Scalable Computing: Practice and Experience, ISSN 1895-1767, http://www.scpe.org
© 2024 SCPE. Volume 25, Issues 5, pp. 3572–3579, DOI 10.12694/scpe.v25i5.3169

HUMAN-COMPUTER INTERACTION INTERFACE DESIGN IN THE CAB OF NEW ENERGY VEHICLES

YANXUE ZHANG*, NANMEI ZHANG†, HUI YANG‡, AND YANYU REN§

Abstract. A new energy vehicle cab control platform based on human-computer interaction is proposed from control device design and control signal acquisition design. A driving mode conversion algorithm based on the threshold is combined with the existing intelligent vehicle driving mode conversion. The MATLAB and Python hybrid program is used to realize the simulation experiment of the driving control algorithm of new energy vehicles. The system can conduct interactive simulations of various typical driving scenarios. Data acquisition and dynamic display functions can present the operating status of new energy vehicles most directly and efficiently. The system can integrate and intelligently process vehicle driving data, road environment data and external data from multiple dimensions of the "vehicle-road-network". The experimental results show that the system enhances the user experience of new energy vehicles and improves the efficiency of human-computer interaction.

Key words: New energy vehicles; Data accommodation; Autonomous collection; Human-computer interaction; Automatic driving

1. Introduction. In the face of energy shortages in all countries, the development of new energy vehicles has become the future direction. Because its energy supply system is different from conventional vehicles, it belongs to a new stage of transformation from electromechanical equipment to electronic equipment, so the design of human-machine interfaces for electric vehicles will also change. For example, the dashboard occupies less and less area, rather than being limited to the conventional form of multiple dashboards combined [1]. Drive-by-wire technology the instrument display architecture of electric vehicles is more diverse. Electronic LCDS can also be used to replace conventional vehicle dashboards. Therefore, human-computer interaction is a significant work when the vehicle is moving. The instrument panel interface of the electric vehicle contains the speed display, remaining power display, mileage display, and a variety of driving state displays [2]. Reasonable arrangement and design of these information interfaces is the key to the interactive interface experience of the instrument panel of electric vehicles. The instrument panel is the essential carrier and communication window for the communication between people and vehicles while driving electric vehicles, and its use experience directly affects whether the information transmission between people and vehicles is friendly, visible, controllable and operable [3]. To achieve the best user experience is the ultimate goal of human-computer interface design. The user interaction experience is a way to take the user's needs as the key and then translate them into the product image. It needs to meet the following points: the human-machine interface is easy to use, and you can learn to use it without particular research; The interface elements and shape model can intuitively reflect the functional characteristics and operation mode of the system, which can conform to the user's natural usage habits. The graphic logo used in the interface should be consistent with the standardization and beauty of the interface elements. The operation and display of the interactive interface should be coordinated, and the human-machine interaction design can be differentiated for different user types. This provides precise operational instructions to various users. At the same time, it can avoid the wrong operation and ensure the safety of the man-machine interface. This paper first studies the trajectory tracking control algorithm of autonomous driving of new energy vehicles. Construct a new energy vehicle driving simulation experiment

*School of Intelligent Manufacturing, Anhui Wenda University of Information Engineering, Hefei, 231201, China (Corresponding author, btboa005@163.com)
†School of Intelligent Manufacturing, Anhui Wenda University of Information Engineering, Hefei, 231201, China
‡School of Intelligent Manufacturing, Anhui Wenda University of Information Engineering, Hefei, 231201, China
§School of Intelligent Manufacturing, Anhui Wenda University of Information Engineering, Hefei, 231201, China

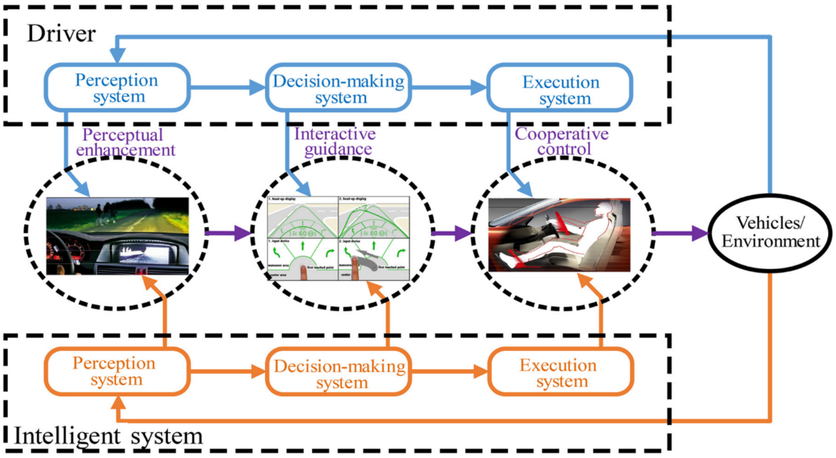

Fig. 2.1: *Hardware architecture of human-computer interaction system for autonomous driving of new energy vehicles.*

platform based on multi-modal information [4]. Under extreme conditions, it will lay a foundation for vehicle performance analysis and human-vehicle-environment interaction research.

2. Human-machine interaction requirements for driving new energy vehicles.

2.1. Physical Requirements. The human-computer interaction platform for intelligent management and control of new energy vehicles adopts a hierarchical structure composed of three levels: vehicle terminal, road test equipment/edge control unit, and intelligent management and control cloud platform [5]. Build an intelligent network-connected vehicle cloud platform that integrates "human-vehicle-road-network-cloud." Multi-mode communication networks such as 5G are supported on the network to achieve high-speed, low-latency data access and information transfer between vehicles, roadside devices and the cloud. Realize real-time scheduling and network management in specific unmanned driving application scenarios to ensure network security [6]—construction of traffic network architecture system to realize vehicle-road cooperation. Achieve effective vehicle-device-data collaboration. To realize the central scheduling and multi-objective optimal control for all sections and regions.

The comfort problem in the interactive simulation system of driver operation is systematically studied based on the actual vehicle driving situation. While ensuring the accuracy of data signal acquisition as much as possible, people pay more attention to the actual driving experience [7]. The steering wheel and seats are the same material as the vehicle. The clutch, throttle, and brakes are identical to the actual vehicles. In the autonomous driving mode, the design of the autonomous driving mechanism and the transformation of the driving mode are mainly studied [8]. The overall architecture composition of the system is shown in Figure 2.1 (the picture is quoted in IET Intelligent Transport Systems, 2019, 13(6): 960-966).

The platform operating equipment operates the manual driving mode, and the obtained detection information is transmitted to the signal acquisition board [9]. Through the collection and processing of the data, the data is finally transmitted to the computer. In the process of autonomous driving through the operation interface, the vehicle can dynamically adjust the driving path during the driving process. These two driving modes can complete the vehicle's driving simulation, laying a solid foundation for future intelligent research.

2.2. Functional Requirements.

2.2.1. Data integration and intelligence services. Eventually, multiple industry interconnection standards related to the vehicle will be formed, covering all scenarios of the entire intelligent network travel. Standardize information exchange among all links of the travel ecosystem, such as vehicles, traffic, roads, first aid, and meteorology [10]. To create an autonomous and controllable industrial environment for intelligent travel.

Multi-source information is integrated by establishing multi-source information such as road equipment status, road traffic events, and road traffic participants. The vehicle-cloud communication protocol consists of MQTT and TCP channels. Through the way of business reservation, it can realize dynamic lane planning, traffic control information, traffic speed limit information, real-time traffic flow prediction, dangerous road condition reminder, real-time status of signal light, future status of signal light, meteorological reality, conventional weather forecast, catastrophic weather warning, minute level precipitation forecast, parking lot information and other functions.

2.2.2. Real-time monitoring of road network. The lane and lane-level congestion operating conditions on both sides of the road are collected. Collect abnormal conditions such as landslides and large pits on the road surface [11]. Collect traffic lights, speed limits, road hazards, and other information. Browse the car accident list and display the information on the electronic map. The data on road construction and temporary traffic control are collected to realize real-time monitoring of vehicle collisions. The functions of "parking," "right turn," and "acceleration and deceleration" are realized. It can publish traffic events such as road congestion, traffic accidents, construction, temporary road closures and other information [12]. In-depth mining and analysis are carried out to build decision support for driving behavior management, traffic situation monitoring, road network optimization and other aspects combined with the historical data of vehicle-road integration.

3. Overall technical framework of the platform. "Vehicle-road-network" intelligent vehicle control cloud platform for cross-scale real-time monitoring, intelligent decision-making and collaborative control. Intelligent control cloud platform is the center of intelligent road networking cloud computing and the hub of data collection, processing, integration and application [13]. It can capture, convert, process and store advanced information in real-time from driverless vehicles, intelligent connected vehicles, facilities and roadside sensing. The integration of new energy vehicle driving information is achieved through the integration, fusion, and analysis of these data. The human-computer interaction platform combines modern cloud storage, cloud computing, big data, 5G, holographic intelligent perception, data communication transmission, electronic control and computer processing and other technologies into the system [14]. The overall technical architecture of the intelligent management and control cloud platform is shown in Figure 3.1 (the picture is quoted in the Novel ITS based-on Space-Air-Ground collected big-data).

The construction of the human-computer interaction architecture of mobile edge computing centers can reduce the signal delay in the automatic driving mode of new energy vehicles. At the same time, it can give full play to the geographical coverage characteristics of edge computing networks and support the cooperative operation of vehicles and roads with regional characteristics. The Computing architecture of human-computer interaction cloud-edge collaboration for new energy vehicles is shown in Figure 3.2 (the picture is quoted in Vehicular Edge Computing and Networking: A Survey).

3.1. Control signal acquisition. The joystick collects and processes this information in real-time as a critical component linking the platform control equipment to the computer simulation. The selected data acquisition board comprises 16 digital input modules and eight analog input modules and is interfacing with the simulation computer through RS232 serial communication, which can well meet the driving and signal acquisition requirements on the analog platform [15]. The communication module processes the signal received by the control device to realize the connection and data transmission with the vehicle vision. Using serial communication technology and the MSComm control program, the time class of serial communication is set to record and collect data in real time. Its control signal is the throttle, brake, steering, brake, and so on for its input. When the sensor installed on the vehicle body sends out the corresponding change, it will cause a change in the displacement, angle, and other electrical signals connected to it. According to the dynamics model of the vehicle, it is processed, and the environment is monitored in real-time.

3.2. Driverless. The system comprises steering wheel control, throttle control and brake control. The steering system mainly comprises the steering servo motor, the universal joint, and the relevant parts between the universal joint and the steering shaft. To facilitate and accurately control the brake and accelerator and ensure that the driver's brake and accelerator will not be interfered with under manual driving mode, a rolling screw sliding platform is specially selected to pull the brake and accelerator pedals [16]. The ball screw can make the rotation linear. The measured travel of the accelerator pedal and the brake pedal is 80 mm, and the

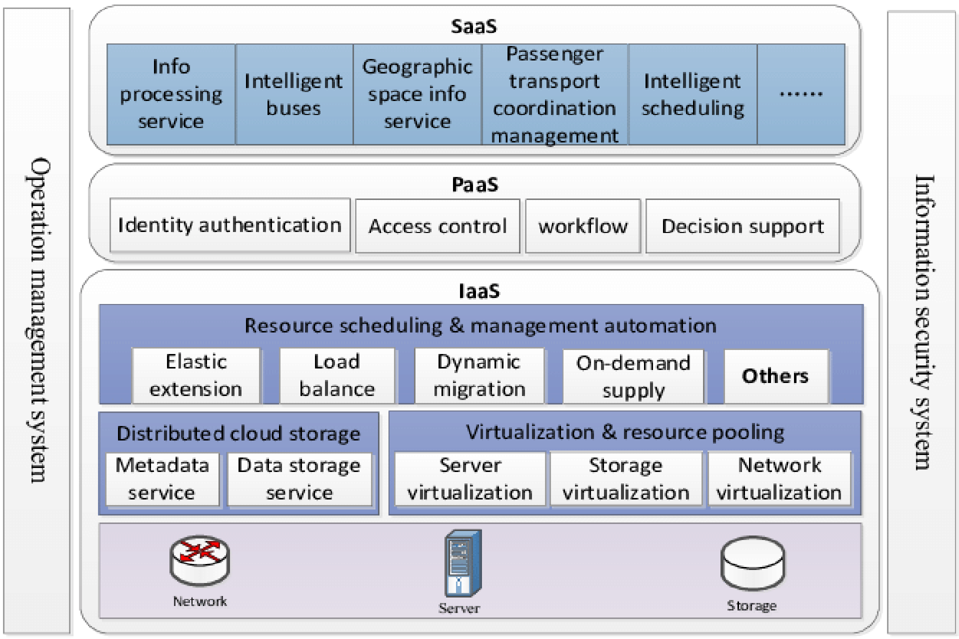

Fig. 3.1: *New energy vehicle driving interactive platform system architecture.*

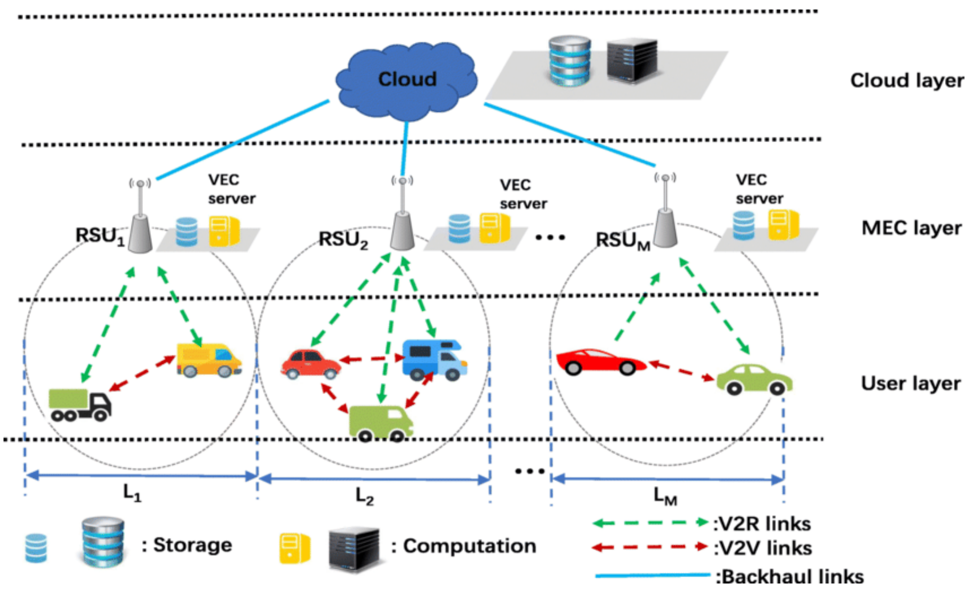

Fig. 3.2: *Computing architecture based on cloud edge collaboration.*

travel of the brake pedal is 90 mm, where the travel is the length required from the release of the pedal to press the drag chain fully. Through the motion control card to complete the mode of autonomous driving, the motion control card is used to transmit the real-time pulse signal to the servo motor, and then the received pulse signal starts rotating to make the slider rod on the lead screw move. Then, drive the platform for steering, acceleration, deceleration and other actions. In the driverless mode, the user can write the vehicle's trajectory tracking function into the motion control card for various simulation situations. Let the motion control card perform the corresponding driving action according to the route.

4. Adaptive cruise control algorithm. The combination of PC and low-level hardware is used to collect and process the vehicle distance in front of the vehicle. Pass the desired acceleration command to the underlying device [17]. The onboard sensor at the bottom of the vehicle collects all the information needed when driving, and the motor completes the action, such as an accelerator and brake, to complete the vehicle's driving. The car must be well-spaced during the journey. Use the front distance to determine the optimal workshop distance:

$$y_{a,y}(x) = \tau_2 u_l(x) + y_{a,0}$$

τ_2 is the distance between cars ahead. $y_{a,0}$ represents the safe distance between parked vehicles. The state quantity $\gamma(x) = [e(x), u_a(x), \delta_l(x), w(x-1)]^T$ of the system is defined. An interference observer that can accurately estimate the system is proposed.

$$\begin{cases} \gamma(x+1) = \lambda\gamma(x) + \eta_w \Delta w(x) + K_\gamma(p(x) - \hat{p}(x)) + \eta_s s(x) \\ p(x) = \mu\gamma(x) \\ \omega(x+1) = Z\omega(x) + K_s(p(x) - \hat{p}(x))s(x) \\ s(x+1) = U\omega(x) \end{cases}$$

$e(x), u_a(x), \delta_l(x), w(x)$ is the distance deviation between vehicles at the time x, the relative speed of vehicles, the acceleration of vehicles, and the acceleration command. The state variables formed by it conform to:

$$\gamma(x) \in \Gamma, \forall x = 0, 1, \cdots$$

$$\Gamma = [-\tau_2 u_{l,\max}] \times [u_{a,\min}, u_{a,\max}] \times [\delta_{l,\min}, \delta_{l,\max}] \times [w_{\min}, w_{\max}] . \lambda, \eta, \mu, Z \text{ and}$$

U are constant matrices. K_γ, K_s is the gain of the observatory. $p(\gamma)$ and $\hat{p}(\gamma)$ represent the calculated deviation of workshop spacing and the actual deviation. The acquisition of $\hat{p}(\gamma)$ is detected by sensors on the car to obtain real-time data. s is an input of uncertain bounded interference. Use $\Delta w(x) = w(x) - w(x-1)$ to determine the incremental control input. Through vehicle networking communication and interaction between participants, perception and control of complex scenes are realized. The requirements for traceability and multiple economic objectives required in driving are given.

$$\begin{aligned} K_1(\gamma(x)) &= z_e\gamma_1^2(x) + z_u\gamma_2^2(x) \\ K_2(\gamma(x)) &= z_\delta\gamma_3^2(x) + z_{\delta c}\gamma_4^2(x) \\ K_3(w(x)) &= z_{sw}\Delta w^2(x) \end{aligned}$$

z_e, z_u, z_δ and z_{sw} are the weight factors corresponding to vehicle time error, speed error, acceleration and acceleration instruction in vehicle-road cooperative driving. It indicates the importance of each indicator. The following are sorted out and combined with the proposed performance indicators:

$$H(\gamma, \Delta w) = \sum_{i=0}^{j-1} \left\{ \gamma^T(i \mid x) Z_\gamma(x) \gamma(i \mid x) + z_{sw} \Delta w^2(i \mid x) \right\}$$

The state matrix is represented by $Z_\gamma = \operatorname{diag}\{z_e, z_u, z_\delta, z_{sw}\} .p$ is the predicted time interval. There exists $[x, x+j](x = 0, 1, \text{ L})$ in the control time domain of model predictive control. The vehicle acceleration parameter $\Delta w(i \mid x)$ is parameterized as follows:

$$\Delta w(i \mid x) = \varphi^i \Delta w(0 \mid x), i = 1, 2, \text{ L}, j-1$$

$i \mid x$ refers to the future value predicted for $x + i$ at sampling time x. And the compliance coefficient φ, appropriate to $[0, 1]$, is a parameter used to adjust the smooth output. Due to the high computational complexity

Table 5.1: *Test parameters of simulation test.*

Argument	Default value
Scene size /m x m	3000×3000
Simulation time /h	24
Node communication radius /m	150
Message size /Mb	5
Message generation interval /s	510
MAC layer protocol	IEEE802.11p
Application layer data flow	CBR
Transmission model	Two Ray Groun

of model prediction, its application is restricted, so the control sequence $\Delta w(i \mid x)$ is parameterized by the current decision variable $\Delta w(0 \mid x)$. This can be compensated by increasing the step size of the prediction time domain j, because a more significant value of j can lead to better performance. When the control gain of an interval $\Delta \bar{w}_{\min}(x) \leq \Delta w(x) \leq \Delta \bar{w}_{\max}(x)$ is given, the physical properties and driving comfort of the vehicle are considered comprehensively. The constraint is:

$$\begin{cases} \Delta \bar{w}_{\min}(x) = \max \left\{ \Delta w_{\min}, \left(w_{\max} - w(x-1)\right) / \sum_{i=0}^{j-1} \varphi^i \right\} \\ \Delta \bar{w}_{\max}(x) = \min \left\{ \Delta w_{\max}, \left(w_{\min} - w(x-1)\right) / \sum_{i=0}^{j-1} \varphi^i \right\} \\ \gamma(i \mid x) = \lambda^i \gamma(0 \mid x) + \\ \sum_{j=1}^{i} \varphi^{i-j} \lambda^{j-1} \eta_w \Delta w(0 \mid x) \\ + \sum_{j=1}^{i} \alpha^{i-j} \lambda^{j-1} \Delta \hat{p}(0 \mid x) \\ + \sum_{j=1}^{i} \lambda^{j-1} \eta_s \hat{s}(i-j \mid x) \end{cases}$$

Since neither the present nor the future disturbance $s(i-j \mid x)$ is known, and the values of past disturbances at various times are used as present forecasts, there is $s(j-j \mid x) = s(x-1), j = 1, 2, \ldots, j$.

5. System inspection. The open-source highway traffic simulation programs SUMOSUMOs and NS 3 are tested and studied. The actual mathematical model of vehicle driving is established using the SUMO method. Use NS 3 to simulate packets' transmission success rate and average transmission delay with different nodes and TTL values. The test was conducted on Ubuntu16.04. The test parameters of the simulation test are shown in Table 5.1. The scenario and operation of the simulation test are shown in Figure 5.1 (the picture is quoted in System architecture for installed-performance testing of automotive radars over-the-air).

The simulation of transmission success rate under different node motion rates is shown in Figure 5.2. When the transmission rate is not high, the system's topology will change slowly, and the communication connection is relatively smooth. When the network transmission rate increases, the instability of the link will decrease, and the transmission success rate of various methods will decrease. At the same time, RSSM can dynamically adjust according to the change in network topology caused by fast movement to ensure the transmission channel's maximum connectivity and improve the transmission success rate.

6. Conclusion. Interaction mode selection, information identification, multi-purpose design and beautiful appearance design will all impact the interactive experience of new energy vehicle users. The purpose of this study is to discuss how to overcome the difficulties and satisfaction of the users in the human-machine interaction design of new energy electric vehicles from the theoretical and practical aspects. The acquisition of operation equipment and signals is studied under manual driving of new energy vehicles. The design of the electric control circuit is proposed, and the main parts and electrical components are selected and tested. It has been found that the system can reproduce the whole car process in real-time through human-computer interaction.

7. Acknowledgements. The work was supported by the Anhui Wenda University of Information Engineering Natural Science Research Project "Research on Human Machine Intelligent Interaction System for New Energy Vehicles" (Project Number: XZR2023A02).

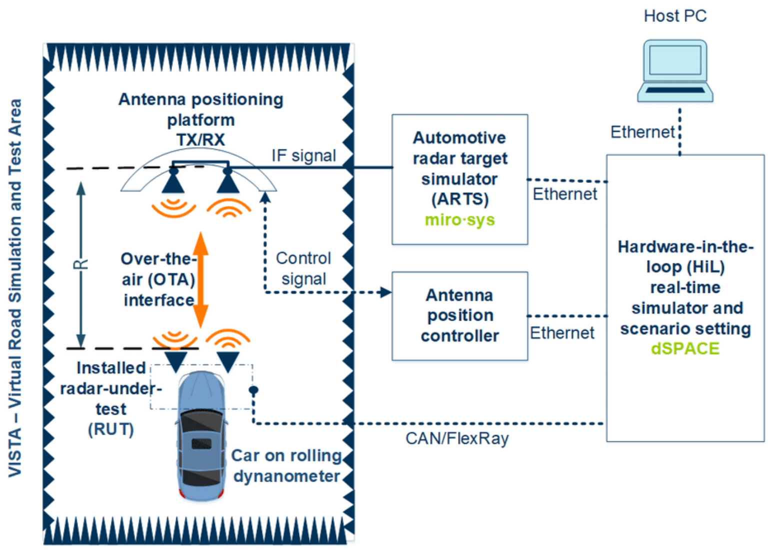

Fig. 5.1: *Operating diagram of simulation test.*

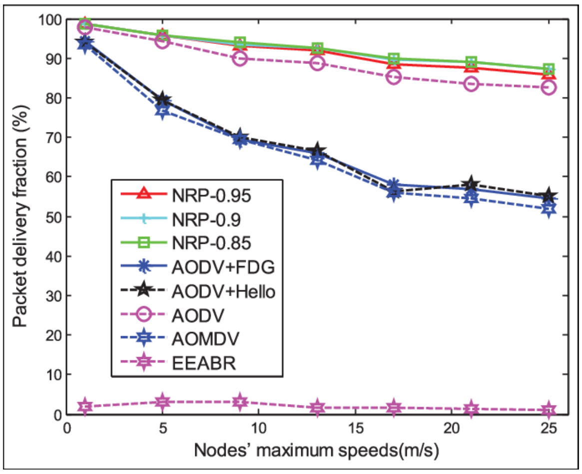

Fig. 5.2: *Simulation of the relationship between network node rate and delivery success rate.*

REFERENCES

[1] Shneiderman, B. (2020). Human-centered artificial intelligence: Reliable, safe & trustworthy. International Journal of Human–Computer Interaction, 36(6), 495-504.

[2] Detjen, H., Faltaous, S., Pfleging, B., Geisler, S., & Schneegass, S. (2021). How to increase automated vehicles' acceptance through in-vehicle interaction design: A review. International Journal of Human–Computer Interaction, 37(4), 308-330.

[3] McDonnell, A. S., Simmons, T. G., Erickson, G. G., Lohani, M., Cooper, J. M., & Strayer, D. L. (2023). This is your brain on Autopilot: Neural indices of driver workload and engagement during partial vehicle automation. Human factors, 65(7), 1435-1450.

[4] Bindhu, V. (2020). An enhanced safety system for auto mode E-vehicles through mind wave feedback. Journal of Information Technology, 2(03), 144-150.

[5] Dargahi Nobari, K., Albers, F., Bartsch, K., Braun, J., & Bertram, T. (2022). Modeling driver-vehicle interaction in automated driving. Forschung im Ingenieurwesen, 86(1), 65-79.

[6] Wang, X., Zheng, X., Chen, W., & Wang, F. Y. (2020). Visual human–computer interactions for intelligent vehicles and intelligent transportation systems: The state of the art and future directions. IEEE Transactions on Systems, Man, and

Cybernetics: Systems, 51(1), 253-265.
[7] Tan, H., Sun, J., Wenjia, W., & Zhu, C. (2021). User experience & usability of driving: A bibliometric analysis of 2000-2019. International Journal of Human–Computer Interaction, 37(4), 297-307.
[8] Wintersberger, P. (2023). Team at Your Service: Investigating Functional Specificity for Trust Calibration in Automated Driving with Conversational Agents. International Journal of Human–Computer Interaction, 39(16), 3254-3267.
[9] Sevcenko, N., Appel, T., Ninaus, M., Moeller, K., & Gerjets, P. (2023). Theory-based approach for assessing cognitive load during time-critical resource-managing human–computer interactions: an eye-tracking study. Journal on Multimodal User Interfaces, 17(1), 1-19.
[10] Qian, X., Ju, W., & Sirkin, D. M. (2020). Aladdin's magic carpet: Navigation by in-air static hand gesture in autonomous vehicles. International Journal of Human–Computer Interaction, 36(20), 1912-1927.
[11] Miller, L., Kraus, J., Koniakowsky, I., Pichen, J., & Baumann, M. (2023). Learning in Mixed Traffic: Drivers' Adaptation to Ambiguous Communication Depending on Their Expectations toward Automated and Manual Vehicles. International Journal of Human–Computer Interaction, 39(16), 3268-3287.
[12] Le Guillou, M., Prévot, L., & Berberian, B. (2023). Bringing together ergonomic concepts and cognitive mechanisms for human—AI agents cooperation. International Journal of Human–Computer Interaction, 39(9), 1827-1840.
[13] Zhou, F., Yang, X. J., & Zhang, X. (2020). Takeover transition in autonomous vehicles: A YouTube study. International Journal of Human–Computer Interaction, 36(3), 295-306.
[14] Wang, D., Yin, G., & Chen, N. (2021). Optimisation of dynamic navigation system for automatic driving vehicle based on binocular vision. International Journal of Industrial and Systems Engineering, 39(3), 411-428.
[15] LUO, W., CAO, J., ISHIKAWA, K., & JU, D. (2021). Experimental Validation of Intelligent Recognition of Eye Movements in the Application of Autonomous Vehicle Driving. International Journal of Biomedical Soft Computing and Human Sciences: the official journal of the Biomedical Fuzzy Systems Association, 26(2), 63-72.
[16] Hancock, P. A. (2022). Avoiding adverse autonomous agent actions. Human–Computer Interaction, 37(3), 211-236.
[17] Riegler, A., Riener, A., & Holzmann, C. (2021). Augmented reality for future mobility: Insights from a literature review and hci workshop. i-com, 20(3), 295-318.

Edited by: Zhigao Zheng
Special issue on: Graph Powered Big Aerospace Data Processing
Received: Jan 9, 2024
Accepted: Feb 3, 2024