HMI Concept for an Intuitive Controller on Steering Wheel—prototype design based on capacitive touch

Yang Li-118705 liyang7684@gmail.com

Interface Design-*Prof. Dr Jens Geelhaar,* Get Connected-*Johannes Deich.* Summer semester 2018 Art and design faculty, Weimar Bauhaus University

Abstract

With more and more functions developing in vehicle, drivers have to operate switches, levers, buttons, knobs and even touch screens while driving. Complicated operations cause distraction and at the meantime, misoperation and hand-off while driving can be dangerous and in some cases, can lead to severe accidents. My work focuses on tactile controller on steering wheel to reduce such hand-off situations. In this article, I design the functions of the controller in specific divining scenario and build a demonstration prototype with the software Processing and Arduino. My goal is to provide a direct and safe input to decrease the potential dangers of multitask. Furthermore, this application can also be used for hand-off detection and driving behaviour correction. My future research will explore more functions on this controller and validate the effectiveness and the help of the tactile controller on driving simulator.

Author Keywords

HMI design; capacitive controller; Arduino, Processing.

Introduction and Related Work

Many surveys showed that "driving with one hand for whatever reason can be dangerous and in some cases, can lead to severe accidents, so the researchers advise driver to keep their hands on the wheel and their eyes on the road." The



Figure 1. How capacity sensing works [7]





Figure 2. The circuit of touch controller

scenario while deal with multiple secondary tasks like adjust music, turn on or turn off air conditioner, pick up the phone, control the blinker, wiper or horn. The complicated tasks attract drivers' attention and result in distraction easily. "If you have gestures on the steering wheel, you spend more time looking at the street," said Albrecht Schmidt [5], Keeping eyes on road and hands on steering wheel are extremely important for driving safety. The psychological scientist James Hartley from Keele University found that out of 230 drivers observed, only around 25% were actually using two hands to grasp the steering wheel at the recommended 9 and 3 o'clock positions [8]. Correct hands behaviour which enable drivers' quick reaction when dangerous scenario happens, sometimes ignored by the public.

Sen [5, p. ix] analysed the maximum injury severity of crashes in different driving scenarios "which revealed that 14% of lane change crashes resulted in some forms of injury". Accident statistics confirm the need for systems that support car drivers when changing the lane [6]. And turn right and turn left are very common driving scenarios in daily transportation.

Researchers [4] from Stuttgart University designed an experimental steering wheel which was made of 11mm thick acrylic that is ringed with infrared LEDs. They use infrared camera attached to the bottom of the wheel detects reflections when the screen is touched and gestures can be made on the screen. Diederichs.etl [1] designed two touch displays embedded in the steering wheel allow control of multiple, situation adaptive functions.

The essence of direct manipulation is not directness operation, but manipulation of task relevant objects in a task relevant manner [2]. Researches show that in kinds of manipulation scenarios, knobs have greater need for driver resources while touch screens have greater need for visual resources. So, designing an instinctive controller has a great significant to help drivers decrease misoperation and overload.

Methods

Driving scenario setup

Setting scenarios is a basic method to define the function and the manipulation in using process. Lane change, turn left and turn right are very common driving scenarios, drivers have to turn on signal when they intend to turn.

Prototype design

Capacitive touch sensing

In this method, the capacitance is measured on each electrode independently. During a touch event, a capacitor is formed between the finger and the foil. The distance between fingers and the foil decide the value of the capacitor. This capacitance is sensed indirectly by charging and discharging a resistorcapacitor (RC) circuit.

• Hardware and software

I use the foil as input material on steering wheel and change the input value by touching or grasping, which works as capacitive sensor (Figure 1). Using resistors (six 100k resistors, two 10k resistors) and 2 foils to build the circuit [9] (Figure 2). Set the pin 2-13 to output mode and write digital "low" to the pins, which means both of the capacitors are arounded and they will discharge. Set the pin 8 and 9 to input mode, since the resistors are fixed, a change in capacitance will be measurable. The distance between fingers and the foils will be the primary variable contributing to the capacitance. Plug the connector into the Arduino, connect cables to the two files (8: signal left, 9: signal right), then provide power by plugging the wire into the Arduino's 5V (Figure 3). The detected signals from Pin 8 and 9 will be sent to the serial port. Via serial communication the data could be received and processed by processing.

In processing, I edit the two "arrows" represent left and right signals. According to the touching signals from serial port via Arduino, the processing demonstrates a simulation of turning lights on a vehicle. Check the maximum and minimums values in serial monitor of Processing, edit the range of the data and define the value of trigger. From the test, I found that the capacitive sensor is very sensitive and the values differ from



Figure 3. Arduino prototype



capacity sensor

Figure 4. Hard grip with left hand



Figure 5. Hard grip with right hand



Figure 6. Hard grip with both hands

person to person, and therefore an initial calibration phase to find the optimal parameters for each user is necessary.

Using a foil to do the test is the very first step of the prototype, the capacitor is instable, but the test result shows that instinct manipulation on steering wheel can be designed based on capacitive sensor. With more functions created, I want to design the steering wheel as a curved touch controller, drivers can achieve more controls on the steering wheel, like swipe, click etc. Fingerprint identification can provide more possibilities in this design, it can recognize which finger has the input (left thumb input refers to exit or cancel while right thumb means confirmation). Drivers can define functions on their own, that means the steering wheel has more individual settings.



Figure 7. Gestures used in design: swipe (left) and click

Figure 8 shows the basic electrode layer. The first layer is the surface of the steering wheel, the second layer is the capacitive sensors, it is made of conductive metal to sense capacitance. To recognise swipe: using multiple adjacent capacitive sensor films and relative signal strength to determine location. Grid: using an overlapping sensing bar to determine the position on both axes; and the third layer is a capacitive touch controller, touch electrodes are connected to (CAP11XX).





Discussion

Designing touch controller is to keep drivers' hands stay on steering wheel, so that they can quickly and accurately take action when they are required. Then, I am thinking about how our findings from the prototype design could support drivers in using these functions in different scenarios.

Lessons Learnt and Future Work

I found some very interesting application about the touch controller on steering wheel for some driving scenarios. Nevertheless, it depends on qualitative analysis, I have not done experiments to test if it is safer and easier so far.

In my future work, I will evaluate the touch controller on driving simulator in Automotive Interactive Design Lab in Tongji University (designing traffic density, weather conditions, emergency situation etc.), including research about drivers' information (over) load, trust in the system etc., to determine the overall potential safety benefits. To validate the results, I consider using the following conditions: a) commercially available blinker/wiper lever, emergency button; b) the touch controller. Future experiments may also benefit from using a Woz Way's [3] approach to ask drivers immediately after they finish the driving tasks to gain insights about drivers' experiences, thoughts, information needs, stress impact, attention distraction, trust etc.

I also consider designing more gestures like swipe, click, double clicks, double finger clicks and so on based on drivers' experience and custom. Considering task (over)load, gestures will be designed as intuitive inputs to carry out certain driving tasks. Furthermore, as a hand-off detection, if there is a takeover request, the tactile controller can give a feedback to vehicle that the driver has taken over the car.

The prototype design in this article is just the start of a more complex consideration of touch controller on steering wheel to improve safety.

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