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Research on Driver Emotion Monitoring and Regulation System in Intelligent Assisted Driving

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Abstract. With the rapid development of smart connected vehicles, the influence, recognition and regulation of driver's emotions are crucial for intelligent cockpits with "emotional interaction". This review aims to provide a comprehensive analysis of driver emotion monitoring systems in intelligent assisted driving. By summarizing and analyzing related literature, the structure and application of emotion monitoring systems are introduced, their principles and evaluation criteria are discussed in depth, and the advantages and limitations of the three sub-systems, namely, detection, decision-making and regulation, are analyzed in detail. The results show that although emotion monitoring and modulation technologies perform well in enhancing driving safety and comfort, their practical applications still face challenges in terms of technology maturity, cost control, and privacy protection. In addition, the reliability and accuracy of current emotion monitoring systems in complex driving environments have yet to be improved. Future research should focus on interdisciplinary cooperation to integrate the latest achievements in psychology, computer science and engineering. At the same time, it is necessary to develop unified technical standards and evaluation guidelines to promote compatibility and interoperability between different systems and enhance research on privacy protection measures to ensure the security and confidentiality of user data. Through these efforts, the field of intelligent driving is expected to achieve comprehensive development and wide application, further enhancing driver safety and user experience.

Keywords: Intelligent cockpit, driver emotion monitoring system, artificial neural network, emotion data analysis, emotion regulation system.

1. Introduction

1.1. Background and significance of the study

In recent years, China's car ownership has continued to grow, making it the world's largest car consumption market. However, with the increase in the number of cars, traffic safety issues have become increasingly prominent. Driving is a complex task and any small disturbance can lead to serious consequences. Emotions are one of the key factors affecting driving safety, and driving in a negative emotional state significantly increases the risk of road traffic accidents.

With the advancement of technology, intelligent Internet-connected vehicles have developed rapidly. These vehicles are expected to eventually replace manual driving because they are outfitted with advanced on-board sensors, controllers, and other devices. They also integrate modern communication and network technologies, complex environment perception, intelligent decision-making, and other functions. The development of intelligent Internet-connected vehicles has also promoted a change in the automotive cockpit, developing from the traditional cockpit to the intelligent cockpit stage.

Until self-driving technology is fully matured, the driver still plays an important role in self-driving cars. Therefore, influencing, recognizing and regulating the driver's emotions in shared control schemes for self-driving cars is crucial for the development of "emotionally interactive" smart cockpits. At the same time, an "emotionally interactive" smart cockpit is also important for self-driving cars, as it can enhance trust in self-driving functions, comfort and well-being, and thus improve the acceptability, safety and enjoyment of smart connected cars.

1.2. Main research content of this paper

This research investigates the driver emotion monitoring and regulation system in intelligent driving systems. Firstly, emotion classification and its impact on driving behaviour and traffic safety are explored. Emotion recognition techniques for facial expressions, speech and physiological signals are introduced, including 2D/3D cameras, rhythmic phonological spectrum analysis and heart rate skin electrical activity monitoring. Driver emotions are monitored in real time through multimodal sensors and intelligent algorithms to enhance safety and comfort.

The Emotion Decision System uses Bayesian networks, artificial neural networks and other algorithms to analyze emotion data and dynamically adjust the in-vehicle environment, such as air conditioning, music and seat position, to optimize the driving experience and improve safety. The system requires strict protection of personal data privacy.

The Emotion Regulation System regulates the environment through music, lighting and scent to alleviate negative emotions. Auditory modulation plays adaptive music, visual modulation uses light colours, and olfactory modulation stimulates the brain through fragrance. Although emotion monitoring and modulation technologies have excelled in enhancing driving safety and comfort, they face technical maturity, cost and privacy protection challenges.

Overall, this paper demonstrates the important role of emotion monitoring, decision-making and regulation systems in enhancing driving safety and user experience, and points out its future directions and challenges to promote the overall development of intelligent transport.

2. Driver Emotion Monitoring System

This section describes the Driver Emotion Monitoring System that enhances driving safety and comfort through sensors and intelligent algorithms. The system is used in a wide range of applications such as personal driver safety, autonomous driving, commercial transport, the insurance industry and smart cockpit technology.

2.1. Monitoring system structure

The monitoring system is a complex and delicate system that is divided into three key phases: detection, decision-making and regulation. In the detection phase, the system utilises multiple sensor modules to comprehensively capture the driver's state. The camera focuses on capturing the driver's facial expression, identifying emotion changes and fatigue states through in-depth analysis of facial features. Meanwhile, physiological sensors, such as heart rate monitors and skin conductance sensors, are responsible for detecting the driver's physiological states, such as heartbeat and sweat secretion, thus reflecting the driver's stress and emotional state. In addition, vehicle status sensors monitor data such as vehicle speed, steering wheel angle, brake and accelerator to provide strong support for analysing the driver's driving behaviour and status.

In the decision-making phase, the data processing module collects real-time data from various sensors and performs pre-processing, such as filtering, denoising and normalisation, to ensure the quality and consistency of the data. Subsequently, the system extracts key features from the preprocessed data, such as facial expression feature points, physiological signal features and driving behaviour features. The emotion recognition module then uses deep learning algorithms (e.g. YOLOv5 model) for facial expression recognition and fatigue detection, while the machine learning algorithm analyses the physiological signals to determine the driver's stress and emotional state [1].

The regulation phase provides real-time feedback and advice to the driver through a human-machine interface, such as a display on the vehicle's dashboard or centre console, as well as a voice assistant. When the system detects that the driver is in an unsafe state, it immediately triggers an alarm system to alert the driver through sound prompts or seat vibration. At the same time, the system also automatically adjusts the interior environmental parameters, such as temperature, humidity, light and music, according to the driver's emotional state, in order to create a more comfortable and safer driving environment.

2.2. Monitoring system application

Driver emotion monitoring systems have a wide range of applications in practice, covering a variety of areas such as personal driving safety, automated driving technology, commercial transport, the insurance industry and smart cockpit technology. In driving safety and security, the system can detect fatigue in real time by monitoring facial expressions and physiological signals, prompting drivers to take a break and preventing fatigue-induced traffic accidents, as well as detecting emotional states, such as anger, anxiety, etc., and providing appropriate interventions to reduce the risks of driving triggered by emotional fluctuations. In automated driving technology, emotion monitoring systems help optimise the human-computer interaction experience. When the system detects that the driver is in a nervous state, it can adjust the automated driving mode to provide a smoother driving experience. At the same time, when it detects driver fatigue or emotional abnormalities, the system can remind or force the driver to hand over control to the autonomous driving system to ensure driving safety. In the commercial transport sector, emotion monitoring systems can monitor the state of long-haul drivers in real time and provide rest suggestions to ensure a safe and efficient transport process. Fleet managers can use the system to understand the status of each driver in real time, optimise scheduling and route planning, and improve overall operational efficiency. In the insurance industry, insurance companies can dynamically adjust premiums based on the driver's emotional and fatigue status data to incentivise safe driving and reduce the risk of insurance claims. In smart cockpit technology, the emotion monitoring system can adjust the in-vehicle environment based on the driver's state, such as music, temperature, etc., to provide a more comfortable driving experience. In summary, the driver emotion monitoring system can effectively improve driving safety and comfort through a variety of sensors and intelligent algorithms, and has demonstrated significant value in a number of application areas.

3. Analysis of Driver Emotion Monitoring Systems

This section outlines the smart cockpit emotion monitoring system that detects emotions through multimodality such as cameras, radar, voice and physiological signals, the decision-making system that analyses the data and provides recommendations or warnings, and the regulation system that adjusts the environment through music, lighting and scenting to enhance driving safety and comfort.

3.1. Analysis of the detection system

A cockpit monitoring system mainly consists of an input terminal (sensing terminal), a control terminal (planning terminal) and an output terminal (execution terminal). The input end usually consists of in-vehicle cameras and radar, which are used to collect information sources and then display the results on the terminal after processing and judgment. Expressions are intuitive features that express emotions, and specific emotional states can be inferred by monitoring facial muscle movements. Facial expression recognition is divided into traditional methods (e.g., geometric features, texture features, optical flow method) and deep learning-based methods (e.g., Convolutional Neural Network (CNN)), which have the advantages of simple acquisition method, low cost, and non-contact. In addition, new methods such as High Purity Feature Separation (HPFS) and CogEmoNet, a cognitive feature enhancement model,

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have been proposed [2, 3]. Driver facial recognition is generally achieved through Driver Monitor System (DMS) cameras, and the location is usually on the A-pillar, steering wheel, or instrument panel. Speech emotion recognition technology analyses emotional states by extracting features such as rhyme, tone quality and spectrum (e.g. pitch, energy, Mel frequency cepstrum coefficients). Speech signals are easily captured in the cockpit at low cost and without disturbing the user. The challenge is to extract and process the human voice from noisy driving environments. The GL-DSED network fuses global acoustic features with local spectral features for driver speech emotion recognition, and in-vehicle microphone arrays and sound-source localisation techniques are used to enhance speech understanding [4].

Neurophysiological signals such as electrodermal activity (EDA), heart rate variability (HRV), breath rate (BR), and electroencephalography (EEG) measure the level of physiological activation and reflect the state of emotional arousal due to their objective and not easily artefactualised characteristics. Different EEG frequency bands correlate with the state of consciousness, and respiratory rate with emotional potency and arousal [5]. Although hardware and user acceptance limit the widespread use of neurophysiological signals, they have shown potential in emotion recognition in research and are expected to be used for cockpit health monitoring and safety alerts in the future. See Figure 1.

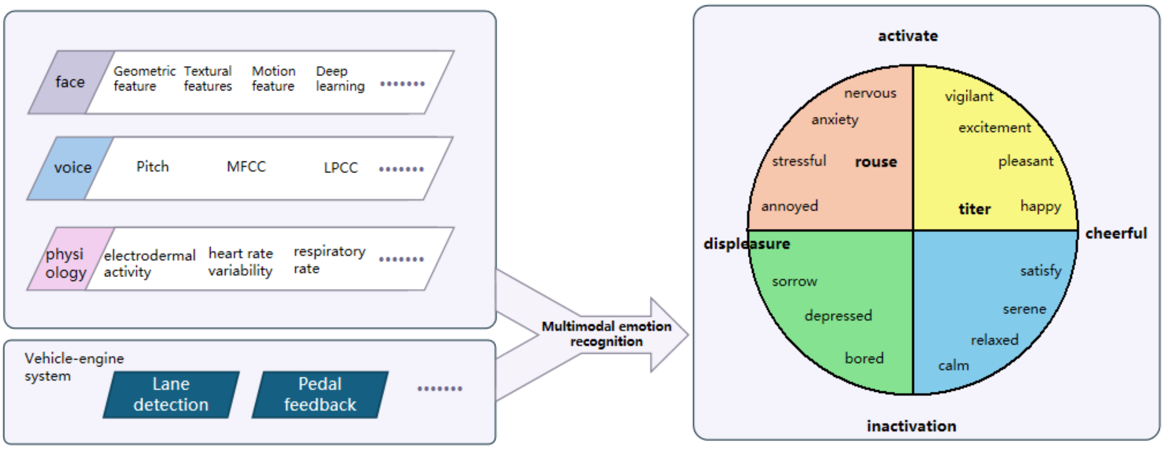

Figure 1. Multimodal emotion recognition framework.

3.2. Decision Systems Analysis

Decision-making systems are intelligent driving systems that use machine learning, and deep learning such as Bayesian networks, artificial neural networks, Hidden Markov Models, best effort algorithms, etc. to analyse the physiological and behavioural data collected after emotion recognition to make appropriate recommendations or warnings [6]. The system should make decisions based on the principles of rationality, systematicity and dynamics. Each decision should be guaranteed to be objective through comprehensive data analysis and scientific algorithms; the system needs to take into account factors such as multiple driving environments and driver emotions to ensure its accuracy. When making decisions, intelligent assisted driving needs to ensure the safety of the driver and passengers on the premise of gradually introducing emotional interaction to achieve the best balance between safety and friendliness. The decision-making system is able to analyse the driver's emotional state in real time, such as boredom, fatigue, dullness, excitement or stimulation, and dynamically adjust the driving mode and in-vehicle environment accordingly to optimise the driving experience and improve safety. For example, when signs of stimulated driving are detected, the system, after image acquisition and analysis, turns on the stimulated state warning and classifies the driver's mental state into grades and makes measures corresponding to the grades. The decision-making modes, and currently, interaction modes such as driver physiological detection, driving behaviour analysis, multi-sensor reminder and warning, interactive suggestions and automatic assistance for parking are very common [7]. The system is able to process data and make decisions quickly when the environment around the car and the driver's emotions change during the driving process. The system should be compatible with different in-vehicle hardware and software platforms to ensure its suitability and applicability [5].

3.3. Analysis of regulatory systems

Through reviewing various literature as well as articles, it is known that most of the current intelligent cockpit driver emotion regulation systems are regulated in three major aspects: auditory, visual, and olfactory. Auditory interference to the driver is smaller than visual, but it has a greater impact on the evaluation of environmental comfort, and the emotional perception range is higher; the emotional perception range of visual is general; the interference degree and emotional perception range of olfactory are smaller, and it needs to be perceived gradually, as shown in Figure 2 [5].

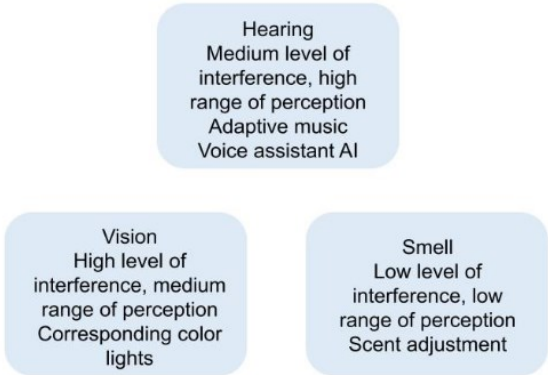

Figure 2. Characterisation and approach taken.

At present, the driver's emotion control system in the intelligent cockpit is mainly regulated through the three aspects of hearing, vision and smell. Auditory, the system creates a personalised driving environment by playing adaptive music and recommending appropriate tracks based on the driver's emotion and music genre. The built-in voice assistant uses empathy and encouragement to communicate with novice drivers, avoiding a "paternalistic" tone and enhancing driving confidence. The system monitors the driver's emotional state in real time, and does not intervene for "neutral" emotions. For emotions such as "excitement", "sadness", "anger", etc., the corresponding soothing music will be played until the emotions are stabilized [8].

Visually, changes in light colour can affect the driver's emotions. For example, blue and lake blue light can calm anger, while red light can ease sadness [6]. By using different light colours, the system can effectively regulate the driver's emotional state and enhance the driving experience [9].

In terms of smell, pleasant odours are able to increase hormone production, relieve fatigue and improve emotion by stimulating the cerebral cortex and modulating the central nervous system. Fragrances, such as peppermint, chamomile and bergamot, can significantly enhance subjective satisfaction and positive physiological responses and are considered to be effective emotion regulation tools [5]. Applying fragrance to the smart cockpit can create a comfortable environment and help drivers better manage their emotions.

4. Strengths and limitations of systems

This section summarises and compares the strengths and limitations of detection, decision-making, and regulation systems in smart cockpits, which excel in emotion recognition, environment regulation, and driver safety enhancement, respectively, but also face technical, cost, and privacy protection challenges.

4.1. Detection systems

4.1.1. Facial detection systems. Current mainstream facial detection systems mainly use 2D or 3D cameras (usually with infrared function) to achieve driver identification, fatigue detection and hazardous behaviour recognition, which are important components of Advanced Driver Assistance Systems (ADAS). 2D face recognition technology uses RGB cameras to capture a flat image of a face and compare it with a library of recorded images, which is a simple and low-cost algorithm, but its recognition accuracy is still limited even when supplemented with "live" detection. Although the algorithm is simple and the cost is low, the recognition accuracy is still limited, even if supplemented with "live" detection. In contrast, 3D face scanning technology is more advanced, with three main technologies: binocular recognition, 3D structured light and time of flight (TOF), as shown in Table 1.

Table 1. Three 3D face scanning technologies.

Camera Type	RGB Camera	Structured Light	TOF
Distance Measurement Method	Passive	Active	Active
Working Principle	RGB image feature point matching, triangulation distance calculation	Projecting structured light patterns, calculating the phase difference	Direct distance measurement based on the flight time of light
Measurement Accuracy	High accuracy at close range, reaching submillimeter precision	High accuracy at close range, reaching high precision (0.01mm-1mm)	Maximum accuracy reaching submillimeter precision
Measurement Range	Limited by the camera's depth of field, generally only measuring close-range distances, generally within 2m (baseline 10mm or less)	Generally within 10m	Measuring long distances, generally within 100m
Influencing Factors	No affection by changes in surface color or texture, affected by ambient light	No affection by changes in surface color or texture, affected by ambient light	No affection by changes in surface color or texture, affected by ambient light
Resolution	Medium to high	Medium	High
Frame rate	Low	Medium	High
Light resistance (principle Angle)	High	Medium	Low
Cost	Low	Medium	High
Computational Complexity	High	/	Low
Internal/External Parameter	Need	/	/

4.1.2. Facial detection systems. Xiao et al. proposed a feature fusion method combining bidirectional long- and short-term memory (Bi-LSTM) and CNN to combine spatial and contextual features of speech signals to improve the recognition accuracy of emotional features. Tests on the IEMOCAP dataset show that the unweighted accuracy of the method is 74.14% and the weighted accuracy is 65.62% [10]. Among them, Bi-LSTM is suitable for capturing long-term temporal relationships in sequences, while CNN focuses on causal modelling and is suitable for processing large-scale speech data.

4.1.3. Physiological Signal Detection System. Abdulhamit et al proposed an advanced machine learning method based on Flexible Analytic Wavelet Transform (FAWT) to detect driver fatigue state through single modal EEG signals and warn at an early stage in order to prevent risks [11]. Shitong Huang et al identified ECG indicators related to fatigue state through statistical analysis of HRV indicators and used k-Nearest Neighbor (KNN) algorithm to achieve fatigue state recognition [12].

4.1.4. Vehicle-based detection. Researchers have captured lane line image information by installing a miniature camera underneath the front of the vehicle to determine driver fatigue. Yoshiteru et al used particle filtering to detect lane changes and determine driving status [13]. Arthur et al used the statistical process control (SPC) method to monitor vehicle and driver behaviour by exponentially weighted moving average method to propose a lane deviation detection method [2]. Riera et al. identified driver fatigue state by monitoring lane deviation and judged whether the vehicle deviated from the lane or not based on the position of the centre of mass in the convex packet region.

4.2. Decision-making systems.

In recent years, based on the driver's real-time emotional state, the system can automatically adjust the in-vehicle environment (e.g., air conditioning, music, seats, etc.) to improve driving comfort. When the emotion is stable, the emotional decision-making system can provide optimal driving suggestions, such as optimising route choice and improving driving efficiency. Analysing the driver's emotions while the system is making decisions involves sensitive personal data and therefore requires strict data protection and privacy management measures. Emotional expressions vary across cultures, so the system needs to be adapted and optimised for different cultures to ensure recognition accuracy [14]. Emotional decision-making systems need to process and respond to emotional changes in milliseconds to ensure driving safety, but the current real-time processing capability still needs to be improved. Drivers' acceptance of system interventions may be inconsistent, and some drivers may feel uncomfortable with the system's frequent interventions, affecting the effectiveness of practical applications. The relationship between emotions and driving behaviours is complex, so more refined models are needed to accurately predict and analyse driving behaviours and make decisions accordingly. During a long period of driving, the driver's emotional state may change many times, and the emotional decision-making system needs to have the ability to adjust dynamically. The annotation of emotional data usually requires subjective judgement, which may lead to data inconsistency and annotation errors, thus affecting the model training effect. In addition, the emotional decision-making system needs to be seamlessly integrated with other vehicle electronic systems (e.g., autonomous driving system, navigation system, etc.) to ensure data sharing and collaborative work.

4.3. Regulatory systems

The Intelligent Cockpit Emotion Control System has significant advantages, and its core value is to bring unprecedented personalised experience and safety to the driver. The system can capture passengers' emotional fluctuations and intelligently adjust the interior environment, from music melodies to lighting colours to appropriate temperatures, every detail is designed to enhance passengers' comfort and satisfaction. More importantly, it constantly monitors the driver's emotional state, effectively preventing fatigue and distracted driving. In addition, the advanced technology and algorithms of the Smart Cockpit not only demonstrate the leap in the level of automotive intelligence, but also pave the way for the future of autonomous driving and intelligent travel [5]. At the moment of sharing the car, it can also recommend appropriate entertainment content according to the passenger's emotion, promote emotional communication, and make the journey warmer and more harmonious.

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However, intelligent cockpit emotion control systems also face limitations that cannot be ignored. Although they have made some progress in technology, their full popularisation still faces many challenges. The maturity of the technology needs to be improved, especially in the accuracy and stability of emotion recognition, and the algorithms and models need to be continuously optimised to ensure the reliability and accuracy of the system. At the same time, high R&D and production costs are an important constraint to market promotion, and these costs will ultimately be reflected in the price of the product, affecting consumers' purchasing decisions. In addition, the issue of user privacy protection should not be ignored. The emotional data collected by the system involves personal privacy, so how to ensure data security and prevent information leakage has become an urgent problem to be solved. What's more worrying is that the convenience brought by intelligence may breed potential safety hazards, such as drivers' over-reliance on smart cockpits leading to a drop in alertness, or in-vehicle entertainment features distracting attention and increasing the risk of accidents. Therefore, balancing intelligence and safety, and avoiding excessive trust and dependence of users, is an important issue for the future development of smart cockpit emotion control systems [8].

5. Growing trend

In recent years, driver emotion monitoring, decision-making and regulation systems in smart cockpits have made significant progress and become an important part of intelligent driving systems. These technologies rely on multimodal sensors and advanced algorithms, such as cameras, heart rate monitors, and galvanic skin response sensors, to collect physiological signals such as the driver's facial expression, heart rate, and galvanic skin response in real time. Through computer vision and deep learning algorithms, the system is able to accurately recognise the driver's emotional state, such as anger, fatigue and anxiety. The control technology then automatically adjusts the cabin environment, such as temperature, lighting and seat position, according to the emotional state to enhance driving safety and comfort [15].

With the development of artificial intelligence and big data technology, emotion monitoring systems are becoming increasingly intelligent and personalised. By analysing long-term driving data, the system can build a personalised emotion model for each driver and provide precise emotion regulation solutions. At the same time, the system combines with Telematics technology to achieve data sharing and collaborative control, further enhancing driving experience and safety. In automatic driving mode, the emotion monitoring system ensures that the driver maintains a good emotional state to enhance interaction and trust with the automatic driving system. Emotion monitoring and regulation systems in smart cockpits are developing in the direction of multimodal sensor fusion, personalised adaptive and Telematics integration to drive the overall progress of intelligent transportation.

6. Conclusion

Although current research has achieved certain results, there are still many pending problems and challenges in the driver emotion monitoring and regulation system based on intelligent driver assistance systems. Therefore, the emotion recognition technology should be improved in the future, which currently relies on the driver's physiological signals and behavioural performance. However, the accuracy and stability of emotion recognition still need to be improved because the driver's emotional state may be affected by a variety of factors, such as the driving environment and traffic conditions. In the future, the performance of emotion recognition can be improved by introducing more data sources and more advanced algorithms, such as deep learning and multimodal fusion. And combine the emotion regulation system with other intelligent driving assistance systems to achieve a more intelligent driving experience. Meanwhile, research on interdisciplinary integration is conducted, and the monitoring and regulation of driver's emotions involves a number of disciplinary fields, such as psychology, neuroscience, and computer science. Therefore, future research can strengthen interdisciplinary cooperation and communication, and jointly explore new methods and technologies for driver emotion monitoring and regulation.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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