A Research of Electrical Engineering and Automation-based Intelligent Technology Application

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Abstract. As a safety-security field, the transportation field always encourages and embraces advanced intelligent technologies to reduce risks. Recently, automated driving has received extensive attention from researchers and industries, as it is expected to improve the flow of traffic, to significantly reduce drivers’ errors and thusly increase safety. Though many efforts have put on automated driving, many challenges remain in achieving fully autonomous, resulting in partially automated driving. The role of drivers in a partially automated car is monitoring and taking over driving in specific conditions, which is significantly different from the manual cars. The novel role of drivers induces new human factors issues and challenges to maintain traffic safety. This study tries to investigate these human factors issues involved in the human and automated driving interactions and to propose a framework of electrical engineering and automation-based intelligent technology application to mitigate risks. Specifically, trust, attention, situational awareness, and alarm fatigue were identified as significant human factors issues in automated driving. An electrical engineering and automation-based intelligent framework for monitoring cognitive states and generate warnings was proposed.

1. Introduction
Safety in transportation fields always draws extensive attentions of researchers and industries. Though many efforts have been put on transportation safety, the accidents rate is still high and the outlook is still grim. It is reported that 1.25 million people died per year due to traffic accidents [1]. According to the traffic accidents analysis, human factors are critical causal factors, causing more than 70% traffic accidents. Especially, human fatigue, which is increasingly considered to be the primary cause of most accidents [2, 3], and the National Highway Traffic Safety Administration (NHTSA) reported that drowsy drivers cause nearly 100,000 crashes per year in the United States of America. Hence, automated driving has been proposed to mitigate the risks of human beings.

It is expected that automated driving can significantly change the role of drivers and improve road safety [4]. However, recent studies found that automated driving will fundamentally change the patterns of road transportation and the interactions between human being and transportation. This great change will introduce some new challenges. First, the importance of human beings increases with the advanced levels of the control system [4]. Furthermore, nowadays, the human driver is still considered to be the last line of defense in automated driving.
Considering the new challenges in the transportation fields, the authors aim to investigate the specific human factors in each level of automated driving and proposed an electrical engineering and automation-based intelligent framework to enhance the communications between human being and the automated system.

The remainder of the paper is organized as follows. The definition of the automated driving level is described and human factors involved in each level are discussed in Section 2. Section 3 presents the proposed framework, which aims to improve information transparency and mitigate the risks of human errors.

2. Human Factors in Automated Driving

Many research studies mentioned that human factors issues remain in the interaction between human beings and the automated driving and are waiting to be addressed. In this section, the authors investigated the human factors across the five levels of automation separately from two aspects: human drivers and passengers.

2.1. Human driver stage

The human diver stage includes assisted automation and partial automation levels.

In the assisted automation, only a driver assistance system is implemented to perform a specific task, such as deceleration or acceleration, the human driver carries the remaining driving tasks. Instead of implementing only one driver assistance system, partial automation applies more assistance systems to perform several specific tasks, such as steering and acceleration. The same with the assisted automation, the human driver carries the remaining driving tasks.

For both the two automation levels, the human drivers conduct all the dynamic driving tasks. Hence, the problems from automation fail should be limited and are not the main human factors at this level. On the contrary, though the human drivers are freed from some critical tasks, their vigilance and sustained attention were still required for a long period of time. Hence, human factors of the drivers related to situational awareness, fatigue, and workload are critical and most important at this level.

From the passengers perspective, since the automated system only performs specific tasks which are mostly unrelated to passing by passengers, few human factors in the interactions between passengers and the assisted automation raise at this level.

2.2. Automated driving system stage

In this stage, all driving tasks are conducted by the automated driving system, and the human drivers are expected to take over upon request. Specifically, conditional automation and high automation levels are included in this stage. Since almost all tasks are automated, the requirements of human-in-loop become relatively important [4]. As mentioned by [4], human divers are required to resume manual control under specific conditions. Hence, in the partial automation level, the skills of human divers should be retained to perform the driving tasks. In other words, factors such as rebuilding situational awareness and hand over time are important at this level.

Under the conditional automation level, human drivers do not need to manual control the car over a long period of time. However, they passively monitor the driving conditions and are required to be vigilant to the warnings. As a result, human factors, such as alarm fatigue, inattentive blindness, monotonous, trust, and over-reliance are critical at this level. Specifically, alarm fatigue, which means a reluctance to respond to alarms, has been a top risk factor of the monitoring operators [5, 6]. Owing to the advanced automated technology, the human drivers may show over-reliance on automation and focus on other unrelated tasks, such as playing games and watching videos, resulting inattentive blindness, which are causal factors of many traffic accidents [7]. Even if the human driver focuses on driving, passive monitoring will result in a monotonous driving environment, leading to a high possibility of human fatigue [2, 3].

From the passengers perspective, passengers will not trust the conditional automated cars and be afraid to come across automated cars [8]. The driving behaviors of conditional automated cars would be
greatly different from the manual cars. Hence, passengers cannot well predict the movements of automated cars, resulting in low trust.

2.3. Full automation
The full automation means that an automated driving system performs all dynamic driving tasks and no intervention is required. Since no human driver is involved in this full automation level, no human factors issue raised from the interactions of driver and automation system anymore. The problem is how the fully automated cars interacted with passengers. Unlike the conditional automated cars, there are no drivers in the fully automated cars. This situation will induce a great problem of trust and responsibility. If an automated car led a traffic accident, who is going to take responsibility. Without solutions to this problem, it is difficult for the public to accept the full automated cars.

3. A Framework of Electrical Engineering and Automation-based Intelligent Technology Application in Automated Driving
In the last section, it was found that automated driving induces many new challenges and human factors issues in maintaining traffic safety. However, it is expected that it can well take advantages of electrical engineering and automation-based intelligent technologies and artificial intelligent (AI)-thinking. Specifically, electrical engineering and automation-based intelligent technologies can be used to improve information transparency and thusly keep human drivers and passengers in the loop of control during automation [4]. It is expected that keeping human beings in the loop can significantly improve the performance of the whole system and enhance the interactions between human beings and the automation driving system. In this section, the framework of the electrical engineering and automation-based intelligent system using AI-thinking is presented.

3.1. Theory of the proposed electrical engineering and automation-based intelligent system for automated driving using AI-thinking
AI-thinking was proposed in 2013 [9]. It refers to a learning process utilized machine learning and deep learning method to extract patterns from unstructured data. Using the AI-thinking, the authors developed a framework to enhance trust between human being and the automated system by interpreting complex human response and the automated system behaviors to each other. The theory of the proposed framework is depicted in Figure 1.

Variables: Traffic conditions, human and cars states are considered in this framework. Specifically, their trust level and other cognitive states, such as stress, workload, situational awareness, vigilance, and fatigue will be monitored. The framework provides this information to the automated system.

Constructs: The proposed framework constructs several modules as follows: (1) the automated cars. This module conducts most of the dynamic driving tasks and modifies its activities based on cognitive states of human beings. (2) The cloud infrastructure. The framework stores all traffic information, human response, human states, and the automation system states in the cloud infrastructure. (3) Adaptive feedback module. This module captures the states and behaviors of the automated systems and provides the analyzed information to human beings. In this way, humans can be kept in the loop of control of automation.

AI-thinking: In this study, the AI-thinking includes two parts, namely learning and adaption. Specifically, the constructs extract information and knowledge from the variables through deep learning or machine learning. Then, the constructs provide adaptive feedback based on the learned information.
3.2. Proposed AI-thinking framework for automated driving

There are four steps to achieve the proposed framework:

Step 1: Data collection and information extraction. In this step, related data including the automated system type and states, cognitive states of the human drivers, and behaviors of the passengers are collected. The states of the human drivers can be monitored by the eye tracker, electroencephalogram [10], and other wearable devices. Hence, the eye movements, brain dynamics and heart rates of the human drivers are collected. The cognitive states of passengers can be predicted by collecting behaviors data [11]. Hence, the behavior data of passengers are collected. The data are preprocessed to rapidly generate profiles of human drivers and passengers.

Step 2: Knowledge extraction. The machine learning methods, such as decision tree, support vector machine, and neural network are utilized to process the data collected [2, 12]. The cognitive model of passengers are established in the cloud and the cognitive model of the human drivers are established by the automated driving system.

Step 3: The adaptive algorithm is implemented to adjust the behaviors, such as speed and direction of the automated cars. Generally, both the states of passengers and human drivers are considered in adjusting.
Step 4: The framework suggests a multimodal interface to communicate with human drivers. The multimodal interface which involves sound, visual, and haptic interactions are presented to gain drivers’ attention. It is expected that the multimodal interface can mitigate the risks of inattentive blindness and alarm fatigue. Under urgent conditions, notice and warnings are displayed to the passengers.

4. Conclusion
This paper presented human factors involved in each level of automated driving and proposed an electrical engineering and automation-based intelligent framework for improving traffic safety in the automated driving environment. It was found that trust is a critical issue in almost all levels of automated driving. It is expected that enhancing the communication between human being and the automated system can address the trust issue. Hence, an AI-thinking framework was proposed. Specifically, the cognitive states of the human driver and passengers are monitored and analyzed. The automated driving system can adjust its behavior accordingly.

This study just provides a theoretical discussion from a human factors perspective. Future studies based on simulated and field experiments should be conducted to evaluate and modify the proposed framework.

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