TECHNICAL REPORT

ISO/TR 23049

First edition
2018-09

Road Vehicles — Ergonomic aspects of external visual communication from automated vehicles to other road users

Véhicules routiers — Aspects ergonomiques de la communication visuelle exterieure du véhicule automatisé aux autres utilisateurs de la route

Reference number
ISO/TR 23049:2018(E)

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Published in Switzerland

Contents

Page

Introduction ..... **iv**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Background **1**
5 Current road user interactions **2**
6 Potential ADS-DV communication **2**
6.1 General 2
6.2 Vehicle information 2
6.2.1 State 2
6.2.2 Driving mode 3
6.3 Vehicle "understanding" of the environment 3
6.3.1 Perception 3
6.3.2 Recognition and acknowledgment 3
6.3.3 Belief state 3
6.4 Guidance 3
6.5 Intent 4
7 Format of ADS-DV communication **4**
8 Considerations for ADS-DV communication **4**
9 Acceptance of ADS-DVs by the public **5**
Bibliography **7**

Introduction

The need for external communication was highlighted in the National Highway Traffic Safety Administration's (NHTSA) 2017 automated vehicle policy: "New complexity is introduced to this interaction as ADSs take on driving functions, in part because in some cases the vehicle must be capable of accurately conveying information to the human driver regarding intentions and vehicle performance".

This document focuses on the various ways to enhance traffic scenarios by suggesting communication from Automated Driving Systems (ADS-DV)s [16]. While communication may involve many modalities (visual, speech, audio signals, haptics, etc.) and combinations thereof, this document mainly focuses on the visual modality, since interaction with vehicles is primarily a visual task [13].

As AV systems enter the market, road users need to understand how to safely interact with these vehicles. This is particularly important when situations occur such as uncertainty of right-of-way involving road users of all types including AVs, pedestrians, bicyclists, drivers, and passengers. Although there is still some discussion about the need to provide external communication, it is important to start working on this concept. Within the minimum sound requirements for hybrid and electric vehicles (2016), the NHTSA requires non-internal combustion vehicles add an audible alert so that pedestrians with visual impairment can hear these vehicles at low speeds, full compliance by September 2019. Since any other audible signals would conflict with this regulated signal, visual signalling is recommended. Since the implementation of supplemental visual signalling on ADS-DVs may help other road users navigate traffic scenarios more easily, there is a need to investigate standardizing signals if they are to be used. Consistency across the automotive industry is needed to minimize potential road user confusion and establish societal trust with respect to ADS-DVs. This includes design considerations made for vehicles of different types and sizes.

It is recommended that if ADS-DVs have external visual communication systems, the communication should be standardized across the automotive industry. Learnability of these systems is a main focus, limiting the number of signals and ensuring they are distinct and salient yet not distractive, with the aim of their implementation providing a positive impact on societal acceptance and traffic safety.

Road Vehicles — Ergonomic aspects of external visual communication from automated vehicles to other road users

1 Scope

The purpose of this document is to provide guidance for developers of visual external communication systems for automated vehicles (AV), particularly Automated Driving System – Dedicated Vehicles (ADS-DV), as defined by SAE J3016.

The main objective of this document is to propose how ADS-DVs could communicate with other road users via an external communication system. It discusses the interaction between humans and ADS-DVs within roadway environments. Recommendations for the type of external visual communication messaging are presented along with the supporting methodological rationale.

This document does not address functionality elements of the ADS-DV external visual communication system itself. Rather, it serves to propose how the system communicates to human users such that it can be learned and understood by society at large.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Background

As ADS-DVs enter the market, road users will need to interact with them in an effective manner. In manually-driven vehicles, the effectiveness of interactions are based intrinsically on the rules of the road that define priorities for given situations. Recent studies have also shown that vehicle behaviour also determines the behaviour of other road users [3]. However, at times it is difficult to resolve a specific situation deterministically. Common situations include conflict with another road user, uncertainty as to who has the right-of-way, accommodation of other road users, and acts of fairness on the road. Currently, such situations are sometimes resolved by coordination and negotiation between two or more humans such as interactions between driver-pedestrian, driver-driver, and driver-cyclist.

Since a human driver may not be in an ADS-DV or a person may be in the vehicle but not actively controlling it, effective human-to-human interactions likely will not be feasible and a substitute may be needed. The vehicle's behaviour will be programmed or will be a response to changing circumstances, which may deviate from what people expect in normal human-human interaction. Therefore, a new way of communication may need to replace these traditional human-to-human communications by communicating the ADS-DV's current or planned behaviour with other road users. Such communication could enable other road users to make more judicious decisions and enable better public acceptance

of ADS-DVs. Studies are currently investigating the needs and benefits of visual communication of automated vehicles to surrounding traffic and other road users.

5 Current road user interactions

Currently, vehicular road communication concerns vehicle state, intent and warnings, and several methods of communication are utilized. Vehicles have dedicated signals that have conventional and sometimes regulated meanings; these signals can provide state information (brake light, reverse horn in trucks), intent information (turn signal to indicate intended departure from current lane), and general warnings (honking, hazard light). These signals are not sent directionally to a specific road user, but all recipients are expected to respond by taking a suitable action or, at least, by taking notice. Additional means of communication are informal vehicle signals, such as blinking the headlights or tapping on the brakes, but the meaning of these messages is ambiguous and depends on local and cultural norms.

A driver can also communicate by taking dynamic actions such as moving into a conflict space, cutting into the gap between vehicles, or creeping forward onto a busy crosswalk. Finally, there are explicit communication forms such as hand signals, head movements, torso movements, as well as implicit communication such as eye contact [11]. What is unique about these human-to-human communications is that they are usually directional and intended for specific road users. Currently, such human-to-human communication is used to resolve difficult situations; for example, in Germany, the rules of the road mandate this kind of communication when road signs and traffic rules are not enough. While human-to-human communication is often effective in resolving traffic situations, it can also be misinterpreted or misused, leading to complications.

The most certain means of communication from a driver is vehicle motion as this indicates what the driver is actually doing as well as the driver's intent. For instance, at a stop if a driver takes their foot off the brake in an automatic-transmission vehicle, the car begins to inch forward, communicating both that the vehicle is starting to go as well as the driver expects to go next. There is a strong correlation between vehicle movement and communications, and any new signalling scheme will need to have that in mind. When vehicle motion state is likely to change imminently, secondary cues could be necessary to better anticipate the future vehicle behaviour. Brake lights fulfil these tasks as well as eye contact between pedestrians or side traffic with the driver of the car concerned. ADS-DVs should enable this information exchange.

6 Potential ADS-DV communication

6.1 General

A traditional vehicle and an ADS-DV can communicate in several methods. The following outline describes these, considering conveyable information and relevance to road users.

6.2 Vehicle information

6.2.1 State

Vehicle state encompasses speed, rate of acceleration, deceleration, idle, etc. Vehicle state has traditionally been communicated implicitly through observable behaviours without the requirement of extra displays; however, this information can be signalled explicitly by multiple modalities. One acoustic modality example is the tone and beeps used by trucks when backing up or the additional sounds generated by EVs in lower speed conditions. A visual example involves brake lights indicating deceleration. In their evaluation of vehicle-to-pedestrian communication displays for AVs, Clamann, Aubert, and Cummings [1] utilized a dedicated visual display on a grid which showed vehicle speed as white text on a black background. The benefits and potential consequences of such explicit signal concepts for vehicle state would need further exploration.