SAFE TRANSITIONS
TO AND FROM AUTOMATED DRIVING

Dr. Annika Larsson, Autoliv Development AB,
SE-447 83 Vårgårda, Sweden

ABSTRACT
The transition and distribution of control between automation and vehicle is a challenge, not only for the driver, but also for the vehicle. It appears that an increasing level of vehicle automation entails an increased need to monitor the driver.

Previous research has indicated that drivers have difficulties in resuming control from automated vehicles, and that the resumption of control has a large cognitive component. The driver needs to go from attending to non-driving related tasks to changing her focus back to driving. This comprises not only regaining motor control of the vehicle, but also getting her bearings in traffic again, something which takes several seconds. Therefore, passing control to the driver cannot be done in ways that are too fast or direct. Instead, the driver needs time to resume cognitive control of the vehicle before she will again be able to perform as well as she normally does. Thus, it is necessary to know under what circumstances it is safe to allow for manual driving again.

Similar concerns also apply in semi-automated vehicles where the driver is set to monitor the car. Driver distraction from the driving task is an important factor in accidents, which may have equally negative consequences in semi-automated driving if the driver is set to monitor a non-perfect system without actually needing to perform any manual driving tasks. Here, drivers need to be kept sufficiently in the driving loop so that they are able and prepared to respond if needed.

This study presents a possible alleviation of these issues by utilizing sensors and actuators that help determining driver position, attention and control, designed for safe transitions to and from automated driving.

KEY WORDS
Automated driving, transition of control, hand-over, out-of-the-loop, active safety, sensors

INTRODUCTION
While driving a normal vehicle, drivers are told to keep their eyes on the road, hands on the wheel, and not use mobile phones or other equipment that could affect their attention to surrounding traffic. Drivers are also told they are not very good at driving, and that they need help in doing so. For example, it is frequently claimed that 95% of all accidents are primarily due to “human error”. Thus, adding automation to vehicles make sense – humans are flawed vehicle controllers, prone to drowsiness as well as distraction away from the driving task. Thus, automation has great potential to compensate for human weaknesses, making traffic safer for everyone.
In the past 5-10 years, the usage of not only emergency or intermittent systems but also continuous automation has grown. Adaptive Cruise Control (ACC) controls both the speed of the vehicle and the distance to the vehicle travelling in front, in contrast to conventional cruise control which only sets and keeps a speed for the vehicle. These continuous systems however come with a caveat – the driver needs to monitor them, be in the loop and able to respond when automation reaches its limits.

For a system designer, this is not news: automation can only control what it has been designed to control. It can only handle what it has been designed to handle. To a user, such logic is not necessarily easily understood. As can be seen in several studies, drivers take advantage of and utilize automation that is reliable enough to be used tactically or strategically (Kircher, Larsson, Andersson Hultgren, 2014). Besides performing the main task of driving, drivers are more likely to e-mail or text compared to driving non-automated vehicles (Llaneras et al, 2013). In focusing away from the driving task though, drivers are less consistent in monitoring the continuous automated system and resume control. Bainbridge in the early 1980s identified one of the ironies of automation: the more advanced the automated system, the more crucial the contribution of the human operator becomes for that system to operate successfully. Monitoring forms a specific part in that.

**The difficulties of monitoring**

Monitoring of automation is a difficult task for humans. Humans are very accomplished at monitoring and executing actions if these tasks form part of a whole – for example driving cars in everyday life. Humans are actually quite excellent drivers, compared to the continuous automation available today. Most drivers have never been in a serious collision, and every day drivers make hundreds of small adjustments to their driving paths that compensate for other road users, bad roads or contextual factors. Most drivers get from point A to point B, every day, without unintentionally veering into other lanes, cars or off the road. This demonstrates that humans are not as bad at driving as statistics might make us out to be.

However, there are circumstances in which drivers are too slow to respond, where automation is highly beneficial. Circumstances where other road users are made to compensate for driver drowsiness. Circumstances where it is very stressful to drive due to the demands placed on that specific situation. For those circumstances, continuous automation can provide a relief and a safety buffer. But, again, monitoring an automated system is a difficult task for humans. Automated vehicles can miscalculate or misperceive the path ahead, and thus fail to follow the road or the lane. Automation may also fail to brake for stationary vehicles due to sensor limitations, something a normal user may or may not be aware of. Therefore, drivers might not necessarily recognize and respond to these events in a timely manner (Larsson, Kircher, Andersson Hultgren, 2014). Not only that, but there are residual negative effects from being out of the loop on driver performance for at least a few seconds after an alarm to resume control.

It might appear that drivers having their eyes on the road and hands on the wheel at all times is the solution to the monitoring problem, but if there is nothing to do for the driver for extended periods of time, such a requirement is not reasonable. Thus, the use of vehicle automation entails being able to communicate with the driver about the need to resume control, and what this control entails. This communication needs to be done in an effective manner, so that the drive is safe regardless of whether human or automation is in control.
RESEARCH ISSUES

In order to resume control of the vehicle, three themes can be identified from what is detailed above; hand position, gaze position, and communication with the driver.

Hand position

Driving as an activity that takes at least three parts rolled into one when a situation is to be described: Context, Vehicle, and Driver. The actions of neither the vehicle nor of the driver can be described without also detailing the context. Resuming control of a vehicle, there is a certain movement time to take into consideration when requiring the driver to respond by moving their hands. This movement time is less than a second, but depending on what the driver is doing this can differ. If the driver is required to put away an item first (book, tablet, phone) movement time to pedals or wheel can increase. Thus, there are different times involved to take control depending on if the driver already has a hand on or very close to the wheel or their hands nowhere near.

Gaze

Visually distracted drivers can be as quick to put their hands back on the steering wheel, and look at the road, as non-distracted drivers (Gold et al, 2013). They are, however, slower to initiate a braking response if needed. Thus, monitoring of driver attention is necessary, so that the vehicle system knows what the driver is doing, and that the driver can respond if needed. The driver may be looking away from the road, meaning they first need to re-orient themselves to look there, or they are already looking at the road and do not need that reorientation.

Communication with the driver

The driver needs information about system performance, as system performance is one of the very reasons drivers may need to get back in manual control. Helldin et al (2013) provided drivers with continuous information about system performance, and found that drivers who were provided with this information were better at performing non-driving tasks without compromising driving safety. Driver attention may also need to be re-oriented. Such information needs to be relayed so that it is intrusive enough to catch the driver’s attention but still not annoying over time.

POTENTIAL DESIGN SOLUTIONS

In order to counteract the issues detailed above, Autoliv have developed concepts to demonstrate the potential of technology available today. The solutions of course differ with the problem. In semi-automated driving, drivers need to be kept sufficiently in the loop so that if something is amiss, they are able to respond. In fully automated driving where the vehicle is responsible, the driver may need to be woken up and re-oriented toward driving.

Autoliv have several technologies that can be used to facilitate the transition of control between a vehicle and its driver. One of these is the Autoliv zForce steering wheel, seen in Figure 1. The zForce

Figure 1 - Autoliv zForce steering wheel
steering wheel uses infra-red technology to sense hand positions, and can also communicate with the driver using different colour LED lights on the rim.

The seatbelt can also be used for communication with the driver, depending on the type of force implemented in the pre-tensioner. For example, the belt can be used to communicate the need to monitor the road (see Ljung Aust, 2014) as an element of a forward collision warning. As the force in the belt is adjustable, different force levels can be used for different levels of urgency. Autoliv’s robust driver monitoring camera can help identify driver attention state, by detecting eyes on the road or off the road. This driver monitoring camera identifies glance time off the road, geometrically described in Figure 2.

**Fully automated driving**

In fully automated driving, a handover scenario can thus be construed this way: When it is soon time to drive manually again, the seatbelt can be used to re-orient the driver toward the driving task, in conjunction with a text message or light signals on the steering wheel. Sound is intrusive to passengers, and may not be necessary. The driver can thus be instructed to begin monitoring the road again, and a countdown to manual control can be initiated. Using a driver monitoring camera such as the one developed by Autoliv, driver eyes-on-road can be detected. In conjunction with driver hands-on-wheel detection thanks to zForce technology, driver readiness to begin monitoring before handover can thus be assessed.

During a handover from automated control, a requested hand position on the steering wheel and a countdown to manual driving can be implemented by lighting parts of the steering wheel. Similarly, various colours or patterns on the steering wheel rim can be used to indicate manual or automated mode.

**Semi-automated driving**

In semi-automated driving, there is a need for the driver to understand the limitations of the system as the driver is still responsible for the vehicle. Thus, the continuous monitoring of driver as well as of the system is necessary. Here, eyes-off-road can be detected in order to make sure the driver is attentive when needed, and that the system is aware that the driver is inattentive. Such information can be used in a variety of ways to ensure safer travels. The zForce steering wheel sensor can be used in order to detect hand positions on the wheel, so that abuse of the semi-automated driving system can be prevented more easily. Also, the steering wheel lights can be used to communicate the need to monitor the roadway more closely, in case the system receives bad sensor readings. Finally, the system can communicate its need for driver input by using the belt as well as the lights on the steering wheel rim.

**CONCLUSIONS**

As the driving task is increasingly automated, driver interactions with the vehicle is evolving. In order for this interaction to be safe, regardless of level of automation, a certain extent of knowledge of driver state is necessary. In the current paper, two concepts for handovers from automated driving are presented by using
Autoliv technologies. Handovers from fully automated as well as semi-automated driving focus on redirecting the driver’s attention toward the driving task, by detecting and re-orienting driver attention and hand positions to those necessary for safe driving.

REFERENCES


