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RESEARCH ARTICLE

DESIGN OF UNIVERSAL CHASSIS SYSTEM BASED ON DIGITAL TWIN AND INTERNET OF VEHICLES

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ABSTRACT

With the development of the electric vehicle consumer market, the Internet of vehicles technology, as an important branch of the Internet of things, is developing rapidly. Due to technological and economic progress, and the development of electrification, networking, and intelligence in the automotive industry, vehicle operation and maintenance methods are being gradually upgraded from traditional "fault maintenance" and "regular maintenance" to "conditional maintenance" and "regular maintenance". Preventive maintenance". Digital twin technology integrates real-time sensing data, mechanism models, historical information and other data for high-precision analysis and calculation, which can realize high-precision, high-efficiency, high-reliability mapping, and evolution of physical entities. This article is based on the equipment layer, the transmission layer, the application layer as the starting point, the design and development of the electric vehicle chassis system combined with the in-wheel motor technology, ZIGBEE wireless transmission, vehicle failure and health management and other technologies, integrating the intelligent operation and maintenance system based on Web3D, WebGL, Threejs and other technologies, design a vehicle chassis control system based on the Internet of Things technology with digital twin intelligent operation and maintenance functions. The system can visualize the data in the 3D model of the vehicle and perform health management based on the data uploaded by the Internet of vehicles in real time. Users can also interact with the vehicles are operated as an excellent solution for Internet of Vehicles security.

KEYWORDS

Fault warning; digital twin; intelligent operation and maintenance; Internet of vehicles; new energy electric vehicles.

1. Introduction

With the increasing awareness of international environmental protection, problems such as environmental pollution and energy shortage caused by fuel vehicles have become more and more prominent. The new energy electric vehicle industry has entered a stage of rapid development, and the number of electric vehicles in the world has continued to increase (Wu, 2022; Wang et al., 2020). According to the current research on the safety of electric vehicles, most car owners are not accurate enough to recognize and judge the faults of electric vehicles and cannot carry out large-scale repairs and in-depth maintenance of vehicles in a timely manner. The existing remote diagnosis of electric vehicles on the market the system cannot ensure the real-time safety of the vehicle itself (Steinmetz et al., 2021). In addition, there are very few internet of vehicles application systems with real-time vehicle condition display and fault diagnosis functions, and very few vehicle visualization platforms that can display real-time information to people (Wang, 2015; Popa et al., 2023).

Based on the actual needs, to accurately and timely diagnose electric vehicle faults and assist the owner in the repair and maintenance of the vehicle, the visual interactive system and wireless transmission technology is used to integrate intelligent operation and maintenance based on digital twin and Internet of Things technology. The system's electric vehicle chassis realizes remote vehicle monitoring and fault diagnosis, which is the solution to the problem proposed by this design.

2. System Framework

The framework of the vehicle intelligent chassis operation and maintenance system based on digital twins is shown in Figure 1. It is mainly composed of three layers, the interface layer, the transport layer, and the application layer. Real-time and efficient data and information between layers is realized through service interfaces and transport protocols. Interaction, each module operates in coordination and closed-loop feedback, to realize visual remote vehicle monitoring and fault diagnosis.

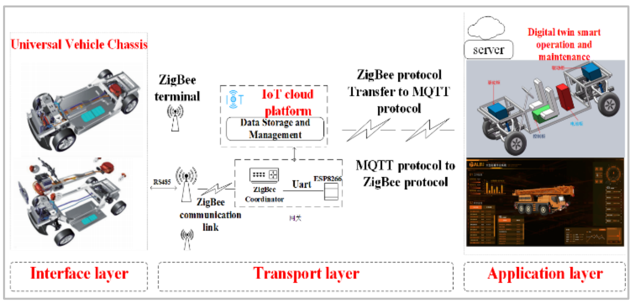

Figure 1: System framework diagram

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3. Design Scheme

The system solution framework is divided into three parts, electric vehicle chassis system, Internet of things and data transmission system, and intelligent operation and maintenance system based on digital twins. The system technology road map is shown in Figure 2.

3.1 Design and Development of Electric Vehicle Chassis System

Using the sensor array, wireless data transmission module and hub-type motor electric vehicle chassis frame to complete the design and produce a set of general integrated vehicle chassis (Liang, 2022; Li, 2022), so that people can add their favorite customization on the integrated chassis according to their own needs body, to produce vehicles in specific application scenarios.

3.2 Design and Development of Internet of Things and Data Transmission System

3.2.1 Network Design of Wireless Data Transmission Module

Sensors that detect vehicle status need a communication medium to upload data, so a wireless communication network must be designed according to vehicle sensor types and data transmission reliability requirements (Barbi et al., 2022). Comprehensively compare communication reliability, networking mode, power consumption data and other factors, select a suitable wireless communication chip without affecting the overall development difficulty and technical route of the system, design the hardware circuit of the communication node and plan the topology of the network, and test the robustness, power consumption and other performance data of the communication network in different communication environments to obtain reliable data collection and wireless network communication systems (Tao et al., 2022; Tao et al., 2018).

The operation process of the wireless transmission system design suitable for the Internet of vehicles proposed in this design scheme includes, at the interface layer, the vehicle sensor is connected to this system through the serial port (UART) communication, and the data such as the vehicle body status information and its environment variables are transmitted from the serial port to the At the ZIGBEE terminal, the data enters the transport layer at this time, and then the sensor or terminal device data will be wirelessly transmitted to the gateway through the ZIGBEE ad hoc network. Next, the gateway performs protocol conversion and connects to the lot cloud platform, thereby further transmitting the data to the visualization platform, and then use the digital twin technology to make corresponding feedback on the 3D model on the web page to digitally restore the state of the car body.

3.2.2 The Establishment of Host Hosting and Data Analysis Server

In view of the need for real-time data hosting and analysis of the data collected by sensors, an upper data hosting server is established to manage and store sensor data, and a data processing server is set up to perform real-time analysis and feedback of uploaded data to realize data statistics, file management, data analysis and other functions, if people need to use their own server for data statistical analysis and other operations, they can also operate and set themselves through the API provided by the scheme.

3.3 Design and Development of Intelligent Operation and Maintenance System Based on Digital Twin Technology

3.3.1 Research on Real-Time Interaction Method of Visualized Data

Considering people's lack of professionalism in vehicle status and maintenance, the scheme team will build a 3D model of the vehicle on the Internet, and make the vehicle data into an interactive 3D model based on digital twin technology, which will help people intuitively judge the vehicle's real-time the data and status are easy for people to view, and can be shared with professional maintenance organizations, so that vehicle faults can be discovered and dealt with in time (Gao et al., 2022; Zhou et al., 2022).

3.3.2 Develop A Platform for Real-Time Interaction, Operation And Maintenance, And Management Of Vehicle Comprehensive Data Based on Digital Twins

Utilize the ZIGBEE communication system and the upper server to build a set of cloud intelligent operation and maintenance management platform, use the vehicle as the core terminal of the Internet of vehicles system, and cooperate with the sensor data in the cloud to realize functions such as fault alarm, fault early warning, data statistics and analysis, and use visualization. The web page builds the human layer of the digital twin system, allowing people to interact, control, and manage the vehicle in a visual way.

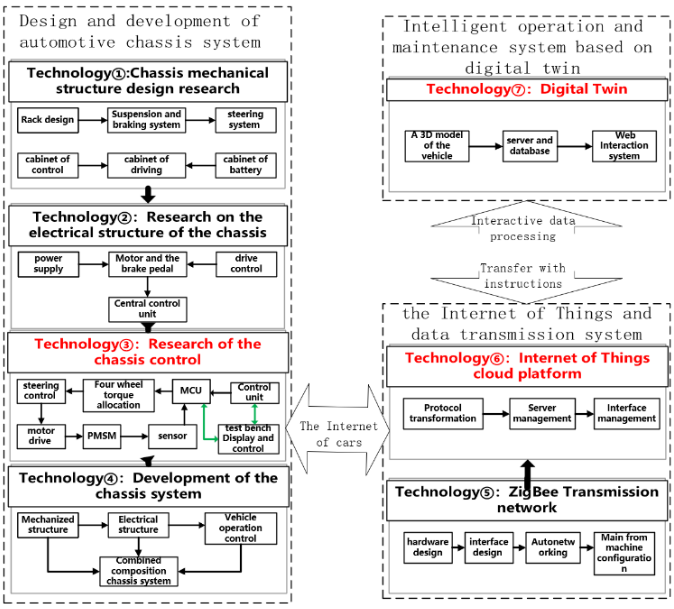

Figure 2: Overall design scheme

3.4 Fault Prediction and Health Management

Car system in the process of using failure will trigger fault protection, and traditional fault protection is often simply to car body equipment to stop work, waiting for people contact operations personnel maintenance processing, when people cannot accurately describe the fault phenomenon, operations personnel is likely to come to the site survey fault cause, the second return to the scene to fully handle the fault (Zhuang et al., 2021). Therefore, in order to improve the efficiency, the use of digital twin and Internet of things technology, build based on the "cloud + edge" "dynamic fault characteristic library", and complete the vehicle condition detection, automatic fault diagnosis mechanism, the design of potential fault early warning mechanism, let the vehicle failure warning before occurs, state monitoring service makes operations personnel through high fidelity model to perspective the actual running state of the vehicle.

Various sensors and data processing methods are used to assess the health status of the vehicle and predict vehicle failure and the remaining life of vehicle parts, thus transforming traditional post-maintenance to pre-maintenance. Digital twin drive fault detection and health management are driven by the twin data, based on the vehicle and vehicle model synchronous mapping and real-time interaction and accurate fault prediction and health management services, the formation of vehicle health management mode, realizes rapid capture fault phenomenon, accurately locate the cause of failure, reasonable design, and validation maintenance strategy. According to the results of the real-time data analysis feedback, the vehicle faults judgment and upload the report, can also according to the fault analysis database stored in the server, the potential fault risk, warning to people and provide maintenance advice to supply urgent processing and reference, and report the data to the cloud, by professional maintenance personnel before the fault, improve the safety and reliability of the chassis.

4. Actual Development

4.1 Vehicle Chassis

The electrical design of the vehicle includes test platform, central control unit, drive control, motor and position sensor and power supply system. As shown in the figure 3, the test platform connects and communicates with the central control unit of the vehicle through RS232. As a human-computer interaction platform for the vehicle test, it can issue instructions such as speed, steering, start and stop, and observe the driving state of the vehicle. The central control unit calculates according to the command signal of the steering wheel (or wire control handle) and the command signal issued by the test platform, and completes the allocation of the rotation speed of each hub motor and the uploading of the vehicle status (driving speed, wheel speed, etc.). The drive control part controls the current of each phase of the motor according to the rotor position obtained by the sensor (Hall sensor or photoelectric encoder) to realize the speed regulation of the motor. The power supply system provides a nominal working voltage of 72V with a working range of 60V-76.8V. Connections between the circuit boards are industrial grade connectors. To shorten the development cycle, select existing modules or circuit boards on the premise of ensuring performance.

4.2 Data Transmission

The design of the wireless transmission system suitable for the Internet of vehicles proposed in this design scheme is shown in Figure 4. The operation process includes, at the interface layer, the vehicle sensor is connected to this system through the serial port (UART) communication, the status information of the vehicle body and its environment variables, etc. The data is transmitted from the serial port to the ZIGBEE terminal, and the data enters the transport layer at this time, and then the sensor or terminal device data will be wirelessly transmitted to the gateway through the ZIGBEE ad hoc network. Next, the gateway performs protocol conversion and connects to the IoT cloud platform. In this way, the data is further transmitted to the visualization platform, and then corresponding feedback is made on the 3D model on the web page through the digital twin technology to digitally restore the state of the car body.

ZIGBEE sits on top of the IEEE 802.15.4 physical layer (PHY) and media access control layer (MAC). In addition, compared with several popular wireless transmission technologies, ZIGBEE will automatically form a network after power-on, without configuration, and has strong self-recovery ability. More importantly, ZIGBEE has low power consumption and will switch to sleep mode in non-working mode, so the battery working time of ZIGBEE nodes can often be as long as 6 months or even 2 years, in contrast, Bluetooth can only work for a few weeks, and WIFI only works for a few hours.

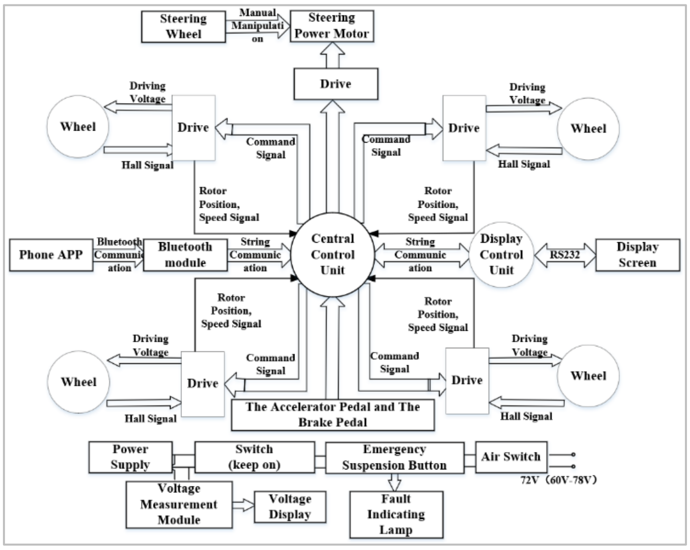

Figure 3: Overall block diagram of the electrical part

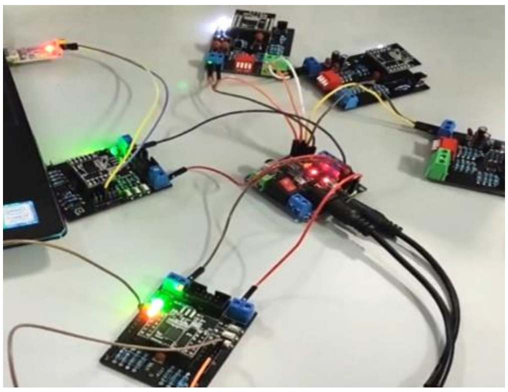

Figure 4: ZIGBEE Networking Test and the Internet of Things cloud platform test

4.3 Digital Twin Models

Use blender to integrate vehicle models and scenes, and use verge3D to combine scenes and add logic commands to manipulate model objects to create 3D interactive web pages. Among them, Verge3D is a powerful toolkit, which can seamlessly cooperate with modeling software such as blender and 3Dmax, and apply simple graphical programming methods to design various interactions. We send the data through the server to make the vehicle model turn as shown in the figure 5. The vehicle model successfully receives the data and makes the wheels of the vehicle model turn. Figure 6 is a side view of the vehicle model after steering, and Figure 7 is a top view of the vehicle model after steering.

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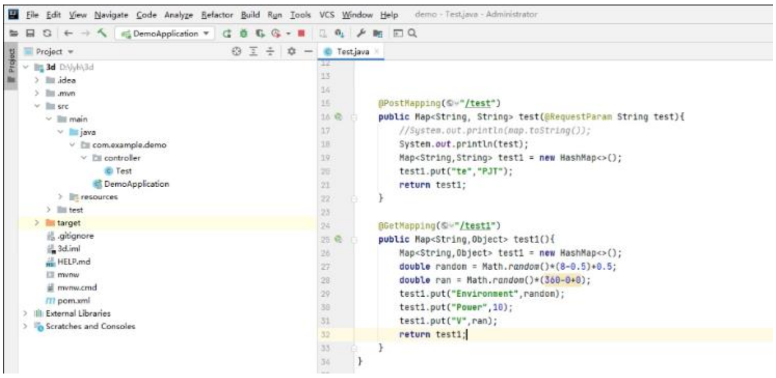

Figure 5: Schematic diagram of server sending data code

Figure 6: Side view

Figure 7: Vertical view

5. Conclusion

The chassis of the electric vehicle plays a role in forming the overall shape of the electric vehicle, bearing the power of the engine, and ensuring the normal running of the electric vehicle. It is one of the most critical and main structures of the electric vehicle. However, due to the collision of the vehicle during the driving process, the constant wear and corrosion of the vehicle structural components and other factors, the possibility of causing the chassis failure increases, which has a great impact on the driving stability, driver comfort and even safety of the electric vehicle. Therefore, based on the application requirements, this paper designs a visual intelligent interaction scheme based on digital twins, which can make people monitor and manage the car body more intuitively.

This program also has many deficiencies. The fault protection will be triggered when the on-board system breaks down in the process of use, while the traditional fault protection is often to simply stop the vehicle body equipment from working and wait for the user to contact the professional personnel for maintenance and treatment. When the user cannot accurately describe the fault phenomenon, the maintainer may have to come to the site to investigate the cause of the fault, and then return to the site for a second time to completely deal with the fault. Therefore, in order to improve the user experience of this product, how to use the Internet of things technology to build a "dynamic fault feature library" based on "cloud edge", and complete the design of the automatic fault diagnosis mechanism and potential fault early warning mechanism of the equipment, so that the equipment fault can be early warning before it occurs, and the maintainer can complete the processing "only once" to improve the user experience.

To ensure the real-time of vehicle body data in the user interaction interface based on digital twins, and because the intelligent operation and maintenance system have the statistical demand for a large amount of vehicle body data, multiple groups of sensors of the transmission system will continuously transmit the effective information of the vehicle body for a period at the same time. The longer the collection duration is, the greater the amount of information transmitted, it is inevitable that there will be data packet disorder, network congestion and other phenomena, which will affect the accuracy of data collection Reliability and real-time. Therefore, the key issues to be solved in this scheme are to compile a set of communication protocols that can flexibly process a mass of data, and to reasonably arrange and arrange multiple groups of sensors and their data transmission in time and space.

However, compared with the traditional vehicle maintenance, the operation and maintenance scheme proposed in this paper will make the whole processing process of the faulty vehicle more efficient, guarantee the stability of the overall operation of the vehicle to a greater extent, and extend its service life, which is conducive to the further research and development of the modern electric vehicle industry.

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References

Barbi, M., Ruiz, A.A., Handel, A.M., Inca, S., Garcia-Roger, D., and Monserrat, J.F., 2022. Simulation-based Digital Twin for 5G Connected Automated and Autonomous Vehicles. In 2022 Joint European

Conference on Networks and Communications and 6G Summit, Pp. 273–278.

Gao, S.G., Zhou, M., Zheng, W., Zhang, L.X., Zhang, B., Song, H.F., Wu, X.T., Li, N. and Wang, K.Y., 2022. Research status and prospect of intelligent operation and maintenance of high-end equipment based on digital twin. Computer Integrated Manufacturing Systems, 7(28), Pp. 1953-1965.

Li, Y.Z., 2022. Common fault diagnosis and maintenance of automobile chassis electronic control system. Internal Combustion Engine and Parts, 4, Pp. 179-181.

Liang, Q., 2022. Application analysis of automobile chassis detection and maintenance technology. Auto Time, 20, Pp. 158-160.

Popa, L., Berdich, A. and Groza, B., 2023. CarTwin—Development of a Digital Twin for a Real-World In-Vehicle CAN Network. Applied Sciences, 1(13).

Steinmetz, C., Schroeder, G.N., Rettberg, A., Rodrigues, R.N., and Eduardo Pereira, C., 2021. Enabling and supporting car-as-a-service by digital twin modeling and deployment. In 2021 Design, Automation and Test in Europe Conference and Exhibition (DATE), Pp. 428–433.

Tao, F., Liu, W.R., Liu, J.H., Liu, X.J., Liu, Q., Qu, T., Hu, T.L., Zhang, Z.N., Xiang, F., Xu, W.J., Wang, J.Q., Zhang, Y.F., Liu, Z.Y., Li, H., Cheng, J.F., Qi, Q.L., Zhang, M., Zhang, H., Sui, F.Y., He, L.R., Yi, W.M. and Cheng, H., 2018. Digital Tinning and its application exploration. Computer Integrated Manufacturing Systems, 1(24),Pp. 1-18, 2018.

Tao, F., Ma, X., Qi, Q.L., Liu, W.R., Zhang, H. & Zhang, C.Y. (2022). Digital twin interaction theory and key technology. Computer Integrated Manufacturing Systems, 1-15.

Wang, X.D., Yang, K., Wang, J., Ma, Z.X., Dong, D.X., Xu, K.H., and Jiang, J.H., 2020. Matching and economic analysis of hub motor driven solar electric vehicle. Mechanical Science and Technology for Aerospace Engineering, 8(39), Pp. 1211-1216.

Wang, Y.L., 2015. Design and implementation of on-board fault intelligent early warning and service system. Hubei University of Technology.

Wu, C., 2022. Some discussion and thinking on the new energy photovoltaic power generation technology. New Energy Technology, 6,Pp. 25-27.

Zhou, X Z., Liu, S., Sun, H., Shi, H.Z., Li, Y.F., Wang, R., and Li, Y.F., 2022. The Internet of things industrial operation and maintenance system based on digital twin. Industrial Control Computer, 5(35), Pp. 115-116+118.

Zhuang, Z., Li, Y.Z. and Li, Y., 2021. Construction of intelligent operation and maintenance platform based on digital twin. Sichuan Architecture, 4(41), Pp. 211-213.