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State of the art on measuring driver state and technology-based risk prevention and mitigation
Findings from the i-DREAMS project

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Abstract

Advanced vehicle automation and the incorporation of more digital technologies in the task of driving bring about new challenges in terms of the operator/vehicle/environment framework, where human factors play a crucial role. This paper attempt to consolidate the state-of-the-art in driver state measuring, as well as the corresponding technologies for risk assessment and mitigation, as part of the i-DREAMS project. Initially, the critical indicators for driver profiling with regards to safety risk are identified and the most prominent task complexity indicators are established. This is followed by linking the aforementioned indicators with efficient technologies for real-time measuring and risk assessment and finally interventions modules are recommended in order to prevent and mitigate collision risk. It is expected that the results of this review will provide an overall multimodal set of factors and technologies for driver monitoring and risk mitigation, essential for road safety researchers and practitioners worldwide .

Keywords: road safety; driver state measuring, literature review; risk prevention;

1. Introduction

Nowadays, transportation research and industry worldwide are concerned with advanced vehicle automation and the incorporation of digital technologies in the task of driving. These new technologies bring about new challenges in terms of the operator/vehicle/environment framework and consequently, the area of human factors needs to be further understood and researched. Several factors of driver state have been persistently demonstrated in the literature as critical for safe transport systems. Distraction, in-vehicle or external, remains a serious threat to road safety (Lee et al., 2009). Fatigue and drowsiness are not limited to professional drivers, they emerge as critical risks for all drivers (Zhang et al., 2016). Fitness-to-drive becomes a key question for all operators, with respect to health concerns (e.g. illness, frailty, cognitive state) especially in an ageing yet technologically challenged society (Eby et al., 2008). Extreme emotions, e.g. anxiety, stress, anger have received so far notably less attention (Mesken et al., 2007). Moreover, differences in socio-cultural factors, are still among the main determinants of road risks. At the same time, technology developments make massive and detailed operator performance data easily available (e.g. new in-vehicle sensors that capture detailed driving style and contextual data, increase in the penetration and use of information technologies by drivers, Internet of Things). This creates new opportunities for the detection and design of customised interventions to mitigate the risks, increase awareness and upgrade performance, constantly and dynamically (Toledo et al., 2008; Horrey et al., 2012).

The objective of the i-DREAMS project is to setup a framework for the definition, development, testing and validation of a context-aware 'Safety Tolerance Zone' for driving, within a smart Driver, Vehicle & Environment Assessment and Monitoring System (i-DREAMS). Taking into account, on the one hand, driver background factors and real-time risk indicators, and on the other hand, driving task complexity indicators, a continuous real-time assessment will be made to monitor and determine if a driver is within acceptable boundaries of safe operation (i.e. Safety Tolerance Zone). Moreover, safety-oriented interventions will be developed. Application areas include: new road safety interventions, improved driver well-being and transfer of control between human and vehicle, as well as a more eco-efficient driving style since safer driving implies more eco-friendly behaviour (i.e., so-called 'smart' driving as defined in Young et al., 2011).

One of the initial pillars of the i-DREAMS project is the measurement of risk-related physiological indicators (e.g. fatigue, distraction, stress, etc.), driver-related background factors (age, driving experience, safety attitudes and perceptions, etc.), and driving environment and traffic complexity indicators (e.g. time of day, speed, traffic intensity, presence of vulnerable road users, adverse weather, etc.) to assess driver capacity and task demand in real-time. Existing systems are limited in their capability as mostly kinematic data is typically captured and driver status information is excluded (Mortimer et al., 2018). Car companies are currently researching the incorporation of heart rate measurements, but this is yet to be realised in the near future (Strickland, 2017). Furthermore, the data does not include measures of fatigue or health (but just driver alertness in some cases (Ramasamy et al., 2014) and is incapable of assessing situational complexity – a key requirement to manage the transition of control between human and vehicle in vehicles with Level 3 automation systems (Katrakazas et al., 2015). In the rail environment such systems are rarely used and following recent crashes have attained much higher relevance.

In order to enhance current driver monitoring, as well as propose novel interventions for keeping operators within the boundaries of safe driving, a review of the state-of-the-art in driver state measuring and technology based risk prevention and mitigation is needed. This forms the scope of the current paper, which aims at critically comparing and contrasting current solutions of in-vehicle monitoring technologies, assess user feedback and intervention applications and give recommendations on the suitability of systems for use case implementation.

2. Review Methodology

This paper reviews and exploits the state of the art on measuring the state of the driver in terms of balance between the given task demands and the driver's available resources to cope with the demands. Fuller's Task-Capability Interface Model (Fuller, 2000) provides the theoretical framework for this endeavour. Since task demands can vary tremendously for different travel modes, this will be done in a multimodal manner for all 'i-DREAMS modes': car, bus, truck and train.

Initially, endogenous factors for monitoring the driver state and exogenous factors for task demand assessment, will be identified. Within this task, variables which influence the level of individual risk in a given traffic situation will systematically be identified. These variables can either be endogenous factors such as distraction, fatigue or cognitive impairment which characterize the driver state (resources) or exogenous factors such as weather, time of day and traffic conditions which can increase the task complexity (demand). The balance of both types of factors is the objective individual risk. The Task-Capability Interface Model serves as a theoretical frame, however, other related models will be reviewed as well, since the suitability might be mode-specific. Furthermore, indicators for factors, identified as relevant for the overall driver state and thus risk level, will be reviewed and compared in a systematic way. As a result, a common set of validated indicators will be synthesised; and these will be combined to assess the individual level of risk of operators.

The next step with regards to the state-of-the-art, will review and - if needed - pre-test state of the art in-vehicle technology to reliably measure relevant endogenous and exogenous factors identified in the previous task. Part of the review is the determination of properties of tools such as smart cameras, on-board diagnostic systems like steering wheel sensors as well as wearables to measure heart rate or skin conductance response. The latter can e.g. serve as indicators for cognitive processes. In order to provide useful information, a list of criteria will be defined to review the state of the art in a systematic manner. Factors such as reliability, non-intrusiveness, acceptability for users etc. will be considered when assessing the technology.

With regards to vehicle technologies, applications for safety interventions associated with risk prevention and mitigation) will also be compared and contrasted as well as assessed for their efficiency. Existing systems and technologies to inform road users either in real-time or post-trip aiming at enhancing knowledge, attitudes, perception and eventually safety behavior, will be overviewed. The technology will be reviewed and assessed by defined criteria such as effectiveness acceptability and usability which are essential for the success of an intervention tool. Tools which provide information, guidance and notifications via smartphone (real-time feedback) and a web-based platform (post-trip feedback) will be reviewed. The outcome of this task is a set of effective real-time and post-trip tools, which can be used for further research process in order to optimise the operational design of such technologies.

3. Expected outcomes and discussion

As it can be understood from the previous section, there is a threefold contribution with regards to the review: i) the critical indicators for driver profiling with regards to safety risk will be identified and the most prominent task complexity indicators will be established, ii) the aforementioned indicators will be linked with the most efficient technologies which are suitable for measuring and assessing these indicators in real-time and iii) interventions modules will be recommended in order to prevent and mitigate collision risk, based on the indicators and measuring technologies.

Special attention needs to be given to cause and effect relationship between risk factors and the safety impact, in order to avoid including indicators which are correlated or repeated. Furthermore, for every indicator there needs to be a clear distinction between its effectiveness for estimating safety level and its utilization or usability in customizing safety interventions. Finally, focus will be given in the transferability of indicators and interventions between cars, buses, trucks and trains, in order to provide an overall multimodal set of factors and technologies for driver monitoring and risk mitigation.

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