Development of an IoT-Based Parking Space Management System Design

Ange Wang; Zhengtao Qin

Faculty of Urban Construction, Beijing University of Technology, Beijing, China
Research Center for Underground Space and Department of Geotechnical Engineering, Tongji University, Shanghai, China
wangange@beijingtech.edu.cn;
* corresponding author

(Received: March 18, 2023; Revised: April 12, 2023; Accepted: April 31, 2023; Available online: July 1, 2023)

Abstract

With the improvement of people's quality of life and the rapid development of the automobile consumer market, the problem of urban parking difficulties has become increasingly prominent. In addition to the insufficiency of the number of supporting parking spaces, the backwardness of the traditional parking lot operation model has led to insufficient openness and transparency of various information, which limits the ability of drivers to obtain parking space information, and limited parking spaces cannot be adequately obtained. Utilization is also one of the reasons for the increasing difficulty of urban parking. This article aims to study the design of parking space management system based on Internet of Things technology, choose TechIO technology to realize wireless communication between parking spaces in the parking lot, analyze the advantages of TechIO technology and the needs of parking space management system, and build a simulation based on the system design the test environment has made relevant tests on the various items of the system. The test results show that the use of TechIO technology makes the system have the characteristics of strong adaptability, low cost, and low power consumption, which not only eliminates the complicated wiring costs in the parking lot, but also brings great convenience to the deployment of parking lot nodes.

Keywords: Internet of Things, Parking Management, TechIO, System Design

1. Introduction

The socio-economic progress in contemporary China, characterized by its unique socialist economy, has led to improved living standards and evolving consumer preferences. As a result, there is a growing demand for cars, accompanied by an increase in the number of vehicles and their frequency of use [1]–[3]. The number of cars in numerous large and medium-sized cities has surpassed millions, leading to an exponential growth in the number of users seeking parking spaces. However, the existing parking services often fail to fully meet the needs of users, resulting in difficulties in finding suitable parking spaces, cumbersome entry and exit procedures, and chaotic handling of charges [4]–[6].

Statistics reveal that approximately 30% of gasoline resources are wasted in large cities. On average, parkers spend around 7-8 minutes searching for available parking spaces [7], [8]. These challenges not only impose significant financial burdens and time costs on vehicle owners but also contribute to environmental pollution and severe traffic congestion [9], [10]. Consequently, it is crucial to effectively address the daily parking problem faced by the population.

To tackle this issue, this research paper proposes the use of TechIO technology for wireless communication between parking spaces within parking lots. By analyzing the advantages of TechIO technology and considering the requirements of the parking management system, a simulation test environment is constructed based on the system design, and relevant tests are conducted on the proposed system. The test results demonstrate that the utilization of TechIO technology endows the system with notable characteristics such as adaptability, cost-effectiveness, and low power consumption. This approach eliminates the need for complex wiring installations in parking lots and significantly simplifies the deployment of parking lot nodes, thereby enhancing overall convenience [11], [12].

In summary, the surging demand for cars in China has resulted in a pressing need for efficient parking solutions. Current parking services often fall short in meeting user expectations, leading to difficulties in finding suitable parking spaces,

convoluted entry and exit procedures, and disorderly payment systems. These challenges not only incur financial and time costs for vehicle owners but also contribute to environmental pollution and traffic congestion. In light of this, this research explores the application of TechIO technology to enable wireless communication between parking spaces within parking lots. Through comprehensive analysis and testing, the study establishes the advantages of TechIO technology, highlighting its adaptability, cost-effectiveness, and low power consumption. By eliminating complex wiring installations and simplifying node deployment, this approach offers a promising solution to address the daily parking predicament faced by individuals and alleviate associated issues.

2. Literature Review

2.1. Advantages of TechIO Technology

2.1.1. Low power consumption and short time delay

TechIO technology operates at a low transmission speed, resulting in a small amount of data being transmitted by the signal. In the working mode, the transmitted signal exhibits low power consumption, approximately 1mW, while in the non-working mode, TechIO signal nodes remain in a dormant state with negligible power consumption of less than 1μW [13], [14]. The device search delay is minimal, only 30ms, with a sleep and activation delay of 15ms, and a waking up delay of 15ms for device channel access in the network. In comparison, Bluetooth devices require 3-10 seconds for access delay, and WiFi devices require 3 seconds, highlighting TechIO's shorter operating time, lower power consumption, and information reception. By utilizing sleep mode within the system, TechIO nodes effectively conserve power, making them highly energy-efficient, especially when powered by batteries. The actual battery life and running time depend on various factors, including battery type, capacity, and usage scenarios. TechIO technology has been optimized and tailored for battery usage, ensuring maximum advantages in terms of power efficiency [9, 10].

In addition to its energy-saving features, TechIO technology offers other benefits. It provides reliable wireless communication with a range of up to 100 meters, making it suitable for applications within parking lots [15], [16]. TechIO's low power consumption and efficient sleep mode make it ideal for long-term deployment in parking spaces, ensuring continuous and reliable communication while conserving energy. Moreover, TechIO networks can be easily expanded and interconnected, allowing for scalability and flexibility in adapting to varying parking lot sizes and configurations. The ability to customize and optimize TechIO protocols for battery usage further enhances its practicality and suitability for parking management systems [11, 12].

In summary, TechIO technology's low transmission speed and small data size result in low power consumption during signal transmission. The technology operates efficiently in both working and non-working modes, with minimal delays for device search, activation, and network access. Compared to other wireless communication technologies like Bluetooth and WiFi, TechIO offers shorter operating times, lower power consumption, and better battery optimization. Its energy-saving features, reliable communication, and scalability make TechIO an excellent choice for implementing wireless communication between parking spaces in parking lots.

2.1.2. Highly reliable data transmission

TechIO's MAC layer incorporates the CSMA-CA collision detection mechanism. This mechanism enables immediate transmission when the receiver has data to be sent, ensuring that each packet sent to the receiver requires acknowledgment before the corresponding confirmation message is received and replied to by the recipient [17], [18]. If a collision occurs during the data transmission process, indicated by the absence of a confirmation message and recipient's reply, the message will be retransmitted to avoid unnecessary interference or collisions. Additionally, TechIO offers optimized applications that prioritize minimizing interval delays, with both the interval delay and activation interval delay kept very short.

The utilization of the CSMA-CA collision detection mechanism in TechIO's MAC layer allows for efficient and reliable data transmission. By initiating transmission as soon as the receiver has data, it ensures prompt communication while maintaining the integrity of the message exchange. The inclusion of confirmation messages and collision detection

enables the system to detect and address any interference or collisions that may occur during transmission, thus minimizing data loss and maintaining the overall reliability of the communication.

Furthermore, TechIO's focus on optimizing applications with shorter interval delays enhances its suitability for time-sensitive operations. By reducing the interval delays and activation interval delays to a minimum, TechIO enables swift and responsive communication, making it well-suited for applications where real-time or near-real-time interactions are crucial. This optimization ensures that time-critical processes can be executed efficiently and effectively within the TechIO network.

2.1.3. Automatic dynamic networking and autonomous routing

The TechIO network operates as a dynamic and adaptable network, allowing for seamless integration of new nodes and the automatic removal of nodes with low power or physical damage [19], [20]. This flexible nature of the network enables nodes to join or exit the existing TechIO network at any location and time [11, 12]. This capability ensures the scalability and resilience of the network, as it can easily accommodate changes in the node composition without disrupting the overall functionality. Whether it involves incorporating new nodes to expand the network's coverage or removing nodes that are no longer operational, TechIO's self-configuring capability enables efficient management and maintenance of the network's integrity.

2.1.4. Compatibility

One of the key advantages of TechIO technology is its seamless integration with existing network standards. With TechIO, the network coordinator can effortlessly establish a network by automatically configuring the network settings [18], [21]. The technology employs carrier sensing and detection methods to access the channel, ensuring efficient utilization of the available bandwidth. Moreover, TechIO incorporates a handshake protocol that guarantees reliable communication by facilitating the exchange of acknowledgment and confirmation messages between devices. This robust protocol enhances the overall reliability and integrity of the communication process within the TechIO network.

2.2. System Design Requirements

2.2.1. Functional requirements

The implementation of an efficient parking management system aims to address various challenges and improve the overall parking experience for car owners [14], [22]. One primary objective is to enhance car owners' ability to obtain parking space information promptly, aligning with the current trend of utilizing the Internet to access information conveniently. By leveraging the power of the Internet, car owners can quickly and effortlessly obtain real-time updates on available parking spaces, reducing the time wasted searching for parking spots.

Another crucial aspect is to enhance the transparency of parking lot information. Irregularities such as arbitrary charges, unauthorized parking space setups, and haphazard parking arrangements are prevalent in many parking lots. Therefore, it is essential to promote transparency and standardization by providing comprehensive and standardized information about parking lots. This increased transparency enables car owners to make informed decisions and ensures fair practices within parking facilities.

Moreover, it is crucial to enhance the capabilities of regulatory agencies or businesses to obtain and supervise parking space information. Currently, parking lots operate independently, leading to fragmented information. Collecting and managing parking lot information under a standardized framework allows regulatory agencies and businesses to access a centralized database, facilitating better coordination and informed decision-making. Additionally, the availability of a vast amount of parking data provides valuable insights for future urban planning and development.

Improving convenience for car owners is another vital aspect of an efficient parking management system. By incorporating embedded devices in parking spaces and integrating mobile phone payment functions, car owners can complete parking and payment processes seamlessly through their mobile phones. Some parking lots can even offer reservation functions through parking lock devices, maximizing convenience for car owners.

Lastly, an effective parking management system aims to reduce the reliance on human capital for parking lot operations. By implementing a parking space control system within the parking lot, the collection and management of parking space information can be automated. This system can regulate car owners' parking methods, provide self-service payment functions, and enable the self-service use of parking spaces. Reducing human intervention streamlines operations, minimizes human errors, and enhances the overall efficiency of parking lot management.

By addressing these key aspects, an efficient parking management system can revolutionize the parking experience, benefiting car owners, regulatory agencies, businesses, and urban planning endeavors.

2.3. Non-functional Requirements

2.3.1. Performance requirements

When designing an Internet-based management and service system for parking, it is crucial to take into account the system's capacity and anticipate future expansion. The system should be able to handle a significant number of communication tasks within parking lots while providing prompt responses to users. In terms of communication within the parking lot system, it is essential for the parking node's capacity to accommodate at least the number of parking spaces found in conventional parking lots. Moreover, the system should be capable of managing the load brought by a large number of nodes, making it suitable for deployment in large and medium-sized parking lots, even in scenarios involving long distances and complex terrain.

To ensure the efficiency and effectiveness of the parking management system, the carrying capacity of the system must align with the demands of the users. This means that the system should be capable of accommodating a considerable volume of parking-related communication tasks while delivering satisfactory performance. In particular, the mounting capacity of the parking nodes needs to match or exceed the number of parking spaces typically found in conventional parking lots. This ensures that every parking space can be adequately monitored and managed within the system. Additionally, the system should be designed to handle the load imposed by a substantial number of nodes, enabling it to operate effectively in large and medium-sized parking lots. It should also possess the capability to function seamlessly in scenarios involving long distances and challenging terrain, providing reliable communication coverage throughout the parking area. This holistic approach ensures that the parking management system is robust and capable of meeting the diverse needs of users while allowing for potential future expansions.

2.3.2. Security requirements

To ensure effective communication, it is essential to establish a comprehensive and secure communication system. Both parties involved in the communication process should implement reasonable encryption measures to safeguard the confidentiality and integrity of the transmitted data. By adopting robust encryption protocols, the system can prevent unauthorized access and ensure the legitimacy of communication. Additionally, it is crucial to anticipate and account for potential abnormal situations that may arise during operation. By incorporating a well-defined exception handling mechanism, the system can effectively address unexpected scenarios, minimizing disruptions and maintaining smooth communication flow.

When designing the hardware equipment for the parking system, it is imperative to prioritize user convenience and accommodate their parking habits. The hardware should be designed in a way that minimizes any interference with the established parking routines of users. This ensures a seamless and user-friendly experience, allowing individuals to navigate the parking process without significant disruptions or adjustments to their accustomed parking habits. By considering the user perspective during hardware design, the system can enhance overall usability and user satisfaction, ultimately contributing to a more efficient and satisfactory parking experience.

2.3.3. Practical needs

A reasonable system design plan should consider the practical value of all aspects of the system, and the operation of the system should produce positive value in terms of manpower and economy. Cost issues, expansion and maintenance issues, etc. should all be taken into consideration.

The operating cost of the system is mainly the deployment of the equipment in the parking lot and the operation of the server. For the equipment problems in the parking lot, energy-saving and environmentally-friendly equipment should be adopted, which requires basic low power consumption, small size and strong reliability. As much as possible to reduce the frequency and time of equipment maintenance and replacement.

In the process of system design, it is necessary to face continuous expansion and replacement of business. For the design of the system in the parking lot, it is necessary to ensure that the low coupling between nodes and damaged or abnormal equipment does not affect the normal use of other equipment. At the same time, it can quickly connect to the automatic system when adding new equipment or replacing existing equipment. Adaptation, the business in the parking lot should not have a relationship with the server-side configuration. There are often new business or function expansion requirements in the software development and design of the server. The overall structure adopts a service-oriented architecture system, and different business requirements are relatively independent. The system is mainly considered to deal with high concurrency and high availability issues.

2.4. Gray Processing Algorithm

The level of picture definition and color richness has a direct impact on the processing speed of computers. Color pictures typically contain a substantial amount of color information, requiring significant memory space and processing time for computers to handle. To streamline the processing of extensive color RGB images, grayscale processing proves to be an efficient approach. When compared to color image processing, grayscale image processing offers notable advantages in terms of resource consumption and processing time. There are three commonly used methods for converting from RGB color space to grayscale: the maximum value method, average value method, and weighting method.

The maximum value method involves selecting the maximum color channel value (red, green, or blue) for each pixel to represent its grayscale intensity. This method emphasizes the most prominent color component in each pixel and produces a high-contrast grayscale image. On the other hand, the average value method calculates the average of the three color channels for each pixel and assigns it as the grayscale intensity. This approach provides a balanced representation of the color information but may result in a loss of contrast compared to the maximum value method. Lastly, the weighting method assigns different weights to the red, green, and blue channels based on their perceptual importance, and combines them to generate the grayscale intensity. This method allows for fine-tuning the grayscale representation by adjusting the weights assigned to each color channel.

In summary, the choice between color and grayscale image processing depends on the trade-off between picture definition, color richness, and computer processing speed. Grayscale processing proves to be more efficient in terms of resource consumption and processing time, making it a preferred method for streamlining color RGB images. Various techniques, such as the maximum value method, average value method, and weighting method, can be employed to convert from RGB color space to grayscale, each with its own advantages and considerations.

2.4.1. Maximum method

The gray value of the maximum method takes the maximum value of the three component values of R, G, and B in the pixel at that point, and the formula is as follows:

$$Gray = Max(R, G, B) \quad (1)$$

2.4.2. Average method

The gray value of the average value method takes the average value of the three component values of the pixel R, G and B at this point, and its formula is shown in formula (2):

$$Gray = \frac{R+G+B}{3} \quad (2)$$

2.4.3. Weighting method

The gray value of the weighting method takes the three component values of the pixel R, G, and B at this point to perform a weighted operation, and the formula is as shown in formula (3):

$$Gray = W_R R + W_G G + W_B B \quad (3)$$

3. Methodology

3.1. The Overall Design of the System

Difficult parking has become a common problem in every city, and the rapid increase in car ownership has led to a serious shortage of parking spaces. In addition to increasing the number of parking spaces, increasing the utilization rate of parking spaces is also a very important solution.

The system completes the collection and control of parking information through small wireless communication equipment placed in each parking space, and uses wireless sensor network technology to form a local area network in the parking lot. Design the parking lot controller to connect with the public network to complete the communication with the server. The server saves the sensor data of all parking nodes in the database and maintains data consistency with the parking lot network. Users can use various parking related services by accessing the web application server. The user's control request is parsed by the server into a specific instruction and sent to the target parking network, and the user's query request server will directly query the database and respond to the child. All parking information is accurate to any parking space and has certain real-time requirements. The overall design structure is shown in Figure 1.

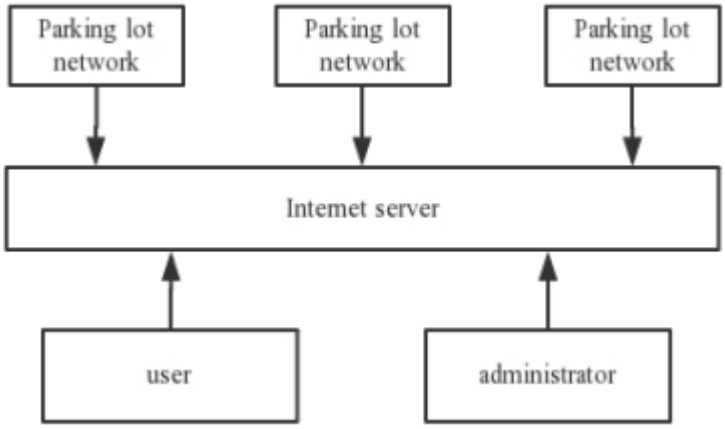

Figure. 1. Overall structure of the system

3.2. HC-SR04 Ultrasonic Sensor Design

The sensor module can provide a non-contact ranging function in the range of 2 to 400 cm, by measuring the distance between the obstacle and the sensor to determine whether there is a car. The module includes ultrasonic transmitter, receiver and control circuit.

The ultrasonic module is activated by changing the level of the TRIG port, using CC2530 to give a high level signal to the TRIG port; the module will automatically send 8401khz sound waves to the outside and detect whether there is a signal return; when the echo signal is received, the module The ECHO port will output a high level, and the duration of the high level is the time from emission to return of the ultrasonic wave. CC2530 uses the counter to monitor the ECHO port level information time duration after sending the detection signal.

3.3. Parking Space Node Design

The parking space node is the smallest module in the system, distributed in each parking space, through the HC-SR04 ultrasonic sensor. Measure the distance of obstacles in the parking space to determine whether there is a car. Various

mechanical equipment can be arranged on the parking space according to the situation, and the function of controlling the parking space can be achieved by changing the pin level change of the CC2530 chip.

1) The task of sensor timing detection

   the parking space node periodically activates the supershen wave sensor to measure data and compare the measured value with the measured value stored locally last time. When the difference of the measured value is greater than the threshold value, it can be considered that the usage status of the parking space has changed. Therefore, the status information timing sending task is executed in advance, and the data is reported to the coordinator.

2) Instruction message receiving task

   This task is a message monitoring task. The coordinator in the system mainly transmits signals and messages to users by means of wireless network broadcasting. The data format is expressed as: nodeid + opcode, when a parking node receives For a command signal and message, if it can be successfully compared with the noded in this signal and message, a custom message corresponding to the opcode can be executed, and if the comparison fails, this signal and message can be ignored.

4. Result and Discussion

4.1. Ultrasonic Testing Function Test

The usage of the parking space is judged according to the measuring distance of the ultrasonic sensor, and there are certain requirements for the measuring accuracy of the sensor. The experiment uses the CC2530 counter to calculate the duration of the sensor's return signal, place the sensor and the desktop as horizontal as possible, and place obstacles at the sound wave sending end of the sensor. The actual distance is measured by a tape measure. The design experiment steps are as follows:

1) Use the serial port to debug to obtain the measured value of the ultrasonic sensor, and calculate the return time of a fixed distance detection sound wave through the CC2530 built-in timer, and obtain the corresponding relationship between the timer value and the distance.
2) Carry out multiple sets of distance measurements and compare actual values.
3) Set the judgment distance multiple times to verify the accuracy of the judgment. The result is shown in Figure 2

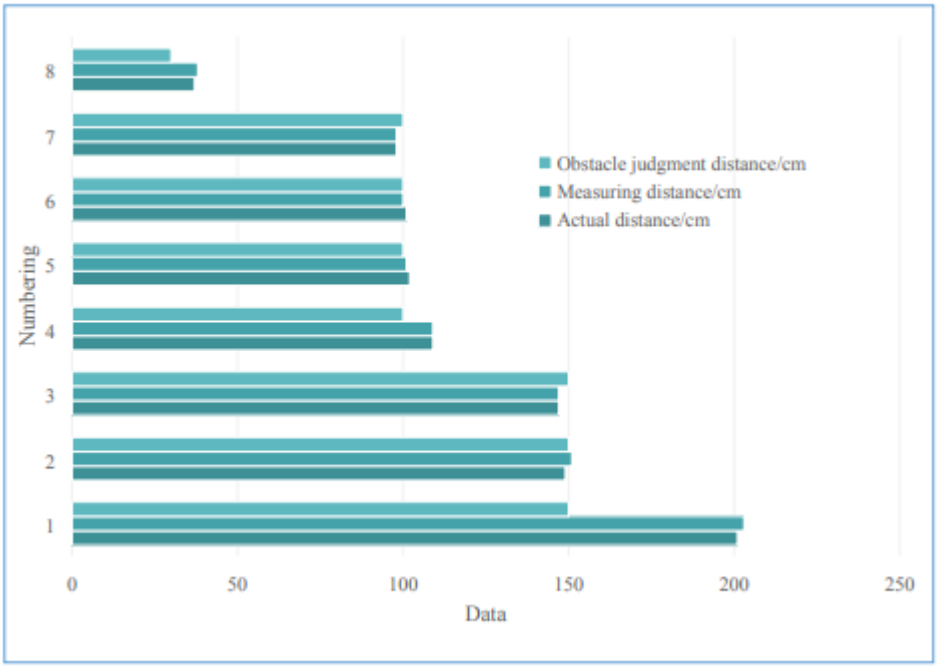

Figure. 2. Ultrasonic test data sheet

The test shows that the measurement error of the sensor is generally no more than 2 cm, which meets the system's measurement accuracy requirements. During the use of the system, the obstacle judgment distance needs to be set according to the installation position of the node. When the measured distance of the obstacle is less than the set distance, the system judges that there is a car. Therefore, a reasonable distance setting has a very important impact on the accuracy of system judgment.

4.2. Functional Test of Parking System

The parking system can directly interact with the hardware in the TechIO network. The detailed function test records are shown in Table 1.

Table. 1. Function test records.

Numbering	Function description	Test steps	Expected input/response	Result
1	Parking options	Click on an unused parking space	A pop-up modal box displays the "Parking Space Reservation" and "Parking Space Use" buttons	Pass
2	Parking space use	Submit the application after entering the operation code on the parking space prompt page	The prompt page is displayed normally. Submit the request after filling in the estimated time and operation code. If the verification is successful, the target node indicator will be turned on to indicate that the parking space is open, and the user is prompted to confirm and wait. If the user authentication fails, jump to the login page	Pass
3	Parking confirmation	Block the ultrasonic sensor	After submitting the request, verify the obstacle approaching status, the	Pass

		on the node within the specified time and submit a confirmation request	verification is successful and the order is generated, prompting the parking is successful, and the verification failure prompts "the vehicle is not detected"	
4	Leave the parking space	After submitting the leave request, remove the obstacles on the ultrasonic sensor	After submitting the request, the system waits for the obstacle to be removed. After the sensor detects successfully, the order is completed, and the node signal light turns off	Pass

The above test shows that the various operating functions of the system are normal, stable and reliable.

5. Conclusion

In conclusion, this research underscores the significance of parking management systems as a crucial component of urban transportation infrastructure. With the continuous growth in the number of vehicles and the increasingly large and intricate scale of parking lots, addressing the challenges associated with daily parking has become imperative. This study delves into the realm of Internet of Things (IoT)-based parking space management systems, extensively investigating the use of TechIO technology. By introducing and analyzing the design of TechIO technology, a comprehensive parking space management system design scheme is proposed. The system design is then subjected to experimental testing to validate its efficacy and performance.

The findings of this research shed light on the importance of developing advanced parking management systems that cater to the needs of a modern society characterized by a growing number of vehicles. By leveraging IoT and TechIO technology, the proposed parking space management system offers a promising solution to alleviate the various social issues arising from parking space challenges. The research encompasses a multidisciplinary approach and explores the intricacies of system design and implementation, providing valuable insights for further advancements in the field.

In conclusion, this study makes significant contributions to the field of parking management systems, particularly in the context of urban transportation. By deepening our understanding of the IoT-based parking space management system and harnessing the potential of TechIO technology, the research proposes a well-designed system that has undergone rigorous experimental testing. This research sets the stage for future developments and enhancements in the realm of parking management, ultimately benefiting individuals and society as a whole.

References

[1] A. Telikani and A. H. Gandomi, “Cost-sensitive stacked auto-encoders for intrusion detection in the Internet of Things,” *Internet of Things*, p. 100122, 2019, doi: 10.1016/j.iot.2019.100122.

[2] P. Helo and A. H. M. Shamsuzzoha, “Real-time supply chain—A blockchain architecture for project deliveries,” *Robot. Comput. Integr. Manuf.*, vol. 63, p. 101909, 2020, doi: https://doi.org/10.1016/j.rcim.2019.101909.

[3] M. Deakin and A. Reid, “Smart cities: Under-gridding the sustainability of city-districts as energy efficient-low carbon zones,” *J. Clean. Prod.*, vol. 173, pp. 39–48, 2018, doi: 10.1016/j.jclepro.2016.12.054.

[4] A. P. Namanya, I. U. Awan, J. P. Disso, and M. Younas, “Similarity hash based scoring of portable executable files for efficient malware detection in IoT,” *Futur. Gener. Comput. Syst.*, vol. 110, pp. 824–832, 2020.

[5] M. Aazam and E.-N. Huh, “Fog computing micro datacenter based dynamic resource estimation and pricing model for IoT,” in *2015 ieee 29th international conference on advanced information networking and applications*, IEEE, 2015, pp. 687–694.

[6] L. Tang, “Evaluation Method of College Students’ Education Management Quality Based on Collaborative Filtering Algorithm and IoT Apps,” *Wirel. Commun. Mob. Comput.*, vol. 2022, 2022, doi: 10.1155/2022/8747964.

[7] I. Machorro-Cano, G. Alor-Hernández, M. A. Paredes-Valverde, L. Rodríguez-Mazahua, J. L. Sánchez-Cervantes, and J. O. Olmedo-Aguirre, "HEMS-IoT: A big data and machine learning-based smart home system for energy saving," *Energies*, vol. 13, no. 5, p. 1097, 2020.

[8] K. J. Co, A. V. Ong, and M. Peradilla, "WSN Data Collection and Routing Protocol with Time Synchronization in Low-cost IoT Environment," *Procedia Comput. Sci.*, vol. 191, no. 2019, pp. 102–110, 2021, doi: 10.1016/j.procs.2021.07.016.

[9] W. Ahmad, A. Rasool, A. R. Javed, T. Baker, and Z. Jalil, "Cyber security in iot-based cloud computing: A comprehensive survey," *Electronics*, vol. 11, no. 1, p. 16, 2022.

[10] A. Alam, "Cloud-Based E-learning: Scaffolding the Environment for Adaptive E-learning Ecosystem Based on Cloud Computing Infrastructure," in *Computer Communication, Networking and IoT: Proceedings of 5th ICICC 2021, Volume 2*, Springer, 2022, pp. 1–9.

[11] E. Moghadas, J. Rezazadeh, and R. Farahbakhsh, "An IoT patient monitoring based on fog computing and data mining: Cardiac arrhythmia usecase," *Internet of Things*, vol. 11, p. 100251, 2020.

[12] L. Yang and Y. Shi, "The Cultivation of Political Identity Literacy in Ideological and Political Classroom Based on IOT and Knowledge Map," *Wirel. Commun. Mob. Comput.*, vol. 2022, 2022, doi: 10.1155/2022/9904314.

[13] S. Shamshoddin, J. Khader, and S. Gani, "Predicting consumer preferences in electronic market based on IoT and Social Networks using deep learning based collaborative filtering techniques," *Electron. Commer. Res.*, vol. 20, no. 2, pp. 241–258, 2020, doi: 10.1007/s10660-019-09377-0.

[14] M. Anbarasan *et al.*, "Detection of flood disaster system based on IoT, big data and convolutional deep neural network," *Comput. Commun.*, vol. 150, pp. 150–157, 2020.

[15] A. Sulhi, "Data Mining Technology Used in an Internet of Things-Based Decision Support System for Information Processing Intelligent Manufacturing," *IJIIS Int. J. Informatics Inf. Syst.*, vol. 4, no. 3, pp. 168–179, 2021.

[16] S. Ojagh, M. R. Malek, S. Saeedi, and S. Liang, "A location-based orientation-aware recommender system using IoT smart devices and Social Networks," *Futur. Gener. Comput. Syst.*, vol. 108, pp. 97–118, 2020, doi: 10.1016/j.future.2020.02.041.

[17] S. Sharma, R. K. Dudeja, G. S. Aujla, R. S. Bali, and N. Kumar, "DeTrAs: deep learning-based healthcare framework for IoT-based assistance of Alzheimer patients," *Neural Comput. Appl.*, pp. 1–13, 2020.

[18] I. J. Jacob and P. E. Darney, "Design of deep learning algorithm for IoT application by image based recognition," *J. ISMAC*, vol. 3, no. 03, pp. 276–290, 2021.

[19] B. Nemade and D. Shah, "An IoT-Based Efficient Water Quality Prediction System for Aquaponics Farming," *Lecture Notes in Electrical Engineering*, vol. 968. pp. 311–323, 2023. doi: 10.1007/978-981-19-7346-8_27.

[20] U. K. Vates, B. P. Sharma, N. J. Kanu, E. Gupta, and G. K. Singh, "Modeling and optimization of IOT factors to enhance agile manufacturing strategy-based production system using SCM and RSM," *Smart Sci.*, vol. 10, no. 2, pp. 158–173, 2022.

[21] S. Khan, S. Iqbal, K. N. Qureshi, K. Z. Ghafoor, P. Kim, and G. Jeon, "Survivability of mobile and wireless communication networks by using service oriented Software Defined Network based Heterogeneous Inter-Domain Handoff system," *Comput. Commun.*, vol. 175, no. May, pp. 177–185, 2021, doi: 10.1016/j.comcom.2021.05.010.

[22] R. Sharma, S. Rani, and S. J. Nuagh, "RecIoT: A Deep Insight into IoT-Based Smart Recommender Systems," *Wirel. Commun. Mob. Comput.*, vol. 2022, 2022, doi: 10.1155/2022/9218907.