STEERING WHEEL SENSOR AS A PUSH-TO-TALK SOLUTION

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Keywords: automotive, speech recognition, user interface

Abstract

In today's vehicles, there are a number of electronic devices that are manually operated while driving. Speech interaction systems are employed to relieve distraction caused by the operation of these devices. Push-to-talk buttons are used to trigger speech recognizers. In this paper we present a new push-to-talk solution that is activated by tapping a finger on the perimeter of the steering wheel, where force sensor strips are located. At the same time these sensors can be used to measure gripping force while driving. The paper describes the design of the sensor system as well as a demonstration setup. A short pilot study was run as a proof of concept, which indicates that the new system does not perform worse than the existing, fixed position PTT solution.

1 Introduction

Speech interaction is becoming a frequently used mode of interaction for controlling in-car devices. For example, because of the distraction that cell phone manipulation causes, speech is used with hands-free kits to place and receive calls. This allows the driver to keep both hands on the wheel at all times [3].

Besides cell phones, speech can be used to control a wide range of entertainment devices (radios, mp3 players, etc.) Some car manufacturers offer speech interfaces as standard options in their vehicles (see Sync Technology). On the other hand, speech interaction is also used in first-responder vehicles (police, ambulance, fire department, etc.) to make their actions safer and more efficient. One such application is Project54, developed by our group at the University of New Hampshire [4], which integrates all electronic equipment in a police cruiser into a single user interface. This system can be controlled either by using a touch screen or via a speech interface. Activating the speech interface requires operating a PTT button which is in a fixed location on the steering wheel.

Our current research explores the effects of in-car speech user interface characteristics on driving performance, taking into account road type and the psychological state of the driver. In a recent study we have found that PTT usage, which is one characteristic of the in-car speech user interface, influences driving performance [5]. This motivated us to explore other possible PTT solutions, which could have a lesser impact on driving. In the work presented here, we hypothesize that a steering wheel could provide an effective PTT sensing surface without a negative influence on driving performance. Specifically, the steering wheel would have pressure (force) sensors on the perimeter that could be activated by tapping. An additional benefit of the pressure sensors would be that they can provide grip force data, which may help estimate the psychological state of the driver.

2 Background

Speech promises better driving performance by allowing drivers to keep their hands on the wheel and eyes on the road when driving and simultaneously operating in-car devices. An overview of studies of in-car speech interfaces [1] concludes that driving performance was generally better and driver workload was lower when using speech interfaces compared to manually operated devices. Still many open questions remain. One problem is that the relationship between the characteristics of the speech interface, the difficulty of the driving task and the resulting driving performance are not very well understood, because of the existence of a multitude of factors.

The one characteristic of the speech interface that we focus on here is the position of the press-to-talk (PTT) button. In previous research [5] we have compared in-car speech interaction when using a PTT button and when speech commands are automatically recognized (no PTT). We found that having to use a PTT button can influence driving when the recognition rate is low.

There are relatively few publications on steering wheel sensors in the literature. In one such publication the authors present a number of sensors attached to the steering wheel for driver physiological state estimation [6]. One of these sensors measures the grip force. The authors state that only qualitative measurement of force can be made with the applied technology. In another publication by the same group, the design of this sensor system is presented [2].

3 The steering wheel force sensor

The system designed in this work is based on pressure sensors such as the one shown in Figure 1.

Figure 1 The Interlink FSR-408 force sensor strip

The sensor strips are 24 inches long and 0.6 inches wide. The active area is 0.25 inches wide. They are polymer thick film (PTF) devices that exhibit a decrease in resistance when pressure is applied on their surface. These thick film devices are printed on a flexible substrate that can be cut, folded, twisted and bent without any damage. They come with a self adhesive stripe on the back, which allows easy application to a wide range of surfaces. In our case, we attached four of these sensors on the perimeter of a steering wheel, as shown in Figure 2.

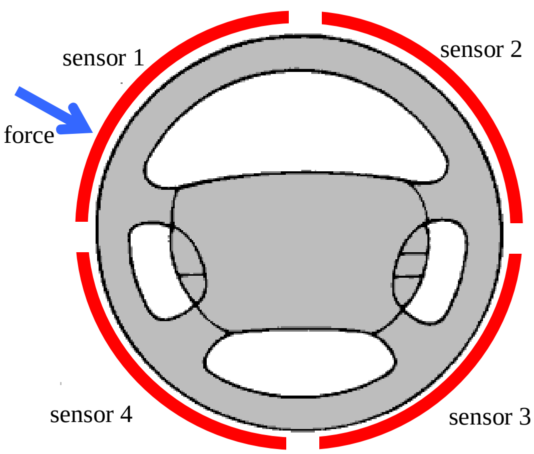

Figure 2 Sensor locations on the steering wheel

The sensors were cut to a length of about 12 inches and symmetrically placed on the circumference of the wheel, each covering one quarter of it. The sensors were connected to a simple amplifier circuit, consisting of a voltage divider, operational amplifier and some additional power stabilizing elements. The schematic of the amplifier board is given in Figure 3. While driving, the steering wheel in a car can be rotated by 540º in each direction from its center position. This caused a problem, when trying to transfer the measured signals from the wheel to a data collecting computer using wires. Therefore a wireless solution was found.

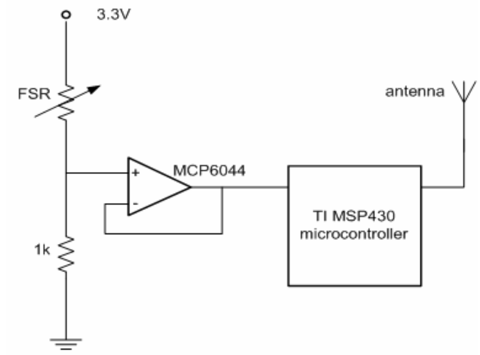

Figure 3 Schematics of the amplifier and transmitter

The output of the amplifier is connected to a Texas Instrument eZ430-RF2500 development board, the core of which is a TI MSP430 microcontroller (Figure 4). This board comes with all the necessary circuitry (antenna, clock, RF transceiver) to be able to transmit the signal wirelessly to the receiver. The receiver is also a small PCB which connects directly to the USB port of the data collecting computer. The data appears on the computer as a COM port stream and can be recorded in a suitably created application.

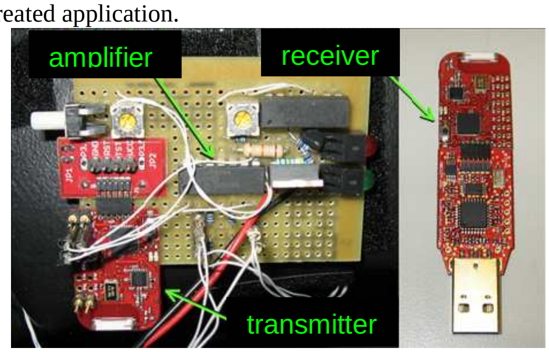

Figure 4 The layout of the electronic boards

The application of this sensor can be two-fold:

1. operating devices by tapping on the wheel
2. gripping force estimation

The gripping force can be measured with this device only in a qualitative manner as opposed to quantitatively, i.e. it is not possible to express the amount of pressure on the sensor in a numerical way that would be in certain units. This is the property of the PTF sensor. Even though it is not intended for precision measurements, the waveforms of the sensor can be recorded and the amount of pressure can be analyzed.

On the other hand, the sensors are sensitive enough to record even slight taps. Taps can be used to perform a controlling action, e.g. to operate a device in the vehicle. 'Double-click' tapping is a very similar action to double-clicking the mouse button. Here, it has a very important task: error avoidance. By requiring double-tapping in a certain way, false activations can be virtually eliminated. In fact, in this work we used double-tapping as the push-to-talk (PTT) trigger.

4 Demonstration setup

The demonstration has the goal to present how our sensor system can be used to:

1. trigger the speech recognizer to listen to Project54 commands and
2. record and visualize gripping force data.

The double-tapping signal works very well for activating the listening phase of the Project54 speech interface. In our preliminary experiments it was virtually never activated unintentionally.

Gripping force data can be recorded and used to estimate the driver's psychological state in ensemble with other driving performance measurements such as brake operation, steering wheel angle, etc. For example, if there is a strong grip on the steering wheel sensor accompanied by a forceful push on the break pedal, it is likely that the driver is experiencing a hazardous driving situation that could result in an accident. The grip force signal could be used in the future by the vehicle's logic to try to assist the driver in avoiding unsafe situations.

The demonstration setup consists of a driving simulator desktop computer, flat screen monitor, Project54 laptop computer, steering wheel console with pedals, microphone and speakers. The setup is shown in Figure 5.

Figure 5 Demonstration setup

The underlying driving simulator is a DriveSafety DS-100c scaled down to a single channel. The driving console is originally a Logitech Momo, which was modified with a regular size, passenger car steering wheel equipped with sensors. The Project54 computer executes the P54 application that is deployed in more than 1000 police cruisers in New Hampshire and nationwide.

In our demo setup users can take a seat in the simulator, drive around in the simulated world while issuing Project54 police cruiser speech commands (e.g. 'lights and siren', 'strobes on', 'front antenna'), and use the steering wheel sensor for PTT activation. At the same time users can track their real-time gripping force signal on the Project54 computer screen.

Figure 6 Driving and issuing police cruiser commands

5 Pilot Study

We conducted a pilot study to compare the influence of the steering wheel force sensors, and a fixed position PTT button, on driving performance[1] (fixed PTT button shown in Figure 5). Driving performance was evaluated by observing steering wheel angle variance (higher variance means worse performance). Additionally, a SeeingMachines eye-tracker device was used to analyze each subject's gaze while driving (more time spent looking away from the road can result in worse driving performance).

The experiments were conducted in a high-fidelity driving simulator with a 180º field of view, a car cab and a motion base to simulate acceleration and deceleration tilt. The participants of this pilot study were 4 male subjects, all students at UNH between 22 and 26 years of age with a valid driver's license. After a 5-10 minute training session with the steering wheel sensor and the simulator, they were asked to drive a city scenario consisting of straight sections, turns at intersections, curves and unexpected situations. These unexpected situations were designed to force the driver to stop abruptly: a pedestrian jumping in front of the vehicle from behind a truck and a car suddenly crossing the line of travel of the subject. They had two 5 minute runs, each with the fixed button or the steering wheel sensor. While driving, Project54 commands appeared on the simulator screen with a pseudo-random period between 3 and 5 seconds. The subjects were given the task to read the commands off the screen and issue them via the speech interface. They were strictly instructed that driving safety is their first priority and that issuing speech commands is the secondary task. We recorded participants' reaction times to the P54 commands (longer reaction times may indicate that participants were not completely comfortable with a given PTT solution).

6 Results and Discussion

Since there were only four participants in this pilot study, and only around 40 minutes of driving data was recorded, none of the results are statistically significant

[1] Video presentations of the steering wheel sensor and the grip force visualization can be found at:
http://www.youtube.com/watch?v=0yUQcixO5mY
http://www.youtube.com/watch?v=DvtdZNg70e8

Accordingly, no strong conclusion can be drawn, and only suggestions for future experiments can be proposed.

We investigated the steering wheel angle variance first. There was no significant difference in the variance between the usage of the steering wheel sensor and the fixed PTT button. On the contrary, the variances were very close to each other (the average steering wheel sensor variance was 3727 square degrees, while for the fixed solution it was 3683 square degrees). This means that in the worst case, the steering wheel PTT did not degrade the driving performance compared to the fixed PTT. We had similar results while analyzing the reaction time to appearing Project54 commands. The mean of the reaction times for the new PTT solution was 1.571 seconds, while for the fixed one it was 1.604. This shows a very slight reduction of reaction time by the tapping system, which is not significant. Further analyzing this measurement, showed a somewhat larger difference between reaction times to P54 commands while taking turns at intersections. Taking turns is the most complex part of driving in a city, because there are many elements that draw attention, thus increasing workload. In these cases, reaction times were 1.826 seconds on average for the steering wheel PTT, and 2.197 seconds for the fixed solution. This shows a larger difference in favor of the novel solution, but without statistical significance. This encourages us to pursue a full experiment that could show statistical significance.

The participants were interviewed after the experiments. Three of the participants expressed enthusiasm about the usefulness of the sensor system, while the fourth said that he would need more training to feel comfortable using it. All of the participants reported that they operated the tapping device more securely towards the end of the experiment, compared to the start, which could mean that more training could have had a beneficial effect on driving performance. Some of the participants also reported that during turns, they sometimes had to divert their glances from the driving scene to try to find the fixed PTT button, because it rotated together with the steering wheel. They did not report this problem with the new sensor system. This result was confirmed by the eye-tracker data, which showed a few glances down, away from the road for the fixed PTT. Any time the driver does not pay full attention to the road is a safety risk, therefore our results indicate that in this aspect the new system may be beneficial.

It was expected that in near-accident driving situations the drivers would apply a higher gripping force on the steering wheel, in order to achieve better control over the vehicle. This was noticed only in some cases. The following figure shows one of these situations. Here, braking is given in normalized values, where 1.0 represents the brake pedal fully depressed. V_{out} is a voltage signal which rises as the gripping force on the sensor rises. In this case, a child stepped in front of the driver's vehicle around t=148 seconds. It can be seen how the subject depressed the brake pedal and gripped the steering wheel to secure control over the vehicle.

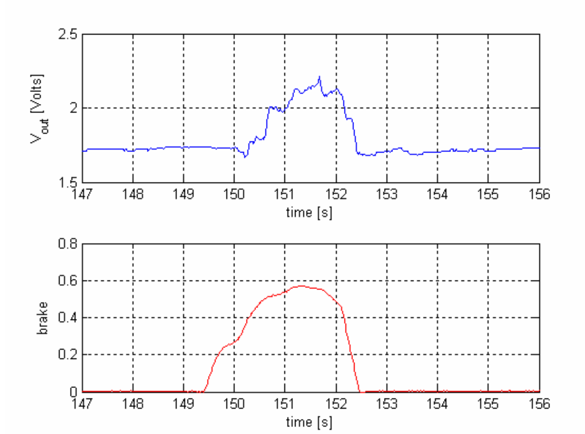

Figure 7 Grip force and braking in one near-accident

7 Conclusion

In this paper we present a new steering wheel sensor system which can be used as a PTT solution for in-car speech user interfaces. The sensor system also allows us to estimate the gripping force applied by the driver to the steering wheel, which may help estimate the psychological state of the driver. We present a demonstration setup which highlights these capabilities of the system. Finally we report on encouraging results of a pilot study, which indicate that the sensored steering wheel may be a viable PTT solution.

8 Acknowledgements

This work was supported by the US Department of Justice under grants 2005CKWX0426 and 2006DDBXK099.

9 References

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