The Application of Eye Tracking Technology in Human-Machine Co-driving System under the Background of Intelligent Vehicle Development

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Abstract. This paper studies the application of eye tracking technology in intelligent vehicle human-computer interaction, and analyzes how eye tracking technology improves driving safety and interaction efficiency through theoretical models. A theoretical model of human-machine co-driving integrated with eye tracking technology is constructed, and the effects and challenges of the model in practical application are analyzed. Reasonable application of eye tracking technology can effectively improve the interaction quality and driving safety of human-machine co-driving system. This study explores the application potential of eye tracking technology in intelligent vehicle human-machine co-driving system and its specific impact on improving driving safety and interaction efficiency. In order to provide a new perspective and method for the design of human-computer interaction in intelligent vehicles, especially how to accurately capture the driver's behavior and psychological state through eye tracking technology, so as to optimize the cooperative work mode of human-computer co-driving. It aims to promote the development of eye tracking technology in the field of intelligent vehicle design.

Keywords: human-computer interaction ; human-machine co-driving ; eye tracking technology ; automotive design

1 Introduction

Under the background of the rapid development of intelligent vehicle technology, human-machine co-driving system has become the focus of research. As a revolutionary progress in the field of transportation, intelligent vehicle technology is reshaping our way of travel. The development of autonomous driving technology and advanced driver assistance systems (ADAS) is not only committed to reducing traffic accidents and improving road safety, but also expected to provide users with unprecedented convenience and driving experience. Although these technologies are becoming more and more mature, the widespread use of smart cars still faces many challenges, especially in human-computer interaction. In the research and development of intelligent vehicles, how to design an effective human-machine co-driving system to ensure the balance between safety and efficiency has become an unavoidable and important issue.

The core of a smart car lies in its ability to automate key operations, including driving

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decisions and control execution. However, the realization of full automation still takes time, and under the current framework of technology and regulations, the driver's intervention is still needed in the driving process. In this case, the human-machine co-driving system is particularly important. It needs to ensure that the interaction between people and machines can be highly compatible and effective. The key to the design and optimization of such systems lies in how to accurately capture and understand the driver's behavior and intention, which requires efficient and reliable monitoring technology ; as a tool to evaluate users' attention and intention, eye tracking technology has been widely used in the field of human-computer interaction in recent years. Eye tracking technology has been proved to be effective in monitoring and analyzing users' visual attention in flight simulation, virtual reality, advertising testing and psychological research. Applying this technology to the human-machine co-driving system of intelligent vehicles can monitor the driver's gaze and attention distribution in real time, and provide data support for the automatic response of the system, thereby enhancing driving safety and intuitive operation[1].

In addition, given the social and economic implications of smart car technologies, this article will also explore how these technologies influence the development of modern transportation systems and their potential contribution to improving road safety and driving experience. The successful implementation of this technology can not only reduce traffic accidents caused by human errors, but also help to optimize traffic flow, reduce congestion, improve energy efficiency, and thus bring a wide range of social and economic benefits.

In summary, this paper will analyze the human-machine interaction problems in intelligent vehicles in detail through the theoretical model of human-machine co-driving integrated with eye tracking technology, in order to provide theoretical support and practical guidance for the research and development of human-machine co-driving system of intelligent vehicles in the future.

2 Research background

2.1 The core position of human-machine co-driving system

The human-machine co-driving system refers to the joint action of human and intelligent systems in the driving process to achieve a higher level of driving safety and efficiency through effective interaction and coordination. In the development of intelligent vehicles, although the degree of automation continues to increase, the driver's intervention is still essential before the technology is fully mature. The design of such a system not only requires the machine to be able to understand human instructions and intentions, but more importantly to be able to predict and adapt to human behavior, ensuring that the machine can take over control or provide the necessary assistance at a critical time. Therefore, the research of human-machine co-driving system not only focuses on the technology itself, but also on how to enhance the understanding and trust between human and machine through technology[2].

2.2 The interactive potential of eye tracking technology

Eye tracking technology, as a method that can accurately capture the line of sight and attention distribution of the human eye, provides a new possibility for human-computer interaction.

When driving a car, the driver's visual attention is the key to ensuring safety. Eye tracking technology can not only monitor the driver's visual focus in real time, analyze whether the driver's attention is concentrated, but also predict the driver's behavioral intention by analyzing the visual data, so as to respond in advance, such as adjusting the speed or issuing a warning. The application of this technology, especially in the man-machine co-driving system, can significantly improve the response speed and accuracy of smart cars, and further improve driving safety[3].

2.3 Research significance and prospect

Based on the above background, this study aims to explore the application of eye tracking technology in intelligent vehicle human-machine co-driving system, and analyze its potential impact on improving driving safety and interaction efficiency. By constructing theoretical models and analyzing practical application scenarios, this study hopes to provide a new perspective and strategy for the human-computer interaction design of intelligent vehicles, and also provide theoretical basis and practical guidance for the development and optimization of related technologies. With the continuous progress of intelligent vehicle technology, effective human-computer interaction design will become one of the key factors to promote the development of intelligent vehicle industry[4].

3 Theoretical framework

3.1 Basic theory of human-computer interaction

Human-Machine Interaction (HMI) theory provides a framework for understanding and analyzing the way people interact with machines. In the context of smart cars, this includes how to design interfaces and systems so that human users can interact with them intuitively and effectively. The key is to understand people's cognitive and behavioral patterns and how these patterns are affected by external stimuli. Eye tracking technology provides a unique perspective in this framework, which can capture the driver's visual attention and cognitive load in real time, thus providing data support for system design and feedback mechanism.

3.2 Theoretical basis of eye tracking technology

Eye tracking technology is based on a series of physiological and psychological theories. These theories believe that eye tracking patterns can reflect the individual's attention distribution, information processing process and decision-making strategies. In the activity of driving that requires a high degree of cognition, the driver's eye tracking data can reveal their perception of the environment, the way they process information, and the actions they will take. For example, the driver's eye tracking patterns when dealing with complex traffic situations can show the focus of their attention and possible areas of insufficient attention[5].

3.3 Transformation from passive interaction to active interaction

The application of eye tracking technology in vehicle design transforms passive interaction into active interaction. Traditionally, the interaction between the driver and the vehicle is mainly passive, such as through buttons, switches or touch screens. However, through eye tracking technology, vehicles can actively perceive the driver's sight and attention, so as to achieve a more intelligent and personalized interaction. For example, when the system detects that the driver's line of sight deviates from the road, it can automatically adjust the driving seat or issue a warning prompt to remind the driver to stay alert. This active interaction not only improves driving safety, but also enhances the personalization and humanization of driving experience[6].see **Figure 1**.

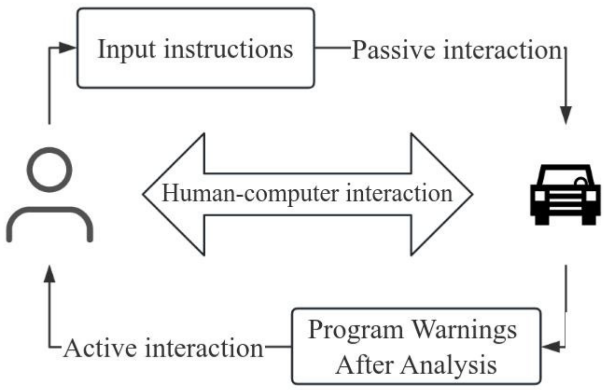

Fig. 1. Passive Interaction and Active Interaction

3.4 Human-machine co-driving model integrated with eye tracking technology

Three main components are considered when constructing a human-machine co-driving model that integrates eye tracking technology : data collection, data analysis, and feedback mechanisms. see **Figure 2.**

Data collection : Use high-precision eye tracking equipment to collect the driver's eye tracking data in real time during driving, such as gaze point, pupil size, blink frequency, etc. These data reflect the driver's visual attention and cognitive state.

Data analysis : The driver's attention distribution, fatigue state, and possible hazard warning signals are identified by analyzing the collected eye tracking data through algorithms and models. The key to this step is to be able to process and interpret eye tracking data in real time in order to respond quickly.

Feedback mechanism : According to the results of eye tracking data analysis, the system can automatically adjust the human-machine interface or provide feedback to the driver. For example, if the driver's line of sight is detected to deviate from the road for a long time, the system can alert the driver to the road ahead through sound or visual signals, or automatically adjust the speed to ensure safety if necessary[7].

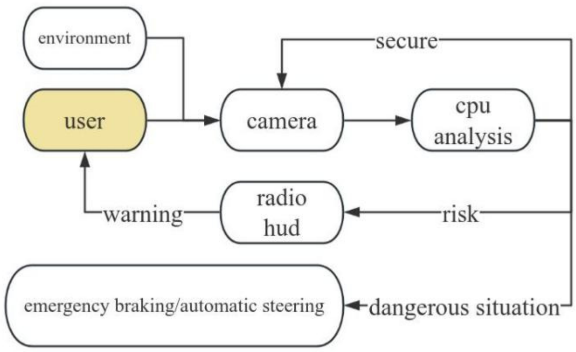

Fig. 2. Human-machine co-driving structure integrated with eye tracking technology

3.5 Application prospects and theoretical contributions

The theoretical framework not only provides a scientific basis for the application of eye tracking technology in intelligent vehicles, but also promotes the development of human-computer interaction design, making it more personalized and data-driven. In this way, smart cars can better understand and adapt to people's behaviors and needs, and ultimately achieve a safer and more efficient driving experience.

4 Theoretical application

In the human-machine co-driving model integrated with eye tracking technology, the application of theory mainly focuses on how to use eye tracking data to optimize the human-machine interaction design of intelligent vehicles, so as to enhance driving safety and improve interaction efficiency. The following part discusses in detail the specific operation and expected effect of the model in practical application.

4.1 application scenario design

Real-time attention monitoring : The eye tracking system is integrated in the smart car to monitor the driver's gaze and eye tracking in real time. This monitoring helps to identify whether the driver maintains concentration at critical moments such as lane change and emergency braking. If the system detects that the driver's sight continues to deviate from the road ahead, it will automatically trigger a warning signal to remind the driver to pay attention to the road conditions.

Fatigue detection : Long-term driving can easily lead to fatigue. Eye tracking technology can judge the driver's fatigue degree by analyzing eye parameters (such as blink frequency, pupil change, etc.). Once the system judges that the driver shows signs of fatigue driving, it can recommend the driver to rest or automatically start the safe driving mode if necessary to reduce the risk of accidents.

Interaction with other interaction methods : The combination of eye tracking technology and voice interaction can improve the interactive performance and user experience of smart cars.

This combination not only enhances the diversity and flexibility of interaction, but also improves the intelligence and naturalness of interaction, so as to achieve a more intelligent, personalized and convenient driving experience, and improve driving safety and user satisfaction.

Interactive interface optimization : Based on eye tracking data, the intelligent vehicle system can optimize the design of its interactive interface, such as adjusting the layout of the information board and the way the information is presented, so as to ensure that the driver can obtain the necessary information quickly and accurately. HUD head-up display can also be used as an operation screen to receive user instructions in an interactive way combining eye tracking and voice under the premise of ensuring safe driving. In addition, the system can automatically adjust the interface according to the driver's visual habits and preferences to make it more intuitive and easy to use.

Further promote the development of intelligent vehicles : The eye tracking data and driving data of each user will be uploaded to the technical personnel to assist the system development. When developing the lane keeping assist function or the automatic lane change function, the eye tracking technology data can help to understand the driver's visual behavior in these cases, so as to design a more intuitive and responsive assist system.

4.2 Technical challenges and solutions

There are some technical challenges to be solved in the application of eye tracking technology to the human-machine co-driving system of intelligent vehicles.

Real-time processing of data : The collection and analysis of eye tracking data requires efficient real-time processing capabilities, which puts forward higher requirements for vehicle-mounted computing systems. In order to cope with this challenge, more efficient data processing algorithms can be adopted, or some data processing tasks can be outsourced to the cloud platform to reduce the burden on the local system.

Adaptability and personalization of the system : Different drivers may have different eye tracking patterns and reactions, and the system needs to be able to learn and adapt to various driving behaviors. Through machine learning technology, the system can continuously learn from the driver's behavior, and then achieve more accurate personalized settings.

User privacy and data security : The use of eye tracking technology involves the collection of a large amount of personal data, so it is necessary to ensure that the security of data and the privacy of users are not violated. To solve this problem, strict data protection measures and transparent user protocols need to be established.

4.3 Expected effect and practical significance

The application of the theoretical model is expected to significantly improve the interactive nature and safety of intelligent vehicles. Through a deeper understanding of the driver's visual attention and behavioral intentions, intelligent vehicles can more accurately conduct risk assessment and early warning, thereby reducing the probability of accidents. In addition, by optimizing the human-computer interaction interface, the use experience and satisfaction of drivers can be improved, and the social acceptance and market penetration of smart car technology can be further promoted.

In summary, the application of eye tracking technology in the human-machine co-driving system of intelligent vehicles has important theoretical and practical value. It can not only improve the safety and efficiency of the system, but also provide new research directions and technical support for the future development of intelligent vehicles.

5 Conclusion

This study constructs and analyzes a human-machine co-driving model integrating eye tracking technology, aiming to explore the application potential of eye tracking technology in intelligent vehicle human-machine interaction and its possible impact on improving driving safety and interaction efficiency. In short, eye tracking technology has a significant application prospect in the intelligent vehicle human-machine co-driving system, which can not only improve driving safety, but also optimize the interactive experience. With the further development and improvement of related technologies, it is expected to play an increasingly important role in the development of smart cars in the future.

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