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Review Article

Study and Analysis of Various Smart Vehicle Vulnerable Prevention Using Digital Twin Technology: A Challenging Review

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Abstract *- In light of the exponential growth of the digital age, several intelligent and autonomous systems are implemented in the intelligent transport system. Safety and security measures of Autonomous Vehicles (AV) significantly minimize accidents and manage a cautious environment for drivers and pedestrians. Therefore, the digital twin approach plays a vital role in data renovation for data-driven vehicles, especially within autonomous vehicle design. This raises the need to obtain novel safety models to boost the security of sovereign vehicle systems. Hence, this survey analyses various Smart vehicle vulnerability prevention techniques using Digital twin technology. This study analyzes the different research papers focused on numerous methods, such as machine learning, reinforcement learning, optimization, graph and deep learning, etc. Finally, the assessment is made based on the year of publication, research technique, evaluation metrics, and accomplishment of Smart vehicle vulnerable prevention research methods using Digital twin technology. In the end, the research comes up with the gaps and challenges of systems so that inspiration for emerging a productive technique for Smart vehicle vulnerability prevention using Digital twin technology is revealed.*

Keywords *- Vulnerable prevention, Smart vehicle, Digital twin, Deep reinforcement learning, Machine learning.*

1. Introduction

In the past few years, many technologies have been developed in several areas, such as computer science visualization, IoT, Machine learning, artificial intelligence and networking [1]. The digital twin knowledge provides an immense probability of fulfilling the break between the IoT sensor data value and the level of estimation of present facts. The major intention of the digital twin is to enhance the execution and design strategy in digital manufacturing by simulation, estimation, and decision-making to different lifecycle phases. The digital twin is a cybernetic picture of a corporal entity or assembly by integrating reproductions and examining data [51], [5]. The developing digital twin technology offers a better solution for resource allocation systems by generating a real-time virtual simulation model [29][11]. The present monitoring and the organization of the practical environment behaviours are performed using digital twins [52][18]. Traffic management has become a major concern of smart city projects. Due to the increasing usage of vehicles, the roads and bridges are facing severe traffic snarls and blockages. In addition, there is huge fuel wastage because of the slow movements of vehicles at the junctions [15]. The rapid growth of smart electric vehicles is a significant measure to resolve the energy crisis and environmental pollution. The information about the detected vehicles, such as location, type and unique identifier, are included in the digital twin; thereby, it provides a better understanding of the real-time environment and enables it to plan manoeuvres more conveniently [49]. The novel technologies affect the Industrial Automation Control System (IACS) and the entire real-time environment. The new security measures are required to adapt to the new approaches. The main challenge in the IACS is data sharing and control, which leads to security issues [29].

Recently, several approaches have been developed to predict vulnerabilities in smart vehicles. Here, the digital twin is the most relevant technique in the vulnerable prediction approach. The Artificial Neural Network (ANN) is used to model the intelligent digital twin for observing and diagnosing the prognosis of electric vehicle motors [3]. When designing the electric vehicle's virtual model to address problems with self-propelled engineering, one well-known approach is Particle Swarm Optimization (PSO) [53]. In addition, a distinct technique called the Non-Dominated Sorting Genetic technique (NSGA-II) is employed to decrease nitric oxide emissions and brake fuel consumption at varying loads and speeds [9]. In addition, there are several methods, including the ADMM [11], Deep Q-Learning based Algorithm [6], nonlinear least square algorithm [8], and Locality-Sensitive Hashing (LSH) technique [10], are used to design the digital twin for forecasting the vulnerable in the smart electric vehicles. In addition, the new platform is developed to build a digital twin technique that enables the vehicle to talk with further physical objects over Vehicle-to-Vehicle (V2V) message and Vehicle-to-Cloud (V2C) message. Also, the V2C communication assist the vehicles to upload the data to the cloud for implementing the digital twin model in the virtual world [28].

Examining current methods for innovatively preventing vehicle vulnerabilities with digital twins is the primary goal of this study. Current methodologies include artificial intelligence, neural network optimization, fuzzy logic, and deep reinforcement. This review is established by contemplating employed software; toolset applied for evaluation, techniques cataloguing, etc. Likewise, accuracy is considered the performance metric for the intelligent vehicle vulnerable prevention method. The challenges confronted by the prevailing techniques are defined when investigating gaps and problems. Therefore, the investigate gaps segment is deliberated as the inspiration for an additional extension of practical approaches in vulnerable prevention methods.

This paper is prepared as shadows: Section 2 briefly explains prevailing investigative works on preventing vulnerability in smart vehicles using digital twin technology. Section 3 shows research problems and gaps in vulnerable prevention techniques. Evaluation of prevention approaches by applied toolset, performance metrics, and year of issued research paper are labelled in Section 4. Eventually, Section 5 establishes the conclusion of the complete work.

2. Literature Survey

Most prevailing techniques forecast the traffic state of the vehicle and process the data to attain safe driving. However, an efficient technique is needed to enhance traffic safety and network security in the process of vehicle maneuver. The various developed approaches utilized for preventing vulnerability in smart vehicles using digital twin technology are elucidated in this section.

2.1. Machine Learning Based Methods

Machine learning is defined as a computational procedure that utilizes input information to obtain an anticipated job without being factually planned to generate a predicted outcome. These algorithms mechanically change their planning over replication to become better at attaining the required task. The various machine learning-based techniques for vehicle vulnerable prevention are presented here:

Venkatesan S et al. [3] industrialized the health monitoring and diagnosis of PMSM employing Knowledge-able Digital Twin (i-DT). The developed method utilized fuzzy logic and Artificial Neural Network (ANN) for recording distances, the runtime of EV, the time period to replenish bearing lubricant, and degeneration of attractive flux to estimate the Remaining Useful Life (RUL) of Permanent Magnet (PM). In addition, the ANN was designed to detect the potential of several portions of traction motors employed in EVs. Thus, i-DT extends the lifetime of PMSM.

Simetti E and Indiveri G [8] introduced a twin thruster Autonomous Surface Vehicle (ASV). The model efficiently detected the standard navigation and the actuator information and also detected the model involving stable state and mobility state variables to actuation controller inputs. Trust region reflective algorithm, named nonlinear least square approach, was used to solve Nonlinear Programming (NLP) problems. The proposed method was more precise in attaining ASV's asymmetric and nonlinear behavior.

Li Y et al. [9] presented a non-controlled arranging genetic algorithm based on the digital twin to progress the fuel budget and cut the emission of the Atkinson sequence machine. The 1D GT-Power simulation system was initially designed and evaluated using Otto cycle engine data. Then, the Otto cycle engine was adapted as an Atkinson cycle engine depending on the geometric compression ratio. Furthermore, the model was enhanced by the NSGA-II algorithm to recognize the optimal conditions of vehicles. This method was also used to develop better energy management approaches in hybrid electric vehicles. "Smart vehicle vulnerability prevention" is an idea that needs to be defined precisely.

A distinction among these elements may be lacking in current research. The precise role of Digital Twin technology in preventing intelligent car vulnerabilities must be well-documented. Very little research has focused on integrating digital twin technology best with preexisting smart car safety regulations. The data security concerns and privacy ramifications of using Digital Twins in smart cars have not been thoroughly investigated. There is a lack of research on the actual acceptance rates and difficulties encountered by the automotive industry while attempting to use Digital Twin solutions to prevent vulnerabilities.

Hu C et al. [10] designed a digital twin-assisted present circulation flow data calculation model by means of evaluating circulation flow and speed of data obtained by Internet of Vehicle (IoV) devices and broadcasted by 5G. This method is employed to augment resource scheduling and minimize traffic congestion in the busy city. The Locality-Sensitive Hashing (LSH) algorithm was used to identify lacking traffic tide and speed in the 5G network. Moreover, time background was measured for better forecasting accuracy and greater prediction efficiency in the traffic forecasting approach.

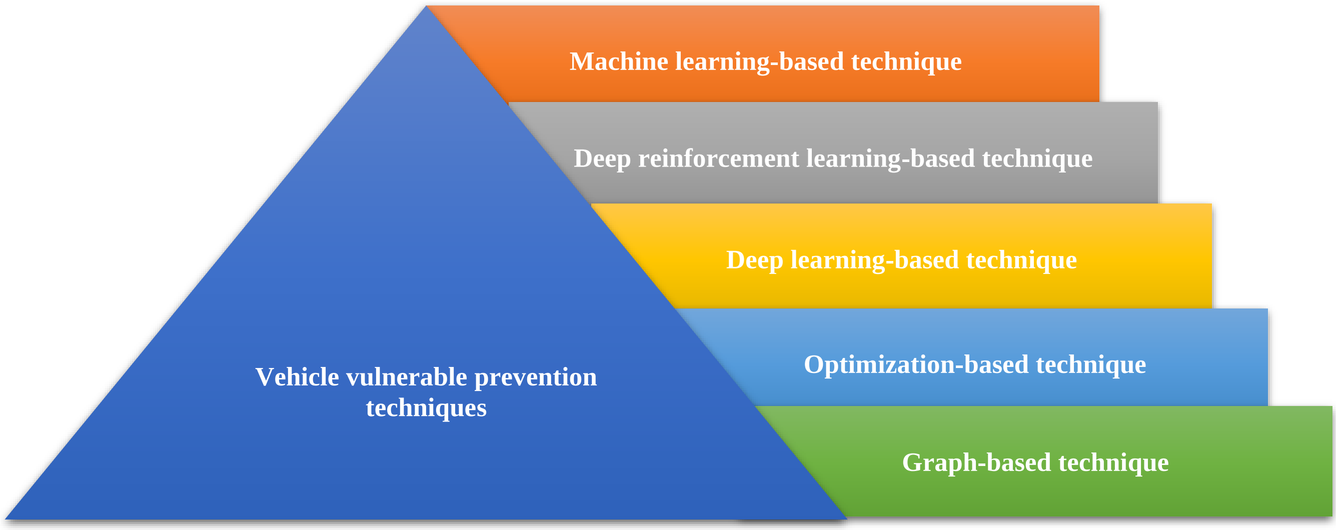

Fig. 1 Classification of Vehicle Vulnerable Prevention Methods

Sun W et al. [11] proposed a dynamic digital twin of aerial-assisted IoV for attaining time-varying source supply to perform resource scheduling and provisioning. In this method, the two-stage incentive model was developed to achieve a resource allocation process. Initially, the model determined that the Road Side Units (RSUs) were willing to offer estimating resources in accordance with the requirements and preferences of vehicles. Then, ADMM was developed simultaneously to enhance vehicular satisfaction and energy efficacy and improve the efficiency of RSUs.

Empowered by state-of-the-art simulation and modelling tools, digital twins can mimic cyber-attacks, physical security breaches, and other weaknesses in a virtual setting. This preventative method enables testing and refining early detection and mitigation techniques before their use in actual cars. Improved vulnerability warning systems are made possible by continuous surveillance capabilities. Digital twins offer constant monitoring and customisable reactions, enhancing overall sensitivity and safety in contrast to state-of-the-art methods that typically depend on scans at predetermined intervals or warnings triggered by predetermined thresholds.

Fraser B et al. [16] introduced an unmanned aerial system to minimize the security impacts of modern-cyber threats and abnormalities during flight, which was attained using digital twin technology and the data-driven approaches in Unmanned Aerial Vehicles (UAVs). The One Class-Support Vector Machine was employed to isolate ordinary instances from abnormal ones based on training data. Additionally, the digital twin was used to model usual behavior using significant information, and the monitoring devices were utilized to detect the cyber intrusion in actual data. Furthermore, the UAV digital twin was employed to analyze security failures and to perceive cyber threats in real-time.

Damjanovic-Behrendt V [17] designed a digital twin-based privacy improvement demonstrator to imitate various conditions in the smart car environment. Initially, the main stakeholders were identified, and stakeholders' vulnerabilities, risks and roles were exposed. Then, the assets comprising complex and private information were detected, and the anomalies were identified and evaluated using an iterative method that uses machine learning approaches for obtaining the car's assets. Finally, the mechanism was designed to accumulate environmental, traffic, and real-time sensor data produced by the functional driving lifecycle. Moreover, the proposed method detected privacy anomalies in self-propelled environments with reduced menaces.

Zhang Z et al. [19] developed a digital twin technique for predicting the energy consumption of smart vehicles. The digital twin was made and exercised by the statistics of the real-time vehicle monitoring system. It consists of four steps: creation, transmission, aggregation and analysis. In addition, the least square method was utilized to accomplish the relationship between the reimbursement coefficient and temperature. The digital twin model was precise, and real-time monitoring data consistently predicted real energy ingesting.

Yurkevich EV, Stepanovskaya IA [22] designed a neural network dispatcher for digital air traffic control in the airport area. The developed method utilized the Socio-Cyber-Physical Self-Organization (SCPS) system into the Available Transfer Capability (ATC) Algorithm to control risk in mobile unmanned and manned vehicles. The SCPS approach enables software and hardware stability through the flexibility of the control system under consideration of varying conditions. This model enhanced the data transfer speed, reduced power consumption and latency, maximised the device connectivity, and broadened the system bandwidth.

Cathey G. et al. [25] planned a Tag-Based Access Control (TBAC) to separate data among several digital twins. The tag attachment was designed to separate data amid more virtual objects, and tags were utilized to control access to various data points through any approved entities. The developed model was assigned at the edge to support low latency and provide real-time safety mechanisms with minimum overhead. Furthermore, data sharing was controlled by the physical sensors, reducing the networking hardware burden.

Ziran Wang et al. [28] designed a Mobility Digital Twin (MDT) context by interconnecting vehicles and cloud computing. The MDT technique comprises three layers: physical, digital, and communication. The physical layer contains humans, transports and traffic infrastructure, whereas the digital layer includes digital models and physical components. In addition, the communication layer lies between the two layers. In addition, the machine learning algorithms were designed to learn about the performance and preferences of all drivers to provide suggestions. Using IoT, the framework converts the connected vehicle into the IoT, minimising the data transmission time and storage cost.

Yun S et al. [33] developed a large-scale digital twin platform to progress an innovative driver assistance system. The Universal Digital Twin platform (uDit) was implemented, which provides an interlink between cyber models and physical assets using communication middleware. The Data Distribution Service (DDS) comprises two layers, such as RTPS and Data-Centric Publish-Subscribe (DCPS) Furthermore, the Functional Mockup Interface (FMI) technology was utilized for context-matched simulation in heterogeneous simulators.

Conde J et al. [37] developed a FIWARE Ecosystem integrated with a list of machinery and the smart information models of digital twins. The proposed model contains three layers: Edge with the IoT, Robots and third-party structures for identifying background data from the physical world and transmitting into actuation; core data administration to achieve the changes in the framework info and the processing, analysis, and visualization to execute the smart conduct of applications in the digital world. In addition, machine learning algorithms were employed to make choices based on real-time prediction data.

Baboli PT et al. [43] established a dynamic identification technique based on Artificial Neural Networks (ANNs) to identify the dynamics of concerned models by integrating system identification methods and nonlinear numerical optimization. The numerical optimization method was used to detect real-time devices. Thus, the device was utilized to reduce the prediction error.

Veledar O et al. [45] developed a multi-metrics security approach for identifying assets and security and safety objectives of autonomous driving systems. The developed method produced the asset dataset, indirect and ancient data, which was processed through an effective algorithm. The proposed method was utilized to detect the selection of vulnerabilities employing virtualization based on digital twins. The developed model was mainly used to enhance the stakeholders' cybersecurity and vehicle safety confidence.

Trani. A et al. [46] developed a method for evaluating aircraft fuel consumption using ANN. The ANN was used to introduce the petroleum consumption model by means of aircraft performance manual information. In order to perform the complex aircraft petroleum consumption functions, the three-layer ANN with nonlinear transfer functions was used for the scramble, cruise and descent phases of the aeroplane. Thus, the devised method maintained better accuracy.

Merkle L et al. [48] developed a technology for estimating the battery's state using digital twins. In contrast, the twin fleet shared the resources captured by the Docker containers in the cloud. The proposed method is comprised of three modules. Initially, the reverse reengineering process was carried out to access the data through the diagnostic interface. Then, the data were obtained using an On-Board Diagnosis (OBD) data vlogger. Finally, the cloud-based digital twin was utilized to estimate the collected data.

2.2. Deep Learning-Built Approaches

Deep learning is a subset of AI algorithms used to learn complex abstractions in data using hierarchical design. Here, the deep learning-based techniques for vehicle vulnerability prevention are described:

Yang J et al. [6] designed a pathway scheduling system for underwater intelligent internet vehicles. This method employed digital twins and device information to represent real ocean locations in digital space, offering a consistent path simulation environment. Then, the closed-loop model based on edge computing was combined with a terminal vehicle to limit the simulation activity of path planning. Furthermore, a reinforcement learning path planning algorithm was developed to discover the optimum network structure constraints, which achieved better flexibility with different ocean conditions.

Wang Z et al. [18] developed a digital twin model by using an Advanced Driver Assistance System (ADAS) for providing advisory rapidity related info to the drivers of connected vehicles. The developed method comprises a physical and cyber layer with several elements. The on-board device was utilized to upload the information to the server by leveraging V2C communication by cellular network. In addition, the server generates a cyber world based on received data for processing and transmits it to the physical world to support drivers. Thus, the devised method prevents the transportation system from communication interruptions and packet losses.

Liao X et al. [47] developed a cooperative ramp merging scheme for adopting integrated automobiles to collaborate with other vehicles. The devised model utilized 4G/LTE-based V2C communication to model cooperative ramp merger structure. The V2C technique was utilized to enhance the scalability of connected vehicles and offered wide data storage to disrupt the constraint of computational power. Furthermore, the map matching algorithm was also utilized to receive the Global Navigation Satellite System (GNSS) data, transmit it into the cloud, and perform the pre-built map matching process.

2.3. Deep Reinforcement Learning-Based Approaches

Deep reinforcement learning is a method used to develop the arena of artificial intelligence. It characterizes a phase towards the rapid growth of independent schemes with a higher-level understanding of the physical world. Several deep reinforcement learning methods used for preventing vulnerability are described below:

Lu Y et al. [5] developed a Digital Twin Edge Networks (DITEN) model by combining digital twins and edge networks. Then, the blockchain-based federated learning scheme was developed to improve communiqué security and data confidentiality protection in DITEN. Finally, an asynchronous aggregation scheme was proposed to enhance the efficacy of integrated models, and the digital twin allows reinforcement learning strategies to assign resource bandwidth. Thus, the proposed integrated system enhanced user data's accuracy and security.

Zhang K et al. [13] introduced a social-aware vehicular edge caching model comprising RSUs and smart automobiles created based on user preference and facility accessibility. The optimum vehicular caching cloud design and edge caching procedures were designed using the Deep Deterministic Policy Gradient (DDPG) method to improve system efficacy in various traffic environments. The developed model was utilized for large content caching in resource-constrained electric vehicles. In this, cache scheduling approaches were attained per the social model, and the collected information was adapted in model construction depending on the caching approaches.

Moorthy SK et al. [14] introduced a novel multi-fidelity simulator for wireless Unmanned Aerial Vehicles (UAVs) by means of UBSim with UB-ANC. The signal exchange between two simulators was performed using middleware called SimSocket. The multi-fidelity simulator offered an original structure for examining the domain adaptation approaches through distinct field dynamics inherent to UB-ANC and UBSim. The proposed method is also utilized in the UBSim optimizer to accelerate policy convergence.

Wei H, et al. To enhance safety and resource conservation, [24] created a new power distribution approach that utilizes deep learning. The torque circulation process was expressed as a Markov decision process, whereas vehicle dynamic behavior was approximated. Actor-critic nets effectually trade with the problem of an incessant torque vector explanation to obtain an enhanced control effect. Further, the deep reinforcement learning controller attained better behavior and stability performance, and additionally, the Distributed Drive Electric Vehicle (DDEV) also minimized the lateral displacement.

Das AP et al. [35] designed a digital twin context of Li-Ion battery packs for a fleet of automobiles. The developed framework included the digital model of battery, contextual information, cloud-based deployment, operational data and data-driven models. In addition, the anomaly detection method was developed using a machine intelligence technique to extend the battery's lifetime. Moreover, the learning-based prediction technique was designed to forecast the battery's health status.

2.4. Optimization-Based Approaches

Optimization is one of the most widely used approaches for problem solving. The optimization algorithm works to discover the absolute optimal value, which, on the other hand, is probably not inferior to any other algorithm. Hence, the optimization-based methods are deliberated in this subsection.

Zhang C et al. [7] established a digital twin prototype of a hybrid vehicle with Particle Swarm Optimization (PSO) to offer an intensity of freedom in performing the trade-off between precision and robustness. The new min-max termination role was also designed to minimize the computational cost and the hybrid terminating strategy. The digital model contains three modules: driver model, control approach and vehicle podium. After the development of the digital model, assembled data were utilized to have early tuning in attaining the function of every module. The hybrid termination model was employed to regulate the desired precision of the digital model and avoid overfitting problems.

Li D et al. [26] developed a smart railway passenger station prototype based on digital twin technology. The six layers, the physical layer, model layer, application layer, I/O layer, data layer, and human-machine interface layer, were incorporated into the proposed framework. The I/O layer contained sensing and driving devices, and the sensing device was the key element for interconnecting the physical world to the digital twin station. The data layer collected information from the detecting device, then the composed information was managed, and the twin model was developed in the model layer. Thus, the developed model offered the opportunity to enhance performance efficacy and the level of passenger facilities in the railway passenger station.

2.5. Graph-Based Approaches

This subdivision describes graph-based methods exploited to prevent vulnerability in smart vehicles using digital twin technology. Azangoo M et al. [20] introduced a hybrid digital twin model for adaptable manufacturing systems in the Automated Guided Vehicles (AGVs). In this method, the graph prototypical of the factory floor was developed for governing and supervising AGVs. Moreover, communication among control layers and digital twins enhanced system performance more efficiently and helped the progress of sub-systems to be comfortable.

Chen D, Lv Z [23], in order to ensure the safety of data transmissions made by self-driving cars in road net traffic, proposed a method for cooperative data transmission and presented a load balance arrangement for transportation networks. A virtual twin prediction method for autonomous vehicles based on load balancing integrated by a Spatial-Temporal Graph Convolution Network approach was developed with the help of algorithms that use deep learning and neural networks. Thus, the developed method enhanced the data transmission security and the stable information delivery rate.

Zhao L et al. [34] introduced an Intelligent Digital Twin-Based Software-Defined Vehicular Network (IDT-SDVN) to enhance the performance of the digital system efficiently. In this method, two routing techniques, policy-based IDT-SDVN and routing-based IDT-SDVN, were utilized. The efficient routing schemes were used to select the better performance in the physical network. After performing the routing, the routing error was detected and the error report was sent to the IDT module. In the IDT, the reinforcement learning algorithm was utilized to promote the routing structures based on vehicles' needs.

2.6. Other Approaches

Other techniques related to digital twin technology for preventing vulnerability in smart vehicles are described in this section.

El Marai O et al. [1] developed the Digital Twin Box (DTB) for the digital twinning of roads that contained a 360° camera and a set of IoT devices. The DTB generates a digital twin by endlessly transferring real-time data, including 360° live stream, Global Positioning System (GPS) position, temperature and moisture measurements to the cloud server. Object detection and recognition were also performed using this method to obtain feasible objects. This information was used in many fields, such as national security, transportation, and tourism.

Guo Y et al. [2] introduced a 3D digital twin model based on roadside sensing of the Cooperative Vehicle-Infrastructure System (CVIS) to visualise real-time traffic. During sensing, the point cloud data and image data were collected, and the collected data were sent to the detection approach. The detection technique generated the recognition result, which includes object type and 3D pose. The Robot Operating System (ROS) bridge sends the object type to the digital world. The developed method used lidar as a sensing device to measure precise 3D location and detect object orientation.

Tuegel EJ et al. [4] presented a reengineering aircraft structural life forecast using digital twin technology to enhance the performance of the computational structure. The developed technique exploited the ultrahigh fidelity model using tail number. The digital twin was amalgamated with the computation of structural refractions and temperature related to the flight condition with ensuing material state evolution. The digital twin carried out the linear modal illustration as well as fluid-structure interfacing operations. In addition, the digital twin has become more reliable in the aircraft service.

Liu Y et al. [12] developed a new device fusion technique combined with camera image and Digital Twin information to forecast the target behaviour and better guide the ego vehicle. The method consists of several data of autonomous vehicles, such as three 3D sources and one 2D source. The vehicle position was utilized for sensor fusion, and the forecasting data was employed for the final visualization of Advanced Driving Assistance Systems (ADAS). Further, the Coordinate Transform Algorithm, Object Detection Algorithm, Depth Evaluation and Distance Matching approaches were established for dealing with sensor fusion problems and providing great safety benefits in speed variance.

Kumar SA et al. [15] developed a digital twin method for forecasting driver aim and reducing circulation congestion. Artificial intelligence technology was used to determine traffic data in the real environment accurately. Fog analytics and the digital twin with several machine learning approaches were used to forecast drivers' objectives. Furthermore, the virtual vehicle model was proposed through a coalition game algorithm to minimize data redundancy in the cloud.

Schranz C et al. [21] introduced a Product Lifecycle Data Management (PLCDM) technique constructed on Digital Twin technology. The Digital Twin prototype is developed to offer observing capabilities to the physical world. This prototype assembles smart vehicle sensor information and exchanges this information among stakeholders with vehicles' lifecycle stages for overcoming security and safety issues. Furthermore, it also reduced safety accidents and provided preventive security measures.

Martínez-Gutiérrez A. et al. [27] introduced a novel digital twin technology for the transportation of Automatic Guided Vehicles (AGVs), which was a newly implemented technique for Material Requirement Planning satisfaction in a collaborative industry. The proposed digital twin is considered an external service combined with communication structure for association with the progressions of Industry 4.0. The approach accepted the ideologies of Industry 4.0, which utilized protocols based on ethernet, was shielded by means of cybersecurity, and enhanced performance accuracy.

Gehrmann C and Gunnarsson M [29] proposed a digital twin Industrial Automation and Control Systems (IACS) adversary model for cloud-based processing and information distribution. The IACS model was protected by the digital twin while exposed for peripheral information distribution and access. Developed methods can manage legacy systems and change management. In addition, the digital twin state replication technique was modelled to offer confidentiality and synchronization protection.

Javed MA et al. [30] introduced an AGV platooning approach to recognize threats, menaces, weaknesses, possible impacts and the reliability of AGV platooning. Several processes, such as gaining data, communication, connectivity and movement control, were included in this method. The Hazard and Operability (HAZOP) and Threat and Operability (THROP) approaches were used to detect the proposed system's threats and hazards. The platooning approach was implemented in the digital twin to avoid risks like spoofing, speed parameters and unauthorized access.

Lee A et al. [31] introduced a geospatial stand based on the worldwide game machine Unity3D for handling significant mobility data for an Urban Digital Twin (UDT) technology. The developed method comprised six modules: Geospatial Information Server, Multimodal Sensor Data Objectification, Multimodal Sensor Data Analysis, Geospatial Data Visualization, Network Video Recorder (NVR) Interface, NVR Viewer and Management. The NVR Interface layer was utilized to transmit the data from Closed-Circuit Television (CCTV) to the Multimodal Sensor Data Objectification layer, where the detected data was analyzed. It provided the behavioural status related to traffic signals. Furthermore, this method was utilized to store and handle the data about the transport system.

Chen X et al. [32] proposed an automatic driving simulation test system based on digital twin technology. The real vehicle scene test layer, net broadcast layer and laboratory simulation test layer were included in this method. The network transmission layer was utilized to transmit the data between the laboratory simulation test layer and the real automobile site test layer. Moreover, the developed model was effectively performed in real-time scenarios for system testing, design, and implementation.

Ahmadi M et al. [36] proposed a digital twin to enable the accurate operation for monitoring and controlling the system. The developed method was utilized in Electric Railway Power Systems (ERPSs), comprising four modules: Power Electronic Converter based TPSS system, Train Traction Motor’s Driving Method, Overhead Catenary System, and Multi-train Operating System Data. The digital twin-based HIL method is a dynamic nodal technique that minimizes cost and time and enhances reliability.

Anandavel S et al. [38] introduced a novel framework based on digital twins for real-time monitoring, intelligent administration, and autonomous regulator of battery packs. The battery pack's lifecycle included features like operation monitoring, manufacturing, design, and second use options. In addition, IoT technology was utilized to improve the system's holistic performance. Digital twins into battery packs of EVs ensure protection and extend the lifetime of battery packs.

Saifutdinov F et al. [39] developed a novel framework based on digital twins for centralizing ground traffic controller schemes in the airport's arena. The purpose of the digital twin was to gather and accumulate data about movable objects' positions and states. The proposed method was utilized to test and develop the real-time software of the airport's ground transport control system.

Martínez A. et al. [40] developed a communication model to create the association between the computer-generated prototypical and truth. Moreover, the web interface, named intuitive simulation interface, was developed to control and monitor the digital twin simulation for enhancing cyber security. The digital world was identical to physical situations to produce more accurate simulations. This method also helped humans to curb virtual environments by maximizing user experience.

Saad A. et al. [41] introduced a technique for implementing Energy Cyber-Physical Systems (ECPSs) for multiple applications. The developed model was classified according to the nature of the application, such as low and high-bandwidth DT models. The low-bandwidth DT was used in predictive maintenance, situational awareness monitoring, market operation and energy management. These models were used to forecast long-term future operation approaches based on long-term historical data. In addition, the high-bandwidth DT model was utilized in real-time outage supervision, what-if possibility assessment, secondary control management and system refurbishment.

Yang C et al. [42] established a digital twin technology to implement the multi-vehicle experiments. The proposed method comprises physical and cyber vehicles for executing organisational tasks. Furthermore, the prototype was made up of a sand table testbed, cloud and twin system. Various techniques were developed to assist human-machine interactions (HMI), such as driving simulators, screen displays, and mixed reality devices, in increasing system interactivity.

Hause M [44] introduced an original approach for subway digital twin building and virtual-real combination process. Initially, the tunnel operations were evaluated to simplify the purpose of the digital twin building. Then, the Building Information Modelling (BIM) approach was utilized to develop a static design of the tunnel scene that modelled the actual subway assembly. Moreover, the three-dimensional recording and projection calculation method was developed to combine the tunnel surveillance video into a three-dimensional computer-generated scene. It possessed the ability to enhance the efficacy of digital management.

Krammer A. et al. [49] developed a hardware and software model to design an Intelligent Transportation System (ITS). This method used the providentia as a distributed sensor system that includes various edge computing nodes, a complex software architecture and a wide range of state-of-art algorithms. The ITS offered data beyond the perception range of distinct vehicles by using a greater sensor perspective and spatial distribution. The proposed method enhanced the safety and comfort of autonomous vehicles.

Jiang Y et al. [50] developed a System Heterogeneous Fair Federated (SHFF) algorithm that designed the effect factor “I” into the optimization and enthusiastically regulates the various performance gear. The proposed algorithm was utilized to control fairness by means of the global fairness parameter “θ”. Thus, the introduced model enhanced average accuracy to a huge extent.

3. Research Gaps Identified

This phase clarifies approximately the study gaps and problems confronted by prevailing practices using digital twin technology in vulnerable prevention. The investigative issues challenged by machine learning-based methods are represented below:

The new technology was developed in [8] for handling and detecting the twin thruster ASVs, and it does not perform the sway parameters identification process and also failed to include the Doppler Velocity Logger and a fibre optic gyro for obtaining better inertial navigation system. A real-time traffic data calculation model was implemented in [5] for short-term traffic state forecasting in the real environment. On the other hand, the $TFVP_{time}$-LSH with several optimization objectives, such as prediction failure, privacy-preservation and energy cost, was not considered for better efficiency.

In [16], the unmanned aerial system was introduced using digital twin technology. However, this framework utilized generative models for modelling high-dimensional time series data instead of autonomously distributed data. The MDT framework was designed in [28] for connected vehicles, but it failed to consider the major factors, such as scalability, cost, reliability and latency, to decide between private and public clouds and the digital twin framework.

In [33], the data-centric middleware was developed to assist the dynamic simulation ecosystem. Conversely, the performance and functionalities of the uDiT method were not obtained to improve effectiveness in the physical objects. The digital twin framework was designed in [21] to obtain real-time and batch data. However, this technique did not consider context broker for enhancing system performance to NGSI-LD standard.

The problems investigated by the deep reinforcement learning-based methods are demonstrated in the subpart below: The social-aware edge caching was designed in [13] for managing the real-traffic environment. However, this method does not include several features, such as service maintenance and composition updates for handling critical traffic environments in vehicle topology.

In [14], the novel multi-fidelity simulator was developed for wireless UAVs by integrating with UBSim and UB-ANC. However, this method does not include adaptive self-configuration, event prediction, enhanced policy generation and off-policy learning schemes for refining the performance of digital twin-enabled wireless nets. The deep reinforcement learning-based direct torque delivery method was developed in [24] to improve care measures and energy-saving purposes. On the other hand, this method failed to consider the road adhesion strategy to ensure better security of vehicles as well as the robustness of control to model the robust deep reinforcement learning approach. The investigative difficulties handled by the deep learning-based methods are explained below:

In [6], the path planning scheme was established using a digital twin for underwater transport systems. This system was not executed effectively in the complex underwater tasks. The digital twin paradigm was proposed in [18] to provide speed-related information to the connected vehicles' drivers. However, this model was not applied in the mixed transport system, whereas not all vehicles have V2C connections.

In [47], the cooperative ramp merging method was introduced to improve the existing ramp merging scenario based on safety and security. Conversely, the update frequency of the digital twin was not clearly defined by this method to tolerate uncertainties brought by packet loss and delay.

The study problems challenged by the graph-based methods remain shown below: The graph-based model of Digital Twin was developed in [20] for controlling AGVs. This method failed to integrate with several advanced approaches for enhancing the performance of the digital twin. In addition, it does not consider the rapid growth of automatic tools for effective synchronization of factory models. The research problems faced by other approaches used in the smart vehicle vulnerable prevention method are illustrated below:

In [1], a novel technique was developed to design a digital twin for road infrastructure. However, to enhance their precision, this method was not considered a face and vehicle plate number detection method. The digital twin research prototype was implemented in [21], providing preventive safety and security measures and minimising the number of accidents. Conversely, the established method failed to design a strong data governance infrastructure to offer traceability of the events throughout their lifespan.

3.1. Digital Twin Architecture

"Digital twin" is an advanced digital model of a real-life thing, system, or activity. Several essential parts make it a faithful replica of the genuine thing. The four main components of an electronic twin are the real thing, the digital representation of it, the data used to link the two, and the analytics used to draw conclusions and make predictions. The physical entity is reflected in the mirror, whether it is just one piece of equipment or a whole factory. The virtual model digitally depicts this real-life object using state-of-the-art modelling methods like Computer-Aided Design (CAD) and sophisticated simulations. The virtual model relies on data flowing continually through the tangible company's sensor and Internet of Things (IoT) devices to reflect current states and real-time changes accurately, and after that, computers and analytics look at the data, using AI and machine learning to offer recommendations for optimisation, proactive upkeep, and insights. This dynamic, real-time model allows improved monitoring, analysis, and decision-making.

3.2. Development of the Virtual Replica

Since its conception, the idea of a digital twin has evolved substantially. Due to technological constraints, making a digital replica of a real-world object was initially mainly hypothetical. Nevertheless, the Digital Twin has evolved into a valuable and potent tool with the rise of the IoT, sophisticated sensors, and more computer capacity.

Aviation and industry were the first to adopt it because of the critical importance of precise surveillance and maintenance. As technology progressed, more complex capabilities, such as machine learning, statistical analysis, and immediate information integration, were added to Digital Twins. Cloud and edge computing have greatly enhanced Digital Twins' capabilities, allowing for more intricate simulations and real-time processing. Healthcare, urban planning, and the automotive sector are just a few that are already making use of digital twins to boost performance, cut costs, and increase efficiency. More and more, digital transformation efforts will rely on digital twins, which are already game-changing thanks to developments in artificial intelligence and big data.

3.3. Recent Studies on Digital Twins in the Automobile Industry

Improving innovative vehicle safety and vulnerability prevention is the current emphasis of automobile research on Digital Twin technology. Cyber risks and operational problems are becoming more common as autonomous and connected cars gain more capabilities. With the help of Digital Twins, scientists are building virtual representations of vehicles that incorporate all the systems—mechanical, electrical, and software. Vehicle performance and security can be studied by simulating and analysing possible vulnerabilities with these models. Digital Twins use the vehicle's real-time data to anticipate and detect irregularities that might be signs of cyberattacks or system malfunctions. To further guarantee the vehicle's resilience against possible dangers, these simulations test and validate system updates and security patches before releasing them to the car.

4. Critical Evaluation and Conversion

This section examines and discusses numerous approaches used in smart vehicle vulnerability prevention using digital twin technology. The analysis is carried out by means of several investigative articles on the source of the employed dataset, the cataloguing of systems, calculation metrics and publication year.

4.1. Investigation Based on Techniques

This unit signifies an analysis of various methods applied to digital twin technology to prevent vulnerability in smart vehicles. The techniques developed for preventing vulnerability in electric vehicles are displayed in Figure 2. Figure 2 shows that 56% of research was carried out based on a machine learning-built system, and 17% of research papers utilized deep reinforcement learning-based techniques. Moreover, 10% of the research work used AI and graph-constructed methods. In addition, 7% of research work was considered optimization-based methods. Hence, this review revealed that machine learning-based techniques are extensively utilized to prevent vulnerability in smart vehicles.

4.2. Examination Based on the Software Package

This unit describes the toolset exploited by the prevailing methods for preventing vulnerability using digital twin technology. Analysis based on various software used for vulnerable prevention is shown in Figure 3. Python toolset was employed in 13 papers, and MATLAB software was used in 7 research works. Furthermore, ROS and Amazon Web Services (AWS) were utilized in 2 research works, and Blender, Kestrel, Simulation of Urban MObility (SUMo), QGroundControl, MiniCPS, Programmable Logic Controller (PLC), OpenCert, VAG-COM Diagnostic System (VCDS) toolsets were individually utilized in the models. Figure 3 shows that the Python toolset is generally utilized as a software program for vulnerable prevention.

4.3. Examining Data According to Revealing Year

This unit assesses the root of published years, in which 50 study documents are viewed to prevent vulnerability in smart vehicles using digital twin technology. The evaluation by means of the issued year is shown in Table 1. Out of 50 papers analysed, extra research papers were issued in the year 2021.

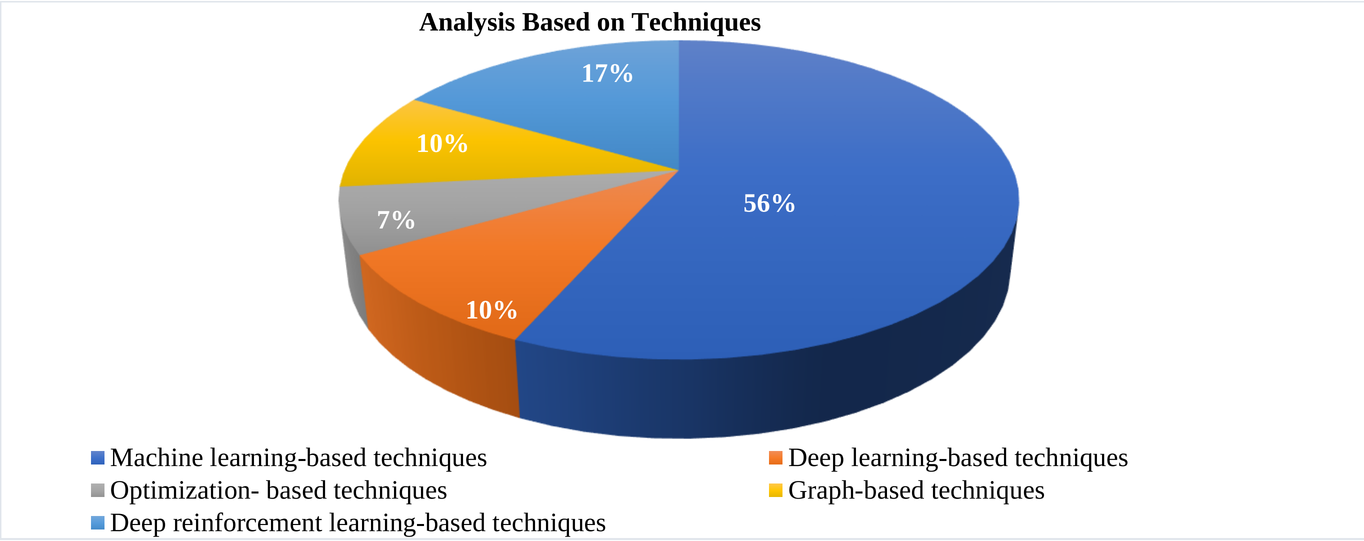

Fig. 2 Analysis based on techniques developed for preventing vulnerability in electric vehicle

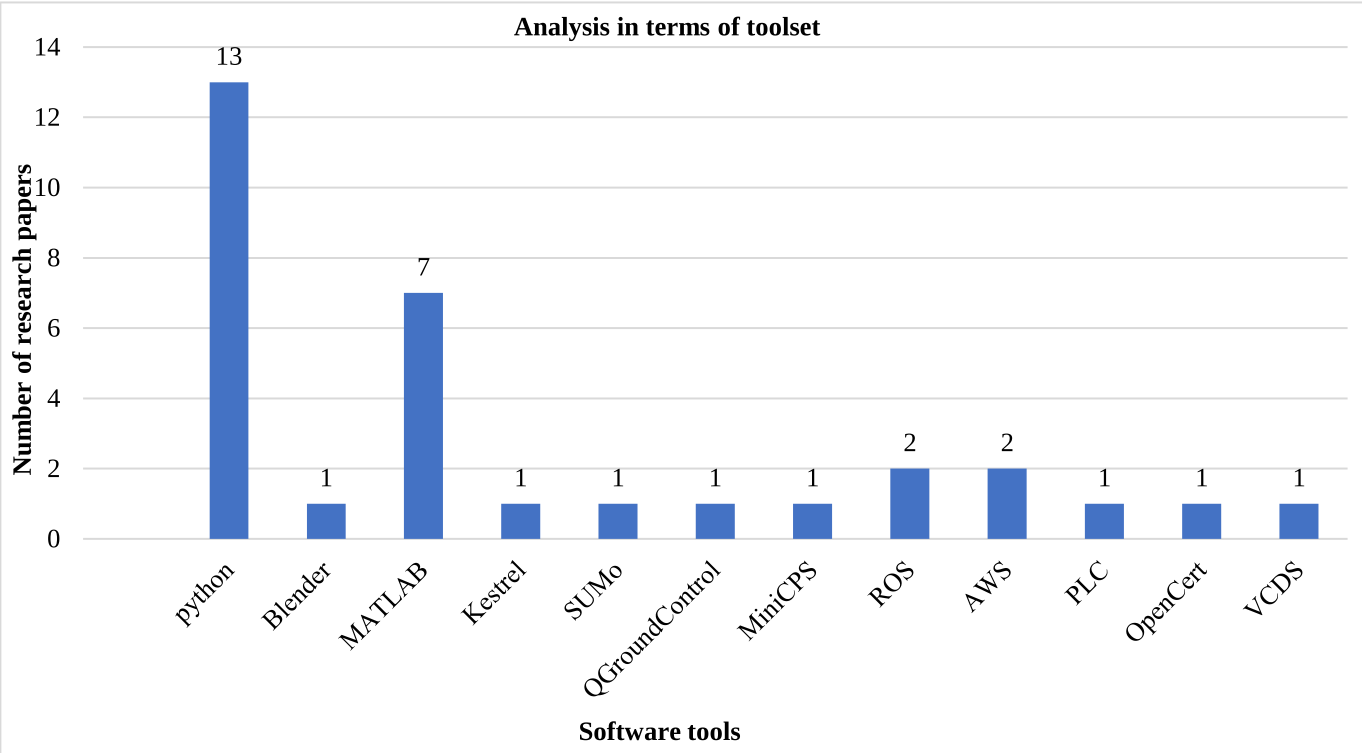

Fig. 3 Analysis based on the toolset

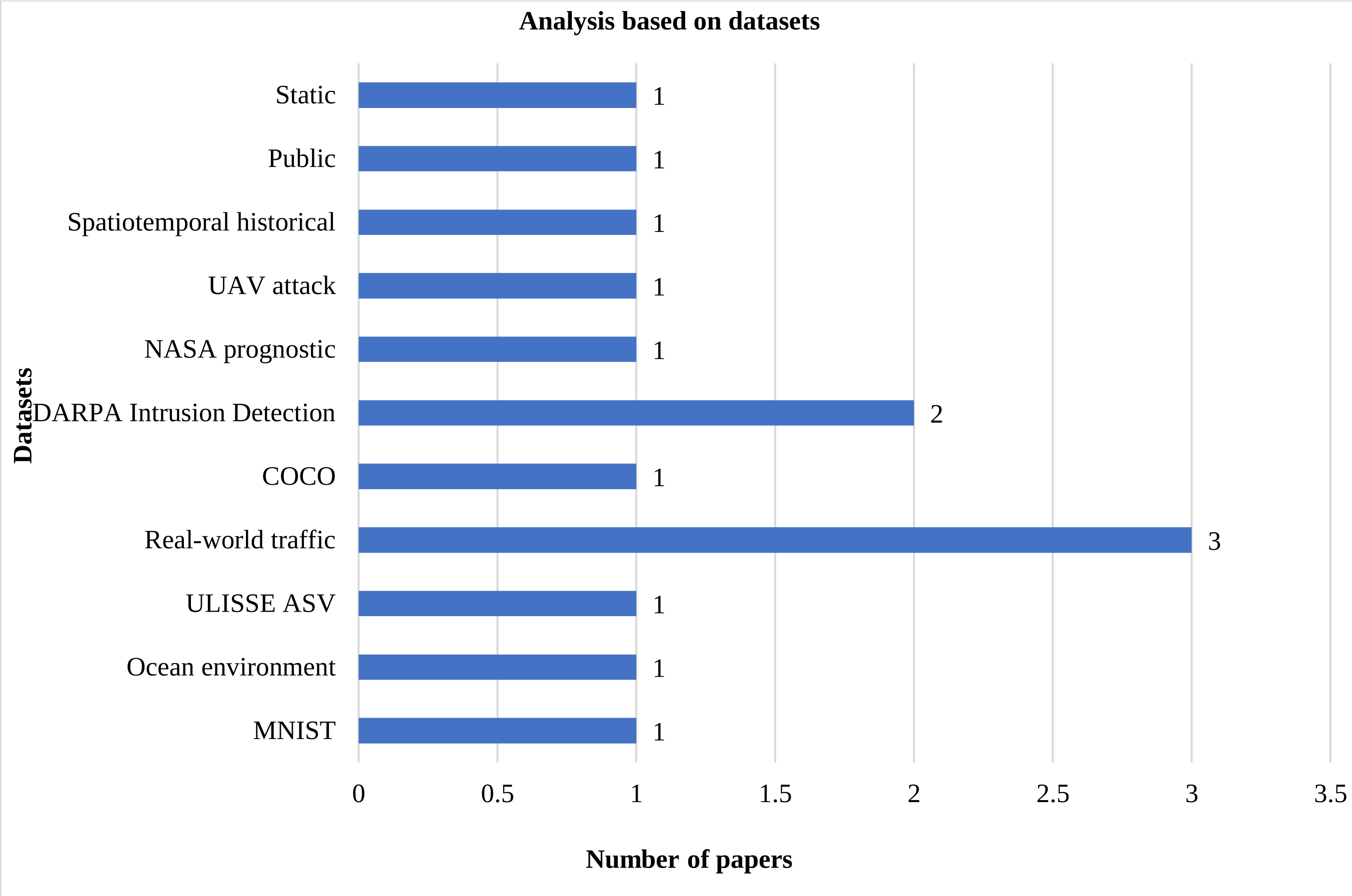

Fig. 4 Analysis based on an employed dataset

4.4. Statistical Evaluation According to the Datasets

This subdivision describes the examination founded on datasets used by existing research works. Figure 4 displays various datasets for vulnerability prevention in smart electric vehicles utilizing twin technology. The real-life traffic dataset was utilized in 3 research works, and 2 study articles employed the DARPA intrusion detection dataset. In addition, the MNIST, Ocean environment, ULISSE ASV, COCO, NASA prognostic, UAV attack, Spatiotemporal historical, Public and Static datasets were employed in only one paper. From Figure 4, it is obviously recognized that the commonly used dataset is a real-world traffic dataset.

4.5. Analysis in Terms of Evaluation Metrics

This section depicts the investigation that was carried out using assessment metrics. Accuracy, recall, F1-score, precision, and definition are some of the outcomes metrics Total Errors Mean (TE), Area The average square error (ASE), Area Under the Curve (AUC), and Receiver Operating Characteristic (ROC), Mean Square Error (MSE), frequency, average time, winding temperature, Root Mean Squared Error (RMSE), casing temperature, PM health, reward, error, speed, battery voltage, yaw rate, Brake Specific Fuel Consumption (BSFC), torque, Mean Absolute Percentage Error (MAPE), delay, utility, ratio redundancy, success rate, compensation coefficient, lateral displacement, sideslip angle, energy cost, angle, model fit are considered. Table 2 illustrates that correctness is the most used assessment metric.

Table 1. Analysis using published year

Year	Number of Research papers
2004	1
2011	1
2017	1
2018	2
2019	5
2020	11
2021	22
2022	7

Table 2. Metrics evaluation analysis

Performance Metrics	No. of Research paper	Performance Metrics	No. of Research paper
Frequency	[1] [47]	RMSE	[10]
Average Time	[1] [10] [25] [29]	Delay	[11] [13] [34] [47]
winding temperature	[3]	Utility	[13]
casing temperature	[3]	ratio redundancy	[15]
PM health	[3]	success rate	[15]
Accuracy	[1] [5] [12] [16] [23] [26] [35] [41]	Precision	[16] [23] [35]
Reward	[5] [6]	Recall	[16] [23] [35]
Error	[7] [19]	F1-score	[16] [23] [35]
Speed	[7] [18] [32] [47]	ROC AUC	[16]
battery voltage	[7]	compensation coefficient	[19]
yaw rate	[8] [24]	Lateral displacement	[24]
BSFC	[9]	Specificity	[35]
Torque	[9]	Sideslip angle	[24]
MAPE	[10]	Energy cost	[24] [29]
MAE	[10]	Angle	[32]
MSE	[43]	model fit	[43]

Table 3. Analysis using Handover failure probability

Accuracy	Number of Research papers
75% - 80%	[12]
90% - 95%	[5] [23]
95% - 99%	[1] [15] [26] [41]

4.6. Analysis Based on the Values of Evaluation Metrics

Here, the study is based on the value of the assessment measure. Accuracy serves as the metric for evaluation here.

4.6.1. Analysis Using Accuracy

This section uses Table 3 to illustrate the investigation in terms of evaluation metrics. Table 3 also provides three levels for evaluation depending on accuracy: 75% to 80%, 90% to 95%, and 95% to 99%. According to the data in the table below, the study articles cited [1], [15], [26], and [41] achieved higher levels of accuracy (between 95% and 99%). Still, the study paper cited [12] achieved lower levels of accuracy (between 75% and 80%). In addition, the percentages in the [5] [23] studies were between 90% and 95%.

5. Conclusion

Through digital twins, this survey covers various techniques to prevent vulnerabilities in intelligent vehicles. Fifty-four studies are used for the analysis, and each is analyzed using multiple methods, such as strategies based on machine learning, optimization, neural networks, deeper reinforcement learning, and graphs. Also, this evaluation draws from several sources, including IEEE, Science Direct, Google Scholar, and others, to compile its research papers. This section analyses research publications and shows how current methods struggle with specific problems. In addition, considering various study gaps and concerns, this analysis suggests future works for vulnerable prevention strategies employing digital twin technology. Procedures for recording, tools for application, data sets, and efficiency indicators are more ways to denote analysis. It is evident from this that research articles typically employ techniques based on machine learning. Similarly, the real-world traffic dataset is commonly employed in the prevalent studies, and Matlab is a software tool frequently used in vulnerable preventive methods. Furthermore, most research studies rely on accuracy as an evaluation parameter.

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