Chapter 1
Introduction

Abstract As an introduction to the book, in the first chapter, trends in automotive innovation such as advanced driver assistance systems and automation are considered, and it is argued that such developments create challenges for designers to create systems and associated user interfaces that customers understand and appreciate. It is concluded that a human-centred design approach is needed to satisfy the needs of the customers.

The car has been used as a means of transport for over 100 years, with the driver manipulating the steering wheel and pedals to make the car go the way s/he wants it to, a process that relies heavily on individual driving skills. Rapid advances in sensor and computer technology have led automotive design engineers to explore ways in which new technologies can assist in driving tasks and even automate them, with the first attempts to do so beginning in the 1980s when CMU (Carnegie Mellon University, USA) played a pioneering role. Today, assistance driving technology has come a long way and has matured to the extent that most cars have one or more assisted driving systems as standard, such as (Adaptive) Cruise Control ((A)CC), Lane Keeping Assist (LKA), Collision Warning, etc., Furthermore, many companies are offering initial automated driving software, and are doing on-road and real-world driving tests of higher levels of automated driving.

The main motivation for working with automated driving is the safety of traffic. In the United States, the number of traffic deaths in 2015 was 55,000. In Europe, 25,000 people died in traffic accidents in 2017. In China, more than 63,000 people were killed in traffic accidents in 2017. Analysis of the causes of accidents shows that the vast majority of accidents are caused by human error (drunk driving, speeding violations, bad judgement, distractions are the most important causes). It is therefore widely believed that accidents caused by human error could be eliminated if drivers were better assisted, or even taken out of the driving task altogether, allowing people to get out of the human–machine-road driving loop (out of the loop), thus significantly reducing the number of accidents and fatalities. Other motivations and other arguments for the development of autonomous vehicle research include convenience (automation enables people to engage in other activities while in a car), comfort (automation can be adjusted to occupant preferences), connectivity (automation and

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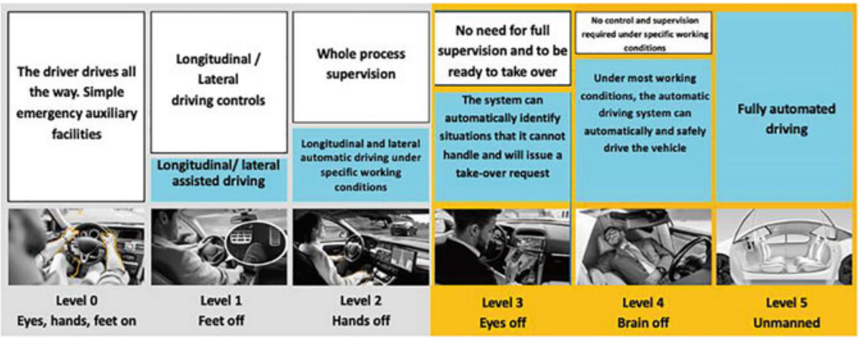

Fig. 1.1 Six-level classification of automated driving systems proposed by SAE International. The white boxes represent the driver's task, the blue boxes represent the system's task

connectivity to the internet allow better adaptation to traffic conditions, various road environments), sustainability (automated systems will drive more smoothly, avoid unnecessary acceleration and deceleration, and reduce energy consumption) and mobility-for-all (driving automation will make auto-mobility accessible for people who are traditionally unable or not allowed to drive, such as intoxicated people, the elderly, young people and the visually impaired).

Automating car driving is a complex process that cannot be achieved overnight. The control part of the vehicle may be relatively easy, and currently self-driving vehicles can perform well under controlled conditions and in confined areas, but the dynamic nature of the real world (traffic conditions, infrastructure, other road users' behaviour and weather conditions which can change unpredictably at any time) increases the complexity of the driving task by an order of magnitude. In order to standardise the discussion, the Society of Automotive Engineers (SAE) has proposed (and subsequently revised) a six-level automation classification in their standard report J3016 (SAE 2021), which has been adopted worldwide and replaced other classifications such as those proposed by BASt (Germany) and NHTSA (USA). Figure 1.1 shows a simple interpretation of this classification from a human factors perspective.

- Level 0 (for classification completeness), called No Driving Automation, is fully manual driving. Driver support features such as Automatic Emergency Braking, Blind Spot Warning and Lane Departure Warning may be available, but the driver is responsible for performing all dynamic driving tasks.
- At level 1, called Driver Assistance, at most one automated driving feature is available, typically adaptive cruise control or lane centring, to support the driver's task, but the driver is driving.
- At level L2, called Partial Driving Automation, (at least) two automated driving features are available, most commonly adaptive cruise control (longitudinal control) and automated lane centring (lateral control). This level of automation is characterised by the fact that, although the vehicle can drive automatically

in relatively simple traffic conditions, for example on motorways under normal conditions without any unexpected events, the driver needs to be aware that s/he is the driver, even if the feet are off the pedal and s/he is not steering. The driver needs to monitor the vehicle's behaviour and the traffic situation continuously to identify situations which the system cannot handle and take over the actual driving again.
- Level L3, called Conditional Driving Automation, indicates that the system itself can handle the task of driving, but only under specific conditions, such as normal conditions on the motorway. However, unlike level 2, where the driver needs to identify which situations the system cannot handle, at level 3 the automated driving system itself can identify situations it cannot handle, in which case the system asks the driver to regain control of the driving (allowing the driver a certain response time). Thus, when the vehicle is in L3 automated mode, the driver does not need to monitor the vehicle's behaviour and traffic conditions and can engage in non-driving related activities, until the system issues a Take-over Request. Regaining control typically requires the driver to perform an action such as pressing two buttons (to prevent accidental interruption of the automated driving system by accidentally hitting a pedal).
- Level L4, called High Driving Automation, is similar to Level 3, with the difference that the system is able to handle more road conditions and therefore more scenarios in which it can drive automatically. Also, if the driver does not respond to the system's request to regain control (for example, if the driver has a heart attack), the vehicle's automated system is able to execute a risk mitigation strategy, e.g., driving the vehicle safely to the emergency lane, bringing it to a halt and automatically notifying the emergency services.
- At level L5, called Full Driving automation, the vehicle can handle all kinds of road conditions that may be encountered while driving. At this level of automated driving, primary controls such as pedals and steering wheel may no longer be available. The driver is not required to monitor the driving, nor is there any situation where the driver is required to take over control, so there is no need for the "driver" to be qualified to drive, and the vehicle can even be driven without a driver.

The development of Internet of Things (IoT) technology makes a further contribution to assisted and automated driving by connecting vehicles to other vehicles (V2V) and to the infrastructure (V2I), bringing many benefits to traffic management and individual vehicle driving. For example, it is possible to collect large amounts of data on traffic flows via the IoT, which can be used to provide navigation guidance for individual vehicles, enable traffic managers to dynamically open and close lanes when required, and provide decision makers with information on traffic and traffic density. V2V connections allow vehicles to be notified of upcoming anomalies on the road ahead and in vehicles, and to coordinate dynamic control of intersections. V2V also plays a major role in following vehicles.

The development of these technologies creates a vast design space and at the same time raises two important questions: (1) Which are the technologies that meet the needs of society and individual users: Which assistance systems should be developed, what should their functions be, and how should automated driving systems be developed? (2) How will we design and present these technologies so that users understand the technology, understand how to use it, and do not begin to misuse or abandon it? How can we design it so that users get the most value out of it?

This requires a human-centred design approach, which ensures that the needs, preferences, abilities and limitations of users are taken into account in the design process, with the aim that the outcome of the product innovation process, through interaction design, will better meet the needs of users. In this context, the term 'user' also includes customers, drivers and sometimes other road users. When developers start to apply relevant and especially innovative technologies, failure to consider the needs of the user can lead to unintended or even counterproductive results. A concrete example is Tesla's Autopilot (automation level 2: a combination of adaptive cruise control and automatic lane keeping). As it is a Level 2 system, the user is required to hold the steering wheel at all times and monitor the vehicle's behaviour, so that s/he can take over driving control in the event of an exceptional situation. However, people often misunderstand this system and think that they can stop monitoring and engage in other activities. The authors' interviews with Tesla drivers in China and the Netherlands show that most drivers who observe that the system works as expected, actually treat it as a level 3 system and start engaging in non-driving related activities (texting, playing games on their smartphones). Another example is that if the autopilot does not meet their current needs (for example, slowing down when passing an intersection or quickly rushing through a yellow light, or displaying braking behaviour due to the unexpected presence of pedestrians), people may consider the system poorly designed and turn off the autopilot. A third example is that people may not understand how the system works. A specific case in point is adaptive cruise control, which is available in two versions: full speed range and a conventional version (which only operates at speeds above 30 km/h). An acquaintance of ours drove a car equipped with ACC and, because he found it so convenient, he asked for a car with ACC when his own car had to go to the dealer for maintenance. Not being aware of the existence of two different forms of ACC, he assumed that ACC would always work across the whole speed range, since that was what he was used to. However, when encountering a traffic jam that drove at a speed below 30 km/h, he discovered that the rental car's ACC worked only at speeds over 30 km/h … Should we expect this person to read the exhaustive manual before starting to use the system? Probably not. Another example is the acceleration performance of ACC systems, which is usually considered to be slow. Another acquaintance of ours solved this problem as follows. He found out that the amount of acceleration depends on the difference between the actual speed and the target speed: the bigger the difference, the higher the acceleration. So, what he does is setting the cruising speed on the motorway to 180 km/h. As he says, his car doesn't actually speed up to a speed of 180 km/h, since there are always cars ahead of him travelling at 120 km/h. However, at one occasion he had to get off the highway ramp; as there was no other traffic at the exit, he found that this method posed a significant risk … These cases show that when people use the new technology in question, they may use it in a way that is very different from what the designers expected. Or they may not even be aware that a particular assistance system is available, so that the targeted benefits are not realised. A recent Dutch study showed that many people were unaware that their vehicle was offered with an assisted driving system.

Other examples of how automated driving technologies may not meet people's abilities or preferences are discussed later in the book (in particular, Chap. 16). As the functionality offered by assisted/automated driving will become more complex, inferring from the above examples, we may assume that there will be an increasing difference between what designers believe will meet user preferences and abilities on the one hand and how people actually understand and use the technology on the other. Due to the rapid development of technology, it seems difficult to obtain information from and about users that helps to give guidance to the design process.

The book contains 16 chapters, divided over five parts. Part I introduced the challenges and the field of Interaction Design. Part II covers the basics of cognitive psychology required for the design of automotive interactions. Multimodal interaction technologies such as speech, graphics and haptics are discussed, as well as the application of intelligent technologies in the creation of predictive interfaces. Part III covers theories related to automotive interaction design. Part IV covers different design processes, especially human-centred design processes, and various design methods and testing methods. To enhance the study of vehicle interaction design, Chaps. 14 and 15 are devoted to issues of driving simulators and the basics of experimental methodology. Finally, in Part V we discuss human factors issues at different levels of autonomous driving, exploring both the challenges that arise at different levels of automation and the challenges that arise as autonomous vehicles will interact with other road users, and categorise various driving scenarios and possible events in order to design how to provide intelligent assistance to drivers.

The main audience for this book is those working in the automotive industry who are involved in automotive design. It can also be used as a textbook for courses taken by students in automotive colleges. It contains some of the basic concepts and theories of interaction design. The examples used and the theoretical and interaction design methods chosen are essential for automotive design. This is a basic textbook for interaction design. For those who need an in-depth understanding of interaction design in cars, especially when it comes to the design of a specific system, further references to other literature and studies are required.

Reference

SAE (2021) Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. J3016_202104. https://www.sae.org/standards/content/j3016_202104/