Turn Drivers Into Users and Keep Them Out-Of-The-Loop to Save Energy

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Presented at the workshop "Should I Stay or Should I Go? Automated Vehicles in the Age of Climate Change", April 25, 2020, Honolulu, HI, USA

Abstract

Human drivers do not always drive optimally in the light of energy consumption. In contrast, automated driving allows to implement optimal eco-driving. However, to take full advantage of this, automated driving has to be used as much as possible. We suggest to implement persuasive technologies to avoid that drivers deactivate automated driving. Moreover, driver-vehicle cooperation can be implemented to broaden the operational limits in which automated driving is feasible.

Author Keywords

Automated vehicles; self-driving vehicles; cooperative driving; fuel efficiency; automation.

CCS Concepts

•Human-centered computing → HCI theory, concepts and models;

Introduction

Automated vehicles promise to free time of their users for non-driving related tasks [16], make traffic safer, more efficient and reduce congestion. Besides these advantages, automated vehicles have the potential to reduce energy consumption and emissions. Consequently, we suggest that automated vehicles should operate in automated mode whenever possible. However, until there are real driverless cars (operational under any circumstance [5]) available, there will be situations in which the human users will control or at least influence the driving task. To reduce potential waste of energy caused by the user, we suggest to persuade the user not to intervene and take over control when unnecessary and to implement cooperative interaction concepts that let the user affect the actions of the vehicle but on a higher abstraction level of the driving task.

Driver Caused Energy Waste

While there are many technological approaches towards saving energy in driving [11] and emission policy directly impacts the design of vehicles [14], improving one's own driving style to be more efficient showed a decrease of fuel usage between 10 - 25% [2, 12]. There are various ways of achieving this efficient driving style: lessons [17, 19] or driving assistants that have been proposed in a range of ways [1,3,18]. Gonder et al. agree that improving driver efficiency could lead (without AVs) to a reduction of about 20% [8]. According to them, stop-and-go, unnecessary idling and acceleration rates (cf. [21]) and speed are the primary contributors to fuel and therefore energy waste [8]. Magaña and Muñoz-Organero [13] additionally state that "slow reaction to the detection of traffic signs and traffic incidents" [13, p. 2437] and the (improper) "use of air conditioning or the choice of the route" [13, p. 2437] lead to reduced fuel efficiency. Especially stops decrease fuel efficiency, therefore, Evans [6] states that faster acceleration is acceptable for avoiding a stop. When using non-automatic vehicles, optimal gear changes also are a factor to reduce energy waste [21]. Finally, Gonder et al. state that the highest reduction in energy waste through better driving is to employ automated vehicles, saving up to 30% [8].

Persuading Users to Keep Automation Activated

It is expected that smooth driving cycles and platooning are one of the main factors for the energy reduction in automated vehicles compared to manual driving [20]. By disabling the automated mode during driving, this benefit vanishes. Therefore, the maintenance of automation usage is an important factor regarding energy efficiency.

In order to maintain automated driving during the ride, the human-machine-cooperation requirements should be fulfilled [4]. Human-machine cooperation requires calibrated trust, a mutual system representation, directability, and a shared situation representation [24]. Hock et al. [10] show that giving feedback about the intention and reasons for the behavior of the automation creates system transparency and can not only lead to increased automation usage but also to an increase of traffic safety. This is in particular important when the automated system outperforms human driving capabilities, e.g. overtaking a vehicle in foggy viewing conditions [26].

Cooperation to Avoid Manual Driving as Fallback

Another means to avoid falling back to manual driving is driver-vehicle cooperation [24]. The automated system and its user are considered team partners that combine their strengths and complement each other. Several efforts have been made to define human-machine cooperation [7,9,15]. According to Walch et al. [22], driver-vehicle cooperation is characterized by a time-limited involvement of the user on higher levels (navigation and guidance) of the driving task. In the following, we describe two scenarios in which a highly automated vehicle and its user can cooperate to avoid a transition to manual driving and with this avoiding unnecessary energy consumption due to inefficient manual driving. The first example is to avoid a handover to the human driver when the system can-

Figure 1: The intention of pedestrians at the roadside can be hard to predict for machines, however, humans can read the body language very well.

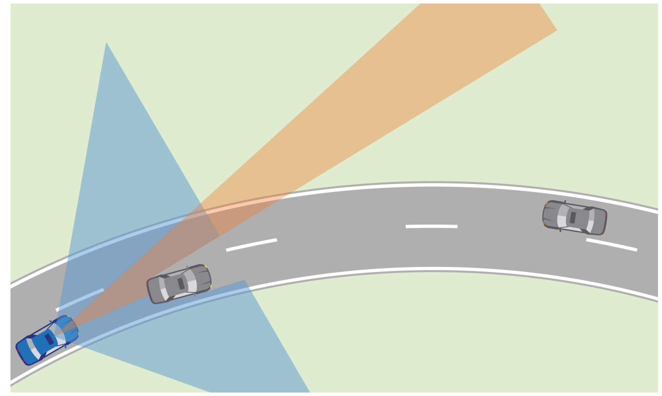

Figure 2: Especially on bended roads, it is likely that an automated vehicle cannot perform automated overtaking maneuvers due to restricted sensor range.

not predict the intentions of pedestrians. In the second example, cooperation can be used to avoid a takeover by the human driver who does not want an automated system to follow a slower vehicle in case automated overtaking is not possible.

Example 1: Pedestrian Intention Prediction
Situations similar to Figure 1 can be very challenging for automated systems: it is hard to predict if pedestrians at the side of the road want to cross—in particular at a crosswalk where the vehicle has to yield. An interaction concept for these situations that allows the system to ask the user whether a crosswalk is clear has been suggested by Walch et al. [23]. In case the system is not sure how the situation will evolve, it has to stop at the crosswalk; a human user can likely recognize if the pedestrians do not want to cross and thus prevent a full stop. After slowing down or stopping at a crosswalk, the vehicle has to accelerate when the crosswalk is clear. This can be done more energy efficient by the system than by a human driver.

Example 2: Overtaking Slower Vehicles
Another scenario in which an automated system can accelerate more efficiently than a human is overtaking slower vehicles. However, on rural roads it is likely that the sensor systems of the vehicle are blocked by the slower vehicle (see Figure 2). Consequently, the system has to drive at the lower speed behind the "obstacle". Cooperative overtaking [25] has been suggested for such situations: in cases, in which the user has a better perception of the traffic scene, an overtaking maneuver can be triggered by the user and executed by the system.

Conclusion
We suggest to persuade users of automated vehicles not to take over and to implement cooperative interaction concepts to allow to overcome system boundaries with the help of users but to avoid that users actually control

the vehicle (i.e. accelerating). Consequently, optimal eco-driving performed by the automated system can be implemented.

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