for the interaction.

Figure 1 presents the lexicon of four microgestures that we have adopted in our study: a) index abduction, b) fist squeeze, c) wrist extension and d) wrist flexion.

This lexicon can be extended to other gestures. The presented microgestures have been chosen to validate different typologies. Indeed, the index abduction represents a category of microgestures performed with the fingers that are easy to detect with sensors on the dorsum (back) of the hand. The wrist extension and flexion gestures validate the possibility of interaction sliding on the steering wheel. Finally, the fist squeeze belongs to the category of the "motionless" gestures. We limited the vocabulary to four microgestures in order to reduce the cognitive load and make the interaction safer.

3. SYSTEM OVERVIEW

The system senses the electrical activity of four muscles: the *First Dorsal Interosseous*, the *Flexor Carpi Ulnaris*, the *Palmaris Longus* and the *Extensor Digitorum*. Figure 2 shows the signals of every sensed muscle for each microgesture. The four channels are sensed by a wireless EMG device [5] that amplifies and sends the information to a processing unit for the feature extraction. We used the following features: signals Root Mean Square, Logarithmic Band Power and Mean Absolute Value. The system processes these signals in temporal windows of 256 ms with an overlapping of 128 ms. Afterwards, signals are stored to train four Linear Discriminant Analysis classifiers (one for each microgesture).

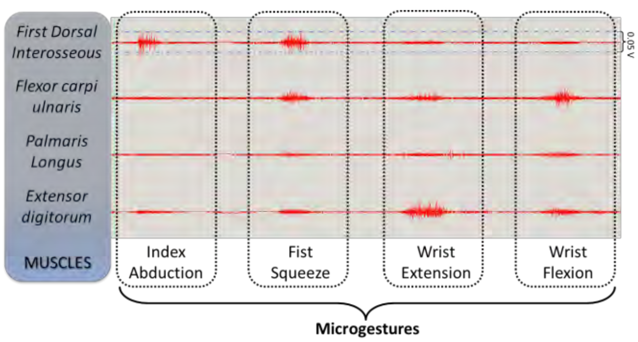

Figure 2. EMG signals of every sensed muscle for each microgesture.

4. SYSTEM EVALUATION

4.1 Protocol of Interaction

Eight people, aged within 23 and 31 years took part to the experiment. None of our participants had any known neuromuscular diseases. Sensors were positioned by non-medical personal following Cram's guide [3].

The experiment was composed by two identical sessions of 3 minutes. Each participant had to perform on a steering wheel 10 times the four microgestures, for a total over the two sessions of 80 gestures. Visual external stimuli led the participants through the experiment suggesting the gesture to perform.

4.2 Results and Discussion

In order to evaluate the system performance, we performed a k-fold cross-validation ($k = 10$) resulting in an average accuracy of 94.55% and a standard deviation of 3.77.

Each microgesture obtained a similar recognition accuracy rate: 92.98% the index abduction, 94.38% the fist squeeze, 95.51% the wrist extension and 95.34% the wrist flexion.

These results are very encouraging; however, further tests with a gesture segmentation system are required for real world scenarios. Moreover, in order to complete the evaluation, we need a test with more participants taking into account also the usability aspects.

5. CONCLUSION

IVISs are becoming more and more complex, providing increasing services but overwhelming the driver with buttons and knobs. Human-computer interaction researchers working in the automotive field identified a promising solution in the gestural interfaces. Indeed, we proposed an interface based on four microgestures performed with both hands holding the steering wheel. The system we developed is composed of a wearable device that captures the driver's EMG signals and of an IVIS that receives these data. The IVIS interprets these data in order to recognize the performed microgestures and to activate the related commands. We conducted a test in order to evaluate the accuracy of the developed system for the proposed microgestures recognition. The results assessed an average accuracy of 94.55% with a standard deviation of 3.77.

The future steps of this research consist in integrating an EMG-based gesture segmentation system (we realized a preliminary study presented in [2]), conducting tests during simulated driving activity and integrating such IVIS in a real vehicle for further testing.

6. REFERENCES

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