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# Face Recognition-Based Door Lock Security System Using TensorFlow Lite

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**ABSTRACT**

A door security system utilizing face recognition technology based on TensorFlow Lite has been developed to enhance access security and convenience. This research aims to design a system capable of accurately recognizing faces in real time, integrating it with door lock devices, and ensuring user data security. Employing the waterfall method, the system was implemented using an ESP32-CAM microcontroller and deep learning algorithms. Testing results demonstrated a face recognition accuracy of 91% in identifying and processing commands from 200 trials with ten facial variations. Successful integration with door lock devices was achieved through serial communication. The system also features activity log recording for monitoring purposes. This solution offers greater practicality and security than RFID systems as it eliminates the need for physical cards. This research contributes to developing more sophisticated and user-friendly home security systems, with the potential for further enhancements in recognition capabilities under various lighting conditions and integration with other biometric technologies.



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## 1. INTRODUCTION

Various home security system features can be utilized and interconnected through the Internet of Things (IoT) [1]. The door lock security system is a critical aspect of securing specific areas from unauthorized access. Traditional technologies such as physical keys and digital passwords have been widely used but present vulnerabilities, such as being susceptible to hacking or loss. The use of biometrics, including voice [2], and facial recognition, offers an opportunity for technological innovation in this field. Facial recognition provides a significant opportunity to develop a more secure and convenient door security system [3], [4], [5].

Face recognition using TensorFlow Lite is a promising solution due to its ability to recognize and differentiate faces with high accuracy, even on devices with limited resources [6], [7]. TensorFlow Lite supports edge computing, enabling the efficient processing of large amounts of data [8]. Utilizing face recognition in door security systems typically involves detection and recognition stages, including the ability to recognize different expressions, poses, and angles [9], [10].

However, implementing face recognition in door security systems presents certain challenges. One such challenge is integrating this technology with door lock hardware to function efficiently and in real-time, particularly in optimizing resource usage and response time [11], [12], [13]. Additionally, personal data security and user privacy must be addressed in the development of this system.

This research aims to design and implement a face recognition-based door lock security system using TensorFlow Lite that is secure, efficient, and user-friendly. The research questions to be addressed are: (1)

How can a system be designed to recognize faces accurately and in real-time? (2) How can the face recognition system be integrated with door lock hardware? (3) How can personal data security and user privacy be ensured?

The benefits of this research include improving the security and convenience of door lock systems by leveraging face recognition technology. Furthermore, this research can serve as a reference for the future development of other biometric-based security systems.

## 2. METHOD

This research adopts the waterfall method, which consists of several stages: requirements analysis, design, implementation, testing, and maintenance.

1. **Requirements Analysis**: In this stage, TensorFlow Lite was used to analyze the functional and non-functional requirements of the face recognition-based door lock security system. Functional requirements include detecting and recognizing faces, integrating with door lock devices, and managing user data. Non-functional requirements cover processing speed, data security, and a user-friendly interface [14], [15], [16].
2. **Design**: The design phase was a meticulous process that involved creating the system architecture, database, user interface, and hardware components. The system architecture was designed with precision to seamlessly integrate the face recognition module using TensorFlow Lite with the door lock device, ensuring a robust and efficient structure.
3. **Implementation**: In the implementation stage, the system was developed according to the design. The face recognition module using TensorFlow Lite was developed with a focus on processing speed and facial recognition accuracy.
4. **Testing**: After implementation, the system's functionality and performance are tested. Functional testing was conducted to ensure that the system can correctly detect and recognize faces and integrate with the door lock device. Performance testing measured processing speed, facial recognition accuracy, and data security.
5. **Maintenance**: The final stage of the waterfall method is system maintenance. In this stage, errors or bugs discovered during testing are fixed, and new features are added if necessary.

To ensure the validity and reliability of the research results, measurements were taken using relevant metrics, such as facial recognition accuracy, system response time, and data security level. The measurements are compared with similar systems or industry standards.

### 2.1. Device Design

The face recognition-based door lock security system, a beacon of accuracy, was developed using TensorFlow Lite and the ESP32-CAM microcontroller [17]. The system implementation involves several components, including software for facial recognition and natural language processing using Python and hardware for door access control using the Arduino IDE.

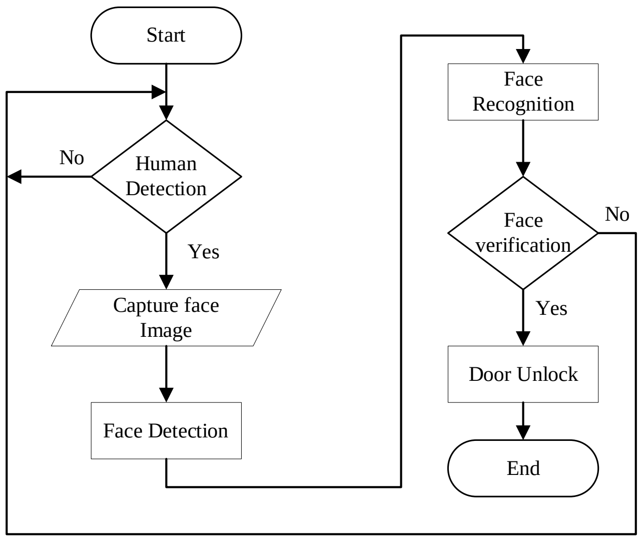


Figure 1. Flow Diagram of the Face Recognition-Based Door Lock Security System

The system flow diagram in Figure 1 illustrates the process, which begins with face detection by the ESP32-CAM camera. TensorFlow Lite processes the captured image to identify the user's face. Afterward, the system checks the user's face against the database and determines the appropriate action to unlock or lock the door.

Table 1. The connection of component pin

| from PIN | to PIN |
|---|---|
| $V_{in}$ (5V) ESP32-CAM | USB to TTL Converter |
| GND ESP32-CAM | GND USB to TTL Converter |
| U0R ESP32-CAM | TX USB to TTL Converter |
| U0T ESP32-CAM | RX USB to TTL Converter |
| GPIO2 ESP32-CAM | IN Relay |
| Relay VCC | Vin (5V) USB to TTL Converter |
| Relay GND | GND USB to TTL Converter |
| Relay NC | VCC Power Supply |
| Relay COM | Positif Solenoid Door Lock |
| Negatif Solenoid Door Lock | Negatif Power Supply |

The electronic circuit in Figure 2 uses the ESP32-CAM microcontroller as the system's core. The connection of each component is critical to ensuring optimal system performance in the development of the face recognition-based door lock security system using TensorFlow Lite. Table 1 shows the connection of component pin on this system.

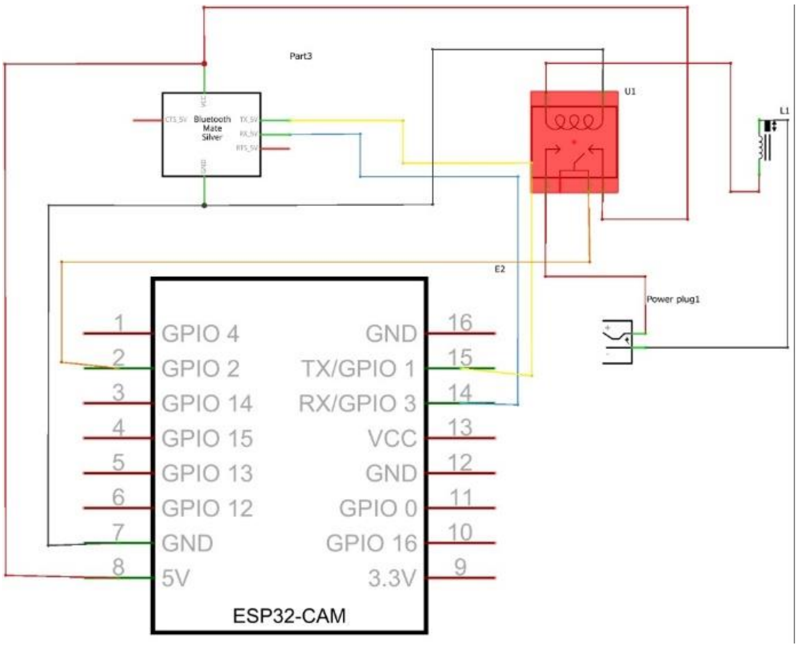


Figure 2. Schematics diagram of ESP32-CAM

## 2.1. System Block Diagram

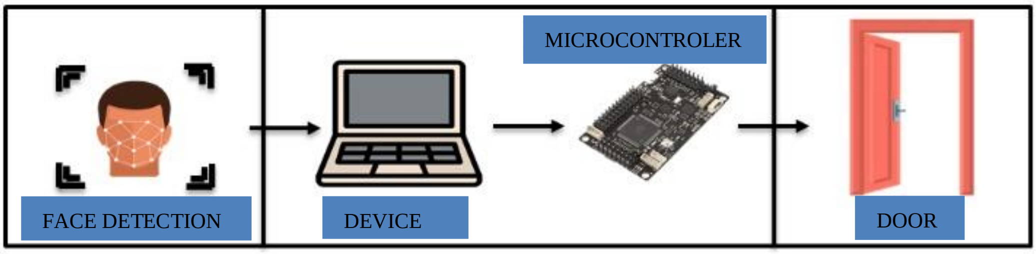


Figure 3. Block Diagram of the Face Recognition-Based Door Lock Security System

The block diagram in Figure 3 shows the system detecting faces using TensorFlow Lite. The system then checks the user's face and identifies the command. The identified command is sent to the ESP32-CAM to either unlock or lock the door.

## 3. RESULTS AND DISCUSSION

### 3.1. Result

The research results involved training data to obtain a model with reasonable accuracy from the collected facial dataset. One of the evaluation criteria for the face recognition system is accuracy (ACC), calculated from equation (1), where accuracy is determined by the ratio of the number of correctly recognized faces (True Positives, TP) to the total number of faces in the dataset (True Data) [13].

$$ACC = \frac{TP}{True\ Data} \quad (1)$$

The system experiments were conducted to ensure that each component worked as intended in the face recognition-based door lock security system using TensorFlow Lite, addressing security, efficiency, and user convenience challenges. The research findings are as follows:

1. **Face Recognition Performance**: The face recognition module, implemented with TensorFlow Lite, achieved an impressive accuracy rate of 92% in recognizing registered users' faces. This high level of accuracy, a testament to the system's robustness, was achieved by applying deep learning algorithms that effectively learn and distinguish facial features.
2. **Integration with Door Lock Hardware**: The developed system was successfully integrated with the door lock hardware via serial communication. The system's response time to unlock the door after recognizing a user's face was less than 2 seconds, meeting the real-time requirements for an entrance security system.


Figure 4. Face model dataset.

Figure 4 displays a face model dataset for testing a face recognition-based door lock security system. The figure consists of images showing the faces of registered users within the system, each labeled with a unique identifier, like "[0] Vrazsa," "[1] Rama," "[2] Haris," "[3] Edward," "[4] Mutiara," and unknown faces not specified in the dataset, to demonstrate the system's ability to recognize and distinguish between different individuals.

### 3.2. Discussion

If the model training uses Firebase ESP32 IOXhop with the Camera Web Server, the model testing showed that there were 182 correct predictions (True Positives, TP). The confusion matrix in Figure 5 provides further details regarding the TP prediction results. Figure 5 displays a confusion matrix for a face recognition model trained using TensorFlow Lite. Using the matrix to evaluate the model's performance in identifying individuals based on facial features. The rows represent the true data (actual identities of individuals), while the columns represent the predicted data (identities predicted by the model). Each cell in the matrix shows the number of times a particular identity (name on the row) was predicted to be another (name on the column). Correct predictions are located along the diagonal from the top left to the bottom right, where the numbers show how many times the model correctly identified each individual. The cells off the diagonal represent misclassifications, where the model incorrectly identified one person as another. The color gradient represents the scale of the values, with darker colors indicating higher numbers, emphasizing the frequency of correct predictions versus errors.

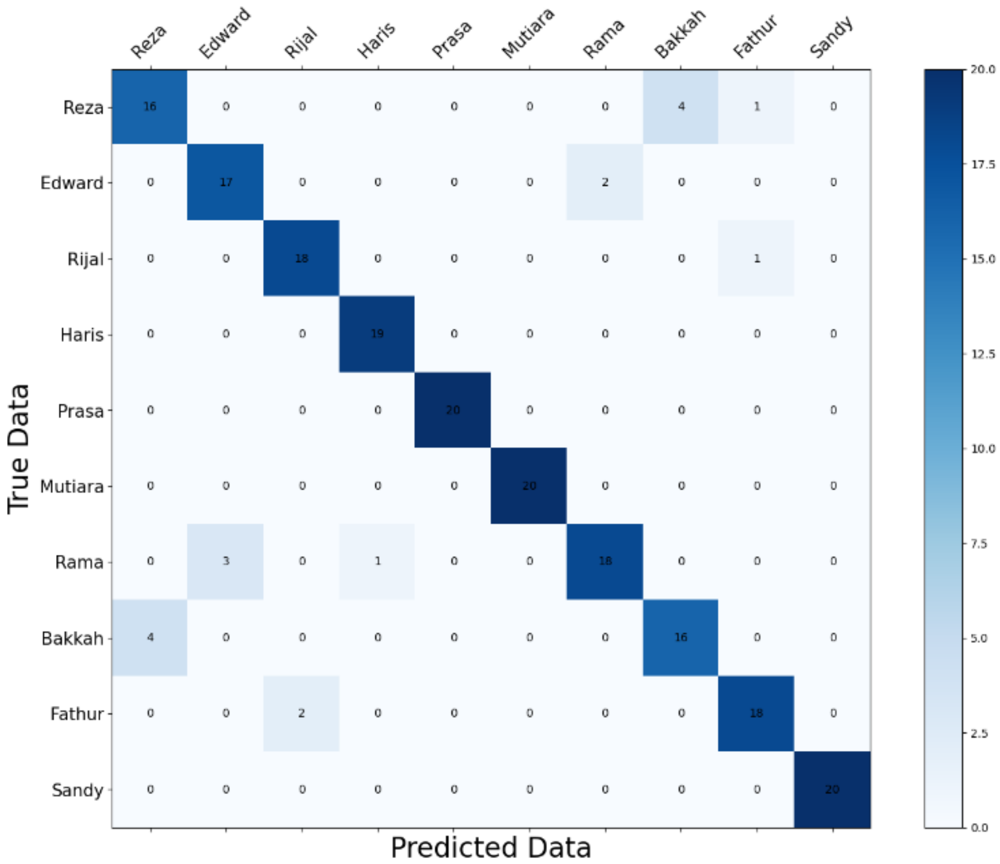


Figure 5. Model training of face recognition using tensorflow lite

The actual labels represent the true test data (True Data), while the predicted labels are the model's predicted outcomes (Predicted Data). Based on the test results above, the following result can be concluded:

$$accuracy = \frac{182}{200} = 0.91\ x\ 100\% = 91\%$$

The results from the model training indicate that the more training iterations are conducted, the more the accuracy level can be determined.

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| Reza | 0.80 | 0.76 | 0.78 | 21 |
| Edward | 0.85 | 0.89 | 0.87 | 19 |
| Rijal | 0.90 | 0.95 | 0.92 | 19 |
| Haris | 0.95 | 1.00 | 0.97 | 19 |
| Prasa | 1.00 | 1.00 | 1.00 | 20 |
| Mutiara | 1.00 | 1.00 | 1.00 | 20 |
| Rama | 0.90 | 0.82 | 0.86 | 22 |
| Bakkah | 0.80 | 0.80 | 0.80 | 20 |
| Fathur | 0.90 | 0.90 | 0.90 | 20 |
| Sandy | 1.00 | 1.00 | 1.00 | 20 |
| accuracy | | | 0.91 | 200 |
| macro avg | 0.91 | 0.91 | 0.91 | 200 |
| weighted avg | 0.91 | 0.91 | 0.91 | 200 |

Figure 6. Evaluation of Precision, Recall, and F1-Score

Based on the data in Figure 6, the values for precision, recall, and F1-Score can be determined. Figure 6 shows the overall classification results, where each class indicates its corresponding precision, recall, and F1-Score values.

Table 2. Result of system testing

| No | Condition | Description | Door Lock |
|---|---|---|---|
| **1** |   | Vrazsa, OK | Open |
| **2** |   | Rama, OK | Open |
| **3** |   | Haris, OK | Open |
| **4** |   | Edward, OK | Open |
| **5** |   | Mutiara, OK | Open |
| **6** |   | Unknown, Failed | Close |

After obtaining the dataset model, the next step is to implement it on the ESP32-CAM device. The model dataset is loaded along with the TensorFlow Lite algorithm to detect facial images from the camera and classify them against the dataset in real-time. Table 1 presents the results of the experimental trials.

## 4. CONCLUSION

This research successfully developed a face recognition-based door lock security system using TensorFlow Lite, which can accurately recognize and process faces to unlock or lock doors with high success rates. The system operates efficiently and reliably by utilizing the ESP32-CAM microcontroller and integrating hardware components such as relays and solenoid door locks. The results of 200 tests involving ten facial variations demonstrated the system's strong ability to recognize and process face recognition commands. Additionally, the system recorded activity logs with an accuracy rate of 91%, providing valuable information for further monitoring and analysis. This system offers a more practical and secure solution than RFID-based door lock systems, eliminating the need for cards or tags that can be lost or damaged. Future studies will improve face recognition in various light conditions and integrate it with other biometric recognition technology.

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## REFERENCES

[1] H. Touqeer, S. Zaman, R. Amin, M. Hussain, F. Al-Turjman, and M. Bilal, "Smart home security: challenges, issues and solutions at different IoT layers," *Journal of Supercomputing*, vol. 77, no. 12, 2021, doi: 10.1007/s11227-021-03825-1.

[2] M. Syafrizal, V. Ikawati, A. Siswanto, and N. Lestari, "SISTEM KEAMANAN DOOR LOCK BERBASIS VOICE RECOGNITION DENGAN NATURAL LANGUAGE PROCESSING," *Infotronik : Jurnal Teknologi Informasi Dan Elektronika*, vol. 9, no. 1, Jun. 2024, Accessed: Sep. 18, 2024. [Online]. Available: https://jurnal.usbypkp.ac.id/index.php/infotronik/article/view/3611

[3] O. E. Adetoyi and B. P. Awe, "Face Recognition Enabled Door Access Control System," *FUOYE Journal of Engineering and Technology*, vol. 7, no. 1, 2022, doi: 10.46792/fuoyejet.v7i1.656.

[4] N. Harke, A. Patil, Y. Nimbalkar, S. Khore, and Prof. S. Rathod, "Smart Door Lock System Using Face Recognition," *Int J Res Appl Sci Eng Technol*, vol. 10, no. 5, 2022, doi: 10.22214/ijraset.2022.43015.

[5] A.- Suryansah, R.- Habibi, R. M. Awangga, and Rd. N. S. Fatonah, "Implementasi Face Recognition Untuk Mengakses Ruangan," *Jurnal MediaTIK*, vol. 3, no. 3, 2020, doi: 10.26858/jmtik.v3i3.15176.

[6] M. J. Cypto, B. Yaswanth, S. Charan, K. Suresh, and K. Vishal, "Live Object Detection Using Flutter," *International Journal of Advances in Engineering and Management (IJAEM)*, vol. 4, 2022.

[7] R. Wijaya, A. S. Prihatmanto, A. Sukoco, M. Syahfirin, and M. Shusanti, "BIODIVERSITY CONSERVATION MONITORING SYSTEM IMAGE DETECTION USING TENSORFLOW," *ARPN Journal of Engineering and Applied Sciences*, vol. 15, no. 6, 2020.

[8] M. Z. Khan, S. Harous, S. U. Hassan, M. U. Ghani Khan, R. Iqbal, and S. Mumtaz, "Deep Unified Model for Face Recognition Based on Convolution Neural Network and Edge Computing," *IEEE Access*, vol. 7, 2019, doi: 10.1109/ACCESS.2019.2918275.

[9] A. H. T. Al-Ghrairi, A. A. Mohammed, and E. Z. Sameen, "Face detection and recognition with 180 degree rotation based on principal component analysis algorithm," *IAES International Journal of Artificial Intelligence*, vol. 11, no. 2, 2022, doi: 10.11591/ijai.v11.i2.pp593-602.

[10] S. Liu, Y. Song, M. Zhang, J. Zhao, S. Yang, and K. Hou, "An identity authentication method combining liveness detection and face recognition," *Sensors (Switzerland)*, vol. 19, no. 21, 2019, doi: 10.3390/s19214733.

[11] N. Lestari, T. Purnama, S. Risnanto, B. Fitriadi, A. M. H. Yusuf, and A. S. Prihatmanto, "Asynchronous Data Communication Architecture on Real-Time Face Recognition for Hybrid Laboratory System," in *2023 17th International Conference on Telecommunication Systems, Services, and Applications (TSSA)*, IEEE, Oct. 2023, pp. 1–5. doi: 10.1109/TSSA59948.2023.10366951.

[12] A. Baobaid, M. Meribout, V. K. Tiwari, and J. P. Pena, "Hardware Accelerators for Real-Time Face Recognition: A Survey," *IEEE Access*, vol. 10, 2022, doi: 10.1109/ACCESS.2022.3194915.

[13] L. Li, X. Mu, S. Li, and H. Peng, "A Review of Face Recognition Technology," *IEEE Access*, vol. 8, 2020, doi: 10.1109/ACCESS.2020.3011028.

[14] N. S. Irjanto and N. Surantha, "Home Security System with Face Recognition based on Convolutional Neural Network," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 11, 2020, doi: 10.14569/IJACSA.2020.0111152.

[15] M. Badgujar, A. Wagh, S. Chavan, P. Chumbhale, and R. C. Sonawane, “Iot Based Automatic Door Lock System By Face and Voice Recognition,” *International Research Journal of Modernization in Engineering Technology and Science*, no. 03, 2022.

[16] K. S. Salamah, L. A. Setiyawan, and I. U. V. Simanjuntak, “Design of Smart Home Security System With Face Recognition And Voice Command Based On Internet of Things,” *ELKHA*, vol. 15, no. 1, 2023, doi: 10.26418/elkha.v15i1.62042.

[17] M. Kelvin Difa and J. Endri, “Implementasi Sistem Pengenalan Wajah Sebagai Automatic Door Lock Menggunakan Modul ESP32 CAM,” *PATJou (PATRIA ARTHA Technological Journal)*, vol. 5, no. 2, 2021.