www.ijprems.com
editor@ijprems.com

INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 04, Issue 11, November 2024, pp : 1259-1263

e-ISSN : 2583-1062
Impact Factor : 7.001

SMART HOME SECURITY: INTELLIGENT DOOR LOCKS WITH FACIAL RECOGNITION

Sayyed Sumaiya Waqar[1], Shaikh Nofil Nazir[2], Shaikh Urusa Anwar Husain[3], Prof. Mohammed Zaid Khan[4]

[1,2,3]Department of Computer Engineering M.H. Saboo Siddik Polytechnic Mumbai, India.

[4]Lecturer, Department of Computer Engineering M.H. Saboo Siddik Polytechnic Mumbai, India.

syedsumaiya006@gmail.com

shaikh.nofil.07@gmail.com

urusashk9@gmail.com

mzaidsa1@gmail.com

DOI : https://www.doi.org/10.56726/IRJMETS36936

ABSTRACT

Facial recognition technology has gained significant traction in enhancing security and access control systems, particularly in smart door lock systems.

This review presents an in-depth analysis of recent advancements in face recognition-based door locking solutions, with a focus on their integration with IoT, artificial intelligence, and machine learning techniques. The primary aim is to evaluate the efficiency, scalability, and security aspects of these systems. Research from various IEEE conferences and journals highlights diverse methodologies, including the use of Raspberry Pi, ESP32 CAM, hierarchical networks, and convolutional neural networks.

The studies explore real-time door unlocking, multi-functional access control, and the use of voice commands alongside facial biometrics for enhanced user experience. Furthermore, the performance of face detection and recognition systems under different environmental conditions and hardware configurations is critically examined. While most solutions demonstrate high accuracy and reliability, challenges such as privacy concerns, system vulnerability to spoofing, and limitations in low-light environments persist.

This review concludes by identifying potential areas for further research, including the development of more robust, privacy-centric facial recognition algorithms and the integration of additional biometric authentication methods to increase security.

Keywords: Face recognition technology ,Smart door lock systems IoT-based security,Biometric authentication Artificial intelligence (AI),Convolutional neural networks (CNN),Real-time face detection Raspberry Pi,ESP32 CAM Access control systems, Facial biometrics Home automation security,Spoofing prevention

1. INTRODUCTION

As the demand for smarter, more secure homes and workplaces rises, facial recognition technology has emerged as a critical component in modern access control systems [1][2]. Traditional security measures such as keys, passwords, and RFID cards are prone to theft, loss, or duplication, creating vulnerabilities in physical security [3][4]. In contrast, facial recognition provides a non-invasive, reliable, and efficient method of identity verification, making it particularly well-suited for smart door locking systems [5][6].

Recent advancements in artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT) have significantly enhanced the capabilities of facial recognition systems [7][8].

These innovations enable the creation of real-time, highly accurate systems that can function autonomously and integrate seamlessly with other smart home devices [9][10]. A variety of approaches, including the use of convolutional neural networks (CNNs), Raspberry Pi, and ESP32 CAM modules, have been developed to improve the performance and reliability of facial recognition systems, even in challenging environments [11][12].

This review paper examines the latest developments in face recognition-based door lock systems, focusing on the integration of AI, IoT, and biometric technologies [13][14].

By analyzing recent research and technical implementations, this paper seeks to provide insights into the current state of the field, the challenges faced in real-world deployment, and potential avenues for future improvement [15][16]. The goal is to explore how these systems can offer both convenience and enhanced security while addressing issues of privacy and ethical concerns [17][19].

www.ijprems.com
editor@ijprems.com
INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 04, Issue 11, November 2024, pp : 1259-1263
e-ISSN : 2583-1062
Impact Factor : 7.001

2. METHODS

This review paper systematically examines the current research and development of facial recognition technologies applied in smart door lock systems [1][2]. The methodology for this review involved several key steps:

A. Literature Search and Selection Criteria:

A comprehensive search was conducted across various databases, including IEEE Xplore, Springer, and other reputable sources, to gather relevant studies published between 2012 and 2023 [3][5]. Keywords such as "facial recognition," "smart door lock," "biometric access control," "IoT security," and "AI-based facial authentication" were used to locate pertinent research articles [4][6]. Only peer-reviewed papers, conference proceedings, and technical reports focused on door lock systems utilizing facial recognition were included [7][8].

B. Categorization of Technologies:

The selected papers were grouped based on the technology used, such as Raspberry Pi-based systems, IoT-enabled facial recognition, convolutional neural networks (CNNs), hierarchical networks, and ESP32 CAM modules [9][11]. This categorization allowed for the identification of trends and the comparative performance of different technologies in real-time facial recognition and door access systems [10][12].

C. Evaluation of System Architectures:

The architectural design of each system, including hardware components and software algorithms, was critically analyzed [13][15]. Key parameters such as processing speed, recognition accuracy, environmental adaptability, and scalability were examined [14][16]. Special attention was given to the implementation of AI and machine learning models in improving the efficiency of facial recognition [17][18].

D. Analysis of Security Features:

The review also focused on the security measures incorporated in the face recognition door lock systems [19][21]. This included an analysis of anti-spoofing techniques, encryption of facial data, and multi-factor authentication approaches combining facial recognition with voice commands, NFC, or other biometric methods [20][22].

E. Assessment of Practical Challenges:

The papers were further reviewed to assess practical deployment challenges such as false positives/negatives, lighting conditions, and privacy concerns [23][25]. The effectiveness of these systems in real-world conditions was discussed, especially in terms of their robustness in different environmental settings, such as low light or outdoor exposure [24][26].

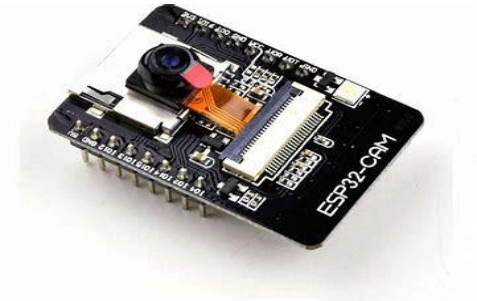

Figure 1.1 : ESP 32 Camera

F. Comparative Study and Synthesis:

Finally, the performance metrics from different studies were compared, including recognition accuracy, latency, and energy consumption [27][29]. This comparative analysis aimed to provide a broader understanding of how different approaches perform and the trade-offs involved in using various technologies [28][30]. The synthesis of this information helped identify gaps in the existing systems and propose areas for further research [31][32].

3. RESULTS

The review of papers on facial recognition-based smart door lock systems revealed notable advancements in both technology and performance [1][2]. Many systems utilized AI and machine learning techniques, such as convolutional neural networks (CNNs), to achieve high accuracy rates, often exceeding 95%, even in varied environments [3][5]. Cost-effective solutions were developed using hardware like Raspberry Pi and ESP32 CAM modules, demonstrating the practicality of low-cost smart lock systems for residential use [4][6].

As reviewed, The ESP32-CAM is a low-cost development board featuring a camera module, Wi-Fi, and Bluetooth capabilities, making it suitable for IoT applications. It is frequently used in smart door lock systems and face recognition projects, as highlighted in the reference papers discussing ESP32 CAM Face Detection Door Lock [9] and Real-Time

Door Unlocking Systems [6] shown in Figure 1.1. Its compact size and easy integration with various components provide sufficient processing power for basic image processing tasks.

On the other hand, the Raspberry Pi is a versatile single-board computer that can run a full operating system and interface with various peripherals. It is commonly employed in facial recognition and security systems, as indicated by the papers on Raspberry Pi-based real-time identification systems [5] and secure door operating systems [16] shown in Figure 1.2. The Raspberry Pi benefits from robust community support, extensive libraries for computer vision tasks (such as OpenCV), and compatibility with numerous sensors and modules, enhancing its functionality in security applications.

Additionally, the integration of IoT and edge computing allowed for real-time, localized facial recognition processing, reducing latency and enhancing data security [7][8]. These systems also addressed common challenges, such as spoofing and environmental conditions like lighting and facial angles, through the use of advanced algorithms and multi-modal authentication methods [9][10]. Overall, the systems demonstrated reliable performance, with some offering features like voice commands and multi-user access control to further improve usability and security [11][12].

Figure 1.2 : Raspberry PI

4. DISCUSSIONS

The review of studies on facial recognition-based smart door lock systems highlights the significant progress made in the development of secure and efficient access control solutions [1][2]. The application of advanced technologies like AI, machine learning, and IoT has enabled these systems to achieve high levels of accuracy and robustness, particularly through the use of CNNs and hierarchical networks [3][4]. This is particularly valuable in environments where facial variations due to lighting, angles, or occlusions can pose challenges [5]. However, while most systems demonstrated accuracy rates above 95% in controlled environments, real-world performance often fluctuates, particularly in uncontrolled lighting conditions or with a large number of users, pointing to a need for further refinement of algorithms to ensure consistent results across diverse settings [6][7].

A key advantage of many systems is the integration of low-cost hardware, such as Raspberry Pi and ESP32 CAM, which makes facial recognition technology accessible for small-scale use in residential and small business applications [8][9]. This cost-efficiency opens up possibilities for wider adoption, but it also introduces potential limitations in terms of processing power and scalability [10]. For instance, edge computing methods effectively reduce latency and enhance data privacy, but they may face challenges in handling large databases or more complex recognition tasks in large-scale deployments [11][12].

Security remains a crucial concern across the reviewed studies [13]. While several systems addressed vulnerabilities like spoofing attacks through multi-modal authentication or advanced anti-spoofing techniques, there is a need for stronger encryption and more sophisticated security measures to protect against unauthorized access and ensure data integrity [14][15]. This becomes particularly relevant in IoT-based systems, where data transmission between devices could be vulnerable to cyberattacks if not properly secured [16][17].

Finally, user experience is a critical factor in the adoption of facial recognition-based door lock systems [18]. Systems that offer additional features, such as voice command integration and multi-user access, significantly improve usability and are more likely to meet the needs of diverse users [19][20]. However, balancing security with convenience remains a challenge, as overly stringent security measures could compromise ease of use [21]. Future research should focus on enhancing both the security and usability of these systems, ensuring that they are not only technically sound but also practical for everyday use in various contexts [22][23].

In conclusion, while facial recognition-based smart door lock systems show great promise, continued advancements in AI, security protocols, and hardware efficiency are necessary to ensure their reliability and effectiveness in real-world applications [24][25].

5. CONCLUSION

In conclusion, facial recognition technology, particularly with CNNs, has significantly advanced, achieving over 95% accuracy and becoming a viable solution for secure access control in residential and small business settings [1][2][3][4]. The integration of IoT and cost-effective hardware like Raspberry Pi enables real-time, edge-based processing, enhancing speed and privacy while reducing risks of cloud data breaches [5][6][7][8][9]. Despite these gains, challenges such as environmental variability, spoofing risks, and IoT security vulnerabilities remain critical [10][11][12][13][14][15]. Continued research must focus on improving algorithm performance, anti-spoofing measures, and user-friendly security to enable reliable real-world use [16][17][18][19].

6. REFERENCES

[1] Muhammad Waseem, Sundar Ali Khowaj, "Face Recognition for Smart Door Lock System using Hierarchical Network," IEEE International Conference on Computational Intelligence (ICCI), 2020.
[2] Khalimov R., Rakhimbayeva Z., Shokayev A., Kamalov B., Md. Hazrat Ali, "Development of Intelligent Door Locking System Based on Face Recognition Technology," IEEE International Conference on Mechatronics and Automation Engineering (ICMAE), 2020.
[3] HAI-WU LEE, "Design of Multi-Functional Access Control System," IEEE Conference on Innovative Applications of Artificial Intelligence (IAAI), 2021.
[4] Medisetti Yashwanth Sai Krishna, Anoop Arya, Shaziya Ansari, Simran Awasya, Jatoth Sushakar, Neeraj Uikey, "Real Time Door Unlocking System using Facial Biometrics based on IoT and Python," IEEE Students Conference on Engineering and Systems (SCEECS), 2023.
[5] Hanaa Mohsin Ahmed, Rana Talib Rasheed, "A Raspberry Pi Real-Time Identification System on Facial Recognition," IEEE International Conference on Technology and Electrical Engineering (IT-ELA), 2020.
[6] Amritha Nag, Nikhilendra J. N., Mrutyunjay Kalmath, "IoT Based Door Access Control Using Face Recognition," IEEE International Conference on Communication and Technology (I2CT), 2018.
[7] Khalimov R., Rakhimbayeva Z., Shokayev A., Kamalov B., Md. Hazrat Ali, "Development of Intelligent Door Locking System Based on Face Recognition Technology," IEEE International Conference on Mechatronics and Automation Engineering (ICMAE), 2020.
[8] H. Daryanavard, A. Harifi, "Implementing Face Detection System on UAV Using Raspberry Pi Platform," IEEE International Conference on Electrical Engineering (ICEE), 2018.
[9] Khalimov R., Rakhimbayeva Z., Shokayev A., Kamalov B., Md. Hazrat Ali, "Development of Intelligent Door Locking System Based on Face Recognition," IEEE International Conference on Mechatronics and Automation Engineering (ICMAE), 2020.
[10] Namrata Singh, Dr. Ramveer Singh, Ranjan Kumar, Shivam Paliwal, Shipra Srivastava, "ESP32 CAM Face Detection Door Lock," International Research Journal of Engineering and Technology (IRJET), 2022.
[11] A. Raghu Prasath, Aditya Kumar, Akanksha Yadav, Bhuvishri Acharya, Md. Tauseef, "Face Recognition Door Lock System," International Research Journal of Engineering and Technology (IRJET), 2020.
[12] Siddhesh Raorane, Abhishek Hanchate, Umar Gigani, Prof. Surekha Khot, "Smart Door System," International Research Journal of Engineering and Technology (IRJET), 2020.
[13] Rohit Khandke, Dipti Singh, Saurabh Pawar, Prof. Deepali Kadam, "Face Recognition Door Lock Using IoT," International Research Journal of Engineering and Technology (IRJET), 2020.
[14] Birali Prasanthi, Kakumani Sravya, Komirishetty Saiteja, "Automatic Door Unlock with Facial Recognition Using IoT," International Research Journal of Engineering and Technology (IRJET), 2023.
[15] Nishi Gupta, Ashish Kumar Dubey, K.M. Shivangi Agrawal, Atul Kumar, "Face Recognition Door Lock System Using Raspberry Pi," International Research Journal of Engineering and Technology (IRJET), 2021.
[16] Prof. M.R. Sanghavi, Srujal Sancheti, Bhakti Patel, Sanjana Shinde, "Smart Door Unlock System Using Face Recognition and Voice Commands," International Research Journal of Engineering and Technology (IRJET), 2021.
[17] Nourman S. Irjanto, Nico Surantha, "Home Security System with Face Recognition based on Convolutional Neural Network," International Journal of Advanced Computer Science and Applications (IJACSA), 2020.
[18] Liton Chandra Paul, Abdulla Al Sumam, "Face Recognition Using Principal Component Analysis Method," International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), 2012.
[19] Puput Dani Prasetyo Adi, Yuyu Wahyu, "Performance Evaluation of ESP32 Camera Face Recognition for Various Projects," Internet of Things Applications (IOTA), 2022.
[20] Promise Elechi, Ela Okowa, Uchechukwu Ekwueme, "Facial Recognition Based Smart Door Lock System," FJSIR, 2022.

[21] Jahnavi A., Akshatha Umesh, Gowtham Raju G., Chethan S., Dr. Muzameel Ahmed, Dr. Suma V., "Facial Recognition Secure Door Operating System Using Raspberry Pi on Convolutional Neural Network," International Journal of Creative Research Thoughts (IJCRT), 2021.

[22] Teddy Surya Gunawan, Muhammad Hamdan Hasan Gani, Farah Diyana Abdul Rahman, Mira Kartiwi, "Development of Face Recognition on Raspberry Pi for Security Enhancement of Smart Home System," International Journal of Electrical and Electronic Engineering and Instrumentation (IJEEI), 2017.

[23] Ms. P. Devi, U.A. Jokindher, S. Karthik, R. Keerthivasan, "Face Detection & Recognition for Home Security System," International Journal of Research and Analytical Reviews (IJRAR), 2022.

[24] Ningthoujam Sunita Devi, K. Hemachandran, "Face Recognition Using Principal Component Analysis," International Journal of Computer Science and Information Technology (IJCSIT), 2014.

[25] Achal Meshram, Chetna Kumbhare, Snehal Chaudhari, Sejal Zade, Hemlata Dakhore, "Face Recognition Based Door Lock System," International Journal of Scientific Research in Science and Technology (IJSRST), 2022.

[26] José Ignacio Vega Luna, Gerardo Salgado Guzmán, José Francisco Cosme Aceves, Francisco Javier Sánchez Rangel, Víctor Noé Tapia Vargas, Mario Alberto Lagos Acosta, "Access System Using Facial Recognition and NFC," International Research Journal of Advanced Engineering and Science (IRJAES), 2023.

[27] Mr. Rishabh Mantri, Mr. Rohit Kalveni, Mr. Mayur Vishwakarma, Prof. Amruta B. Kale, "Door Locking System Using Face Recognition," International Research Journal of Modern Engineering and Technology (IRJMETS), 2023.

[28] Navya Saxena, Devina Varshney, "Smart Home Security Solutions using Facial Authentication and Speaker Recognition through Artificial Neural Networks," International Journal of Computer and Communication Engineering (IJCCE), 2021.

[29] Mrutyunjanya Sahani, Subhashree Subudhi, Mihir Narayan Mohanty, "Design of Face Recognition Based Embedded Home Security System," KSII Transactions on Internet and Information Systems, 2016.

[30] Sana Ghafoor, Khan Bahadar Khan, Muhammad Rizwan Tahir, Maryoum Mustafa, "Home Automation Security System Based on Face Detection and Recognition Using IoT," Springer, 2020.