Developing a strategic controller with haptic and audio feedback for autonomous driving

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June 2015

1 Introduction

This is a summary of the Master's Thesis report with title *Developing a strategic controller with haptic and audio feedback for autonomous driving*, conducted together with Alexander Andjelkovic (Chalmers University) at Semcon, Gothenburg.

2 Problem formulation

Fully-automated cars are expected to be available on the market by the year 2020, but some issues must be solved before the first prototype is ready. One of them is the need to keep the driver aware of the situation, so the control of the car can be taken over in case of technology failure. A possible solution would be implementing a strategic controller which allows the user to influence the car behaviour by inputting commands, and which gives feedback to the driver.

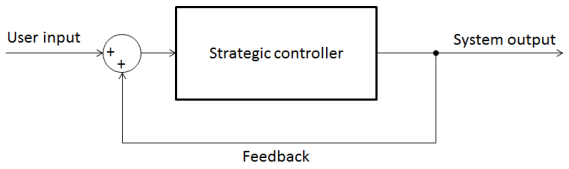

Figure 1: Schematic of the strategic controller. The user inputs commands and the strategic controller decides if it is possible or not to execute it and send feedback so that the driver is aware of the process.

3 Method

The chosen input device used as a strategic controller was a commercial joystick, which was modified to make it suitable for this application (see Figure 3). Multimodal feedback was created, which consisted of haptic and audio signals, using the design process shown in Figure 2.

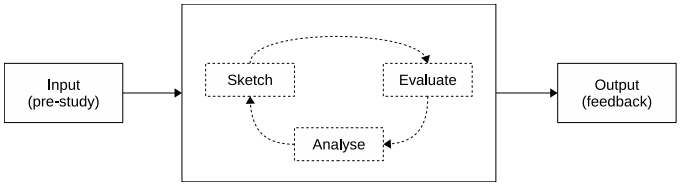

Figure 2: The multimodal feedback design process used in this thesis project. Sketches are evaluated and the results of the analysis are used to improve or create new sketches. The process is iterated until desired results have been achieved.

The evaluation consisted of three stages:

1. Self evaluation. First sketches were evaluated by the team members according to the perceived urgency, annoyance and appropriateness.
2. Expert evaluation. Feedback from Peter Mohlin, senior audio engineer at Semcon, was used to improve the multimodal sketches.
3. User study. The users were involved in order to evaluate the multimodal feedback and find usability issues when using the joystick as a strategic controller.

A validation study was also carried out in order to create a benchmark against which other concepts

Figure 3: The chosen joystick was a Microsoft Sidewinder Force Feedback 2. The knob was changed by the Volvo XC90 gearstick, buttons were removed and the power was doubled.

can be compared. A User Experience Questionnaire (UEQ) was used to evaluate the attractiveness, design quality and use quality of the prototype[1].

4 Results

The possible commands that could be performed using the strategic controller are:

- Overtake slow vehicles.
- Turn left/right.
- Stop the car.
- Change lane
- Increase/decrease speed.

Each command had a specific input pattern (an example is shown in Figure 4) and feedback was provided when some events appeared.

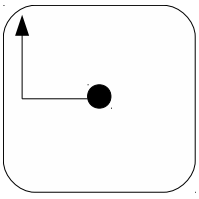

Figure 4: An example of how an overtake is issued by moving the joystick to the left and then upwards.

[1]UEQ analysis tools are available at http://www.ueq-online.org/ (last accessed 2015-06-18).

Haptic and audio signals were created separately and were then combined into multimodal feedback. The number of multimodal sketches was reduced during the different evaluation stages mentioned above and a good combination of feedback sketches was found after the user studies. The prototype software was also modified according to users' opinions and comments.

But how does the controller work? The idle position of the joystick is the middle position and all commands start from this point. Based on a mock-up of the sensors at the car, the system checks continuously which commands are possible to execute. Based on this information, different feedback will be played. If a command is not possible to execute at the moment, rejection feedback will be played and the system will reset. Nonetheless, if a command is safe to be executed, the joystick will lock in place and the command will be queued and will wait for being executed. The queue is a one element queue, so a new command can only be input if the previous one has been executed and the system has been reset. Interrupting a command is also possible by pulling back the joystick to its idle position, as far as the command has not started to be executed.

The concept was validated and compared with a benchmark. The results are shown in Figure 5.

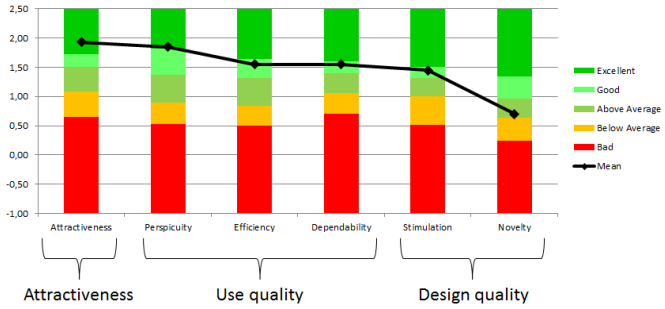

Figure 5: Scales visualized in comparison to the UEQ benchmark.

In comparison with the benchmark, the concept had fairly good results for attractiveness and use quality. However, the value for novelty, which represents the innovation and creativity of the system, was just above the average. This result was not considered bad as command inputs was found similar to changing gears, what could lead to users accepting the system quicker.

5 Conclusion

Even though, as mentioned before, the joystick was not considered innovative, according to users' opinions from both the user and the validation study, the strategic controller was found easy to use and worked as they expected. Users could remember the input patterns with no effort and they stated that they could trust the system and they would use it in their daily commute from and to work.
Furthermore, the multimodal feedback was appreciated and found to be useful.

References

[1] Andjelkovic, A., and Guijarro, S. Developing a strategic controller with haptic and audio feedback for autonomous driving. Master's Thesis ISRN LUTFD2/TFRT–5969–SE, Department of Automatic Control, Lund University, Lund, Sweden, 2015.