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Current study on interaction design in automotive intelligent cockpit

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Abstract. In recent years, with the rapid development of Internet communication digital technology represented by artificial intelligence, Internet of Things, big data, the human-computer interaction of automobiles has also been further developed, showing a new look. As the main part of automotive interaction design, the digital, intelligent and Internet-oriented characteristics of intelligent cockpit are becoming increasingly obvious, especially in recent years, the intelligent cockpit design of new energy vehicles has broken the traditional interaction mode of automobile cockpit in the era of industrial machinery, and more intelligent and immersive interaction design is adopted. And the cockpit of the car not only has a single function for driving, but also provides a space for leisure and entertainment for the driver. Key technologies and design cases of cockpits and its interaction design were sorted out and summarized, and then the problems that cockpits interaction design faces and its future development were analyzed in this paper.

Keywords: Human Computer Interaction, Intelligent Cockpit, Driving Safety.

1. Introduction

The application and development of interaction design in the automotive intelligent cockpit have revolutionized the way we interact with vehicles. As cars become increasingly sophisticated and connected, the cockpit has evolved from a simple control panel to a complex interface that integrates various technologies to provide a seamless user experience and enhance driving safety. Interaction design plays a crucial role in shaping the user experience within the automotive intelligent cockpit. It focuses on designing intuitive and user-friendly interfaces that allow drivers and passengers to interact with the vehicle’s features, entertainment systems, navigation, communication, and more. By using technologies such as touchscreens, voice recognition, gesture control, and augmented reality, interaction design enables users to access and control a wide array of functions with ease. One of the key goals of interaction design in the automotive cockpit is to minimize driver distraction and ensure safety on the road. Designers strive to create interfaces that provide essential information and controls at the driver’s fingertips, reducing the need for them to take their eyes off the road. This involves careful consideration of visual hierarchy, simplification of menus and controls, and the use of voice commands and tactile feedback to enhance the usability of the interface. Furthermore, the development of interaction design in automotive cockpits is in tandem with advancements in artificial intelligence (AI) and machine learning. These technologies enable the cockpit to adapt and personalize the user experience based on individual preferences, driving patterns, and contextual data. For example, intelligent voice assistants can understand natural language and provide real-time assistance, while AI algorithms can learn from user behavior to anticipate their needs and provide relevant suggestions. The development of information technology and internet technology has driven digitalization and intelligent transformation in various fields. In the realm of transportation, the digitization and upgrading of intelligent in-car devices have allowed modern car users to experience more intelligent and boundary-pushing services within the vehicle space. Cars have evolved from being mere transportation tools in the past to becoming diversified spaces integrating driving, communication, entertainment, and information retrieval. In recent years, automotive manufacturers and technology companies have made significant investments in the development of intelligent cockpits. They are focused on creating seamless, connected experiences that integrate smartphones, wearable devices, and other smart technologies with the vehicle's cockpit. This convergence allows for a more integrated and personalized experience, enabling users to access their preferred apps, music, maps, and other services seamlessly while on the go.

In conclusion, the application and development of interaction design in the automotive intelligent cockpit have transformed the way we engage with vehicles. It empowers drivers and passengers with intuitive and personalized interfaces, enhances driving safety, and enables seamless integration with other smart devices. As technology continues to advance, we can expect further innovations in interaction design that will shape the future of automotive cockpits and elevate the overall driving experience

2. Intelligent cockpit in human-computer interaction

When talking about the development of intelligent cockpit in human-computer interaction, we can tell that as technology advances, the means of interaction are going through a series of innovation and creation, here's the development of the intelligent cockpit in human-computer interaction.

2.1. Touch interaction

Early center console screens only displayed radio information, and most of the area accommodated a large number of physical interaction buttons, which basically communicated with humans through tactile interaction [1]. Physical interaction buttons on vehicle's center console screen was shown in th Figure 1. As the development of the intelligence interaction, screens that are controlled by the center, and the touching bars begin to disappear on the monitor, and the screen is becoming bigger, which takes a more important place. Traditional buttons and physical controls are gradually being replaced by touchscreens and high-definition displays. These displays provide more information and functionality, and more intuitive control through touch operation.

Figure 1. Audi A8's central control button.

2.2. Automatic recognition and interaction

Wake-up methods for voice systems. The wake-up methods for voice interaction systems can be categorized into physical wake-up and voice wake-up. For automotive scenarios, physical wake-up involves placing physical buttons on the steering wheel or other convenient touch points. Users can simply press the button to wake up the voice system. Voice wake-up, on the other hand, requires the system to be configured with specific wake-up words. Users can speak the corresponding wake-up word to activate the voice system [2].

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Voice-controlled operation. Drivers and passengers can use voice commands to control vehicle functions such as adjusting navigation destinations, changing music, and answering or rejecting calls, without manually operating buttons or a touchscreen. By integrating voice recognition technology and artificial intelligence assistants, smart cockpits can provide intelligent conversations and personalized services. Drivers and passengers can use their voices to answer questions and answers with the cabin, and voice assistants can also learn user preferences and habits to provide more personalized recommendations and services.

2.3. Gesture interaction

Drivers and passengers can use gestures to control various functions of the vehicle, such as adjusting volume, changing music, answering calls, and more. For example, if the driver wants to adjust the volume, simply swipe up or down with a gesture without touching the control panel or pressing physical buttons. With the advancement of machine vision, intelligent cabin gesture recognition primarily relies on vision-based approaches, and several companies have already introduced related products. In 2015, BMW became the first company to introduce a gesture control system in the BMW 7 Series, as shown in Figure 2. For example, a simple mid-air click gesture allows the driver to answer phone calls. The latest generation of the BMW 7 Series offers 9 gestures in total, controlling 7 functions and 2 user customized functions. In a study conducted by Michael Geiger, in a driving simulation environment, the effects of tactile and gesture control modes on driver distraction during non-driving tasks were compared. The research findings indicated that using gesture control in cars can significantly reduce distractions [3].

Figure 2. Gesture interaction to answer the call [3].

2.4. Facial interaction

Facial interaction-based fatigue detection in automobiles is a method that utilizes tracking technologies such as facial expressions and head postures to detect and recognize the fatigue state of the driver. This technology employs in-vehicle cameras or sensors to monitor changes in the driver's facial expressions and head postures to determine their levels of attention and fatigue. Through facial expression recognition, the system can detect signs of fatigue driving, such as significantly reduced blink frequency, prolonged eye closure, and frequent yawning. Additionally, head posture recognition can monitor behaviors like head tilt and deviation from the normal driving position, further assessing whether the driver is in a fatigued state.

When the system detects signs of driver fatigue, it can initiate various warning measures, such as sounding audible alerts, providing vibration warnings, displaying reminder messages, or suggesting rest. These measures serve to remind the driver to take a break, thereby helping them avoid accidents caused by fatigue driving. The application of facial interaction-based fatigue detection in automobiles can significantly enhance driving safety. It assists drivers in timely recognizing and responding to the dangers of fatigue driving, reducing the occurrence of traffic accidents. Example of providing facial recognition, attention warning system of fatigue warning were shown in the Figure 3.

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Figure 3. Mercedes-Benz's latest S-Class glasses-free 3D instrument cluster camera provides facial recognition, attention warning system of fatigue warning.

3. The Technical and safety drawbacks

3.1. Technical drawbacks

3.1.1. Accuracy and reliability. One of the significant challenges with intelligent cockpits is ensuring accurate and reliable recognition and interpretation of voice commands. Speech recognition systems may struggle with understanding accents, dialects, or variations in speech patterns, which can lead to misinterpretation and errors in executing commands.

3.1.2. Ambient noise and disturbances. In noisy environments such as a moving vehicle, it can be challenging for speech recognition systems to isolate and accurately capture voice commands. Background noise and disturbances can interfere with the accuracy of speech recognition, affecting the overall performance of the intelligent cockpit.

3.1.3. Limited vocabulary and command variation. Intelligent cockpits typically have a predefined vocabulary and limited command variations they can understand and respond to. Users may face limitations in expressing commands or requests in their preferred language or phrasing, leading to reduced flexibility and potentially frustrating user experiences.

3.1.4. Privacy and security concerns. Data issues include data volume and data security issues. For multi-modal human-computer interaction in the intelligent cockpit, the data required is diversified, some of these functions such as face recognition, fingerprint recognition, voice dialogue, etc., need to collect data involving user security and privacy, how to ensure the recognition accuracy and not to collect information excessively, as well as data storage, access rights, are the current difficulties [4, 5].

3.1.5. Misoperation and improper use. Complex human-machine interfaces can cause drivers to make mistakes or misoperate during operation. For example, improper operation can lead to improper seat adjustment, opening the wrong function, or misoperating the vehicle control system. This can have an impact on driving safety and the safety of occupants of other vehicles. Therefore, the design of the human-machine interface should focus on simplicity, ease of use, and consider measures to prevent misoperation, such as confirmation prompts and safety restrictions for control settings.

3.2. Safety drawbacks

Distract the driver: While intelligent cockpit systems can provide a wealth of features and information, drivers can be distracted while using these features. For example, touchscreens and complex menu structures may require drivers to stare at the screen for long periods of time instead of focusing on the

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road. This can increase the risk of accidents for drivers. Therefore, when designing the human-computer interaction interface, attention should be paid to simplifying the operation process and optimizing the interactive experience to reduce the interference to the driver.

4. Discussion

4.1. The advantages of the intelligent cockpit in human-computer interaction

Improved human-machine interfaces make it easier for drivers to control cabin functions. Technologies such as touchscreens, voice control, and gesture recognition simplify the operation process, allowing drivers to adjust settings such as seating, music, and temperature more quickly without becoming too distracted. This effective human-machine interaction design enhances driver safety by reducing driver distraction, improving focus and reflexes, and reducing the potential risk of accidents. Additionally, these improved interfaces provide richer information and functionality. Drivers can access multiple functions such as navigation, entertainment, communication, and vehicle information through touchscreen or voice control. This convenience allows drivers to better understand road conditions, access the information and services they need, and improve the comfort and efficiency of their travel.

4.2. Improvement

4.2.1. Introduce natural language interaction. Integrate voice recognition technology to allow drivers to interact with the vehicle using natural language, such as controlling cabin functions and adjusting navigation destinations. This would make operations more intuitive and convenient, reducing the risk of driver distraction [3].

4.2.2. Enhance gesture recognition technology. Set a threshold speed: First of all, setting an threshold value, determine an appropriate speed threshold to differentiate intentional actions from accidental actions. Generally speaking, intentional actions have noticeably higher speeds than accidental actions, so gestures that exceed the threshold can be considered intentional. And, comparing the current gesture speed with the previous gesture speed. If the current speed is significantly higher than the previous speed and exceeds the set threshold, it can be judged as an intentional action. This method captures the trend of speed changes to determine the intention behind the gesture. And setting a time window to monitor the gesture speed within that window. If the gesture speed remains consistently high throughout the entire time window, it can be judged as an intentional action. Conversely, if the gesture speed fluctuates or changes minimally within the time window, it can be deemed as an accidental action. This method observes the continuity of speed to assist in determining the intention behind the gesture.

By utilizing these methods, you can establish suitable thresholds and time windows based on the specific application scenario and characteristics of the gestures. These methods can help identify the intention behind the gesture, distinguishing intentional actions from accidental actions.

The flow of detecting gesture speed system was shown in the Figure 4.

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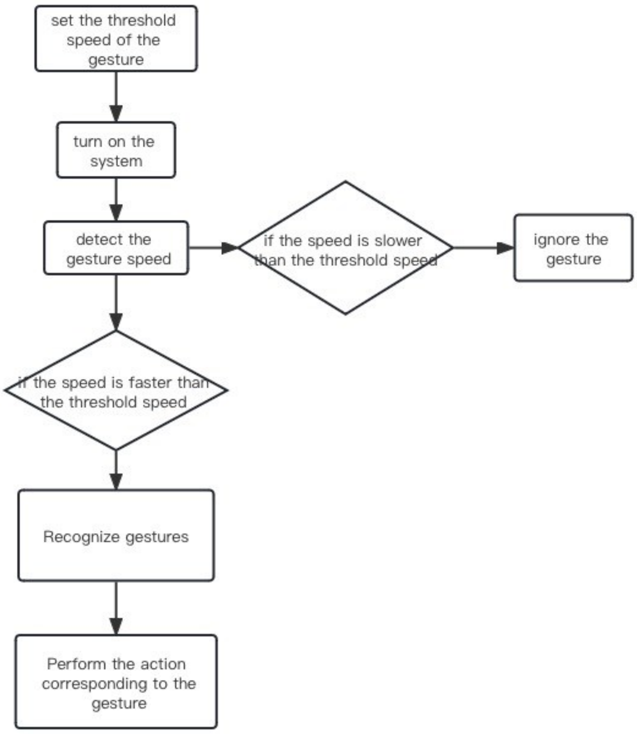

Figure 4. Flow for detecting gesture speed.

4.2.3. Provide personalized choices. Offer customized user interfaces to allow drivers to personalize their frequently used functions and preference settings. For example, creating some shortcut keys which can change the channel and turn up the volume at the same time. This can improve user satisfaction and better cater to the needs of individual drivers.

4.2.4. Improve the accuracy of automatic speech recognition. Tomoko Kawase et al. developed a novel system by automatically adjusting the front-end speech enhancement to maximize the accuracy of a given ASR engine. A genetic algorithm (GA) was used to generate parameter values for the front-end speech enhancement for a given environment [6]. This system will reduce the disturber of the noise when using the automatic speech recognition system.

4.2.5. Improve the accuracy of identifying the position of the speaker
With the use of Deep Feed forward Networks (DFNs) and Recursive Neural Networks (RNNs) in the field of Natural Language Processing (NLP), the long short-term memory (LSTM) capabilities of speech dialogue systems have been improved, leading to an enhancement in their intelligence level.In 2018, iFlytek introduced a new generation of intelligent voice control systems at CES, featuring three major characteristics: narrow-beam, sound source localization, and stereo echo cancellation. Among them, the narrow-beam technology reduces background noise interference, especially in car driving scenarios. The sound source localization system quickly and accurately identifies the position of the speaker, enhancing the user experience [7].

4.3. Prospect
With the rapid development of internet technology and the automotive industry, the integration of intelligent cabins has become a major selling point for many vehicles. The goal of human-machine interaction in smart cabins is to create a personal assistant that deeply understands the driver and passengers and can meet their driving and non-driving needs. As the demand for interactions within the

cabin increases and technology advances, multi-modal interaction is becoming mainstream, and multi-modal human-machine interaction is evolving towards the following trends[8]: 1) Fusion of Different Modalities: Different modalities will merge to improve the effectiveness and comfort of interactions. For example, the fusion of auditory and visual modalities can enhance the overall experience[9]. 2) Advancements in Voice Interaction: Voice interaction is receiving significant development, making the voice intelligence inside the cabin closer to human-like capabilities. The progress in natural language processing technology allows voice assistants to understand increasingly complex commands[10]. 3) Rapid Development of Gesture Recognition: Gesture recognition interactions are rapidly advancing, with improved accuracy and speed. This enables intuitive and convenient control of various functions within the cabin. 4) Rapid Development of Facial Recognition: Facial recognition technology is progressing rapidly, allowing the system to identify driver fatigue based on facial expressions and other cues. This helps enhance driving safety by alerting the driver when they may be experiencing fatigue.

These trends signify the ongoing evolution of intelligent car cabins towards more advanced and intuitive human-machine interactions, improving the overall driving experience and safety for drivers and passengers alike.

5. Conclusion

The intelligent car cabin serves as the interface between the driver and the vehicle, playing a crucial role in completing driving tasks. It is not only a space for driving operations but also carries vehicle information display and interaction functions. From an industrial design perspective, the design quality of the car cabin directly affects the user's experience and satisfaction. With the continuous development of intelligent car technology, cabin design has undergone a series of evolution. From traditional physical button-based interactions to the current full touchscreen and digital interactions, there have been significant changes in the information layout of intelligent cabins. This change has not only altered the way users interact with the cabin but also had a profound impact on human-machine interaction behavior and driving behavior. Against this backdrop, this article discusses the technological developments in human-machine interaction aspects of intelligent car cabins. With the widespread adoption of touch and digital interactions, drivers can operate and control the cabin through touch screens, voice assistants, gesture recognition, and other methods, providing more functionalities and interaction choices. Such developments bring about a more flexible and personalized driving experience for drivers. However, intelligent cabins also have drawbacks and safety concerns during their technological development. In order to improve the technological shortcomings of intelligent cabins and enhance driver safety and driving experience, this article proposes three methods to enhance driving safety and satisfaction.

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