<u>Original Research Article</u>

Facial Recognition-Based Entry System for Student Residence Halls: Enhancing Security and Accessibility

Abstract—
Protecting an organization from numerous threats both inside and outside is the primary function of the security system. Automated embedded systems have come a long way in the contemporary era and have shown to be highly beneficial in applications related to security and surveillance. Face recognition is one of the study fields in computer vision, which is commonly used in security systems for video surveillance. Even though facial recognition technology has advanced significantly and is employed in several significant applications, numerous challenges need to be solved. These challenges include changes in posture, occlusions, expression, aging, lighting, and other elements. Deep learning can be useful in these situations. By using several processing layers to develop data representations with multiple feature extraction layers, deep learning may achieve higher accuracy. With the purpose of providing better security for student residence halls, in this work, we present a real-time deep learning-based facial recognition system that can be used to identify an individual's identity and give a warning when the individual's face is not recognized in front of the system. Here, faces from the face database are matched in order to identify students based on a video of their arrival into the residence halls. This process begins with face detection and ends with face recognition. We used a Convolutional Neural Network (CNN) based model Multi-Task Cascaded Convolutional Neural Networks (MTCNN) for face detection and recognizing faces using the Google FaceNet model. The model was trained on around 330 photos, taken by 30 distinct people.

Keywords: Video-based Face detection, Face Recognition, Convolutional Neural Network (CNN), FaceNet model.

1. INTRODUCTION

Facial recognition has gained increasing interest in recent years due to the rapid growth of artificial intelligence. Face recognition is more advantageous than conventional card recognition, fingerprint recognition, and iris recognition. These benefits include high concurrency, non-contact nature, and user-friendliness. It has a great deal of potential for usage in public spaces, governance, e-commerce, security, retail, education, and many other sectors. Conventional facial recognition techniques model faces with feature operators, which are straightforward and simple to use. With more investigation, these algorithms may prove to be quite successful in identifying linear structures, but they frequently provide inadequate identification outcomes when dealing with possible nonlinear structures.

Face recognition has advanced significantly in terms of accuracy, speed, and nonlinear structures with the introduction of deep learning and deep convolutional neural networks. Yet the outcomes from various deep learning models and networks range greatly from one another. According to Taigman et al. [1]earlier deep network-based face recognition techniques employ a classification layer and see face recognition as a classification job. As a result, the entire model must be retrained each time a new sample is received. Although FaceNet uses a triplet-based loss function to directly train its output to be a compact 128-D embedding [2]. This method has the advantage of substantially higher representational efficiency because it only requires 128 bytes per face to deliver state-of-the-art face recognition performance. Therefore, we model faces using FaceNet, a 128-dimensional vector, and then utilize vector distance to recognize faces. We initially do face detection using MTCNN in order to attain higher results [3]. MTCNN network is a popular target detection network that is lightweight, real-time, and has a high detection accuracy. Then, to conduct facial recognition, utilize the output of MTCNN as the input for the FaceNet model. Therefore, face detection and face recognition are the two primary processes in our face recognition procedure.

The facial recognition system that is suggested in this study records video streams using a camera. It has the ability to automatically identify and track faces in images, determine the identification of an individual, and then transfer that identity information to security modules for further use. Finally, the security module determines if the individual is unfamiliar and issues a warning if they are.

A. Motivation

Financial, client, and intellectual property data can be stolen via unauthorized access. The reputation of any individual or group might be harmed by this. Operations may be halted by interfering with computer networks or systems. Resources and time might be squandered. Fraud risk is also increased by unauthorized access. In this case, face recognition may confirm users' authorization prior to granting entry to a secure system or area. Unauthorized access and trespassing can be identified and stopped by the system. Intruders are immediately identified via facial recognition. In a variety of circumstances, it can limit access and enhance security. Unlike fingerprint or iris scanning, face recognition allows authentication without ever touching the device. Face recognition is therefore more precise and dependable now.As a result, businesses may more readily implement face recognition technology to improve security. Facial recognition technology can automate the authentication procedure. As a result, real-time facial recognition systems are anticipated to be in high demand for access control. These systems will be helpful not only in investigating illegal activity but also in putting an end to it.

Face recognition technology in student residence halls offers a high degree of security as it is hard to fake or spoof someone. Limiting access to the resident hall to just approved students and personnel helps lower the possibility of theft, unlawful entry, and intruders. Face recognition makes it possible to keep track of when residents and staff enter and leave the residence hall, which enhances accountability and facilitates better monitoring of who enters and leaves.

2. Related work

Recently, research on face detection and identification has been done by multiple institutions throughout the globe. A real-time, GUI-based automated Face detection and identification system was created by D. Mary Prasanna et al. [4] utilizing OpenCV. Feature extraction, recognition, and detection are the three stages of the system. The system recognizes faces in

photos taken using a webcam and extracts 128 facial attributes from those images using a deep neural network technique. The identification process is then carried out using a support vector machine, or SVM classifier. To lower the dimensionality of facial images, the system applies the Histogram of Oriented Gradients (HOG) technique. The system's average detection accuracy of 75% was achieved during testing on 60 photos. The study does not address the system's performance with a high number of users or photos. Limitations of the Open Face tool, such as its sensitivity to changes in position and lighting conditions, are not discussed in the research.
M. H. Khairuddin et al. [5] suggested a smart building security system with intelligent face detection and identification. The hardware design and the software design make up the two separate parts of the system. The devices, which included a Raspberry Pi 3 and a camera sensor, were in charge of recognizing and detecting human presence. The software design step involved utilizing HTML and a cloud storage infrastructure, primarily Dropbox, to store the captured photographs. The efficiency of the system was assessed by contrasting the photos that were taken and stored in Dropbox and Cloudinary, two instances of cloud storage. The findings showed that Dropbox is better in terms of both the performance features and the quality of the images that it generates.

In order to identify an appropriate face identification approach, Mayank Chauhan et al. [6] investigated a number of various face detection techniques that are already in use. To evaluate and contrast the various methodologies, some evaluation metrics that may be utilized include the learning time, the execution time, the number of samples needed for training, and the detection rate vs false alarm ratio. The paper provides a theoretical evaluation of various current approaches based on important factors. Among these techniques are Geometric-based Face Detection and Haar-like Feature-based Face Detection. The advantages and disadvantages of a number of currently used techniques, including feature-based face detection, geometric face detection, and Haar-like feature-based face detection, are also covered in the study.

Ilhan Aydin et al.'s method [7] combines computer vision and the Internet of Things to identify faces. The camera and passive infrared (PIR) sensor in the suggested system cooperate to detect motion and take images. Following the application of computer vision algorithms to these photographs, faces are detected, and the resulting images are sent to a mobile device for viewing. The system's hardware components include the Raspberry Pi 3, a PIR sensor, a Raspberry Pi camera, a smartphone, SD card memory, and a power source. The face detection technique utilized in the work is based on the Viola-Jones approach. The accuracy of the results decreases proportionately with the amount of datasets. When five photos are used, the accuracy rate is 100%. However, when 25 photos are being evaluated, the accuracy is 97.36%. No precise quantitative statistics or performance measures for the suggested approach are provided in the study. The face detection technique is discussed in the literature without any explicit mention of the use of any specific dataset or training data.

AnshunRaghuwanshi and colleagues [8] put out and contrasted methods for a video-based facial recognition automatic attendance system. It offers a more effective and precise way to track attendance by using biometric facial recognition technology to identify and register students' attendance from a video. Initially, Face Detection is employed to distinguish faces from other objects. The discovered face is then compared to a list of students' names and photos in the face database using Face Recognition. The number of attendees is recorded on an Excel sheet if there is a valid match. Face recognition is completed with the aid of the Principle Component Analysis (PCA) and Linear Discriminant Analysis (LDA) algorithms, and the results are compared according to how well they perform. The 400 photos in the ORL database, with 10 photos devoted to each of the 40 subjects, are used for the experiment. By contrast, there are just 25 photos in the class database, five of which are assigned to each individual. In contrast, PCA's accuracy is just 66.07% and 53.33%, respectively, while LDA's is 83.57% for the ORL database and 60% for the class database.

A real-time facial recognition system for home security service robots was presented by Jiakailin Wang et al. [9]. It may be used to identify a person's face in front of the robot and issue a warning when the person's identity is unknown. The research suggests a novel alignment technique that increases the accuracy of the system by cropping and aligning images based on the position of people's eyes. The face area was chopped off and faces were located using Local Binary Patterns (LBP). The Labelled Faces in the Wild (LFW) database is tested using Eigenfaces, Fisherfaces, and the Support Vector Machine (SVM). Eigenfaces have a 59% precision, Fisherfaces an 81% precision, and SVM an 86% precision. The approach is predicated on a face database comprised of raw images of every family member's face, which could not accurately reflect the range of faces encountered in everyday life. The study notes that a number of variables, including angle, size, lighting, and surroundings, make it difficult to completely eradicate human face recognition mistakes.

Soniya V et al. [10] created a system that tracks a student's attendance on a regular basis and automatically recognizes when they enter the classroom. This system has the potential to be a very effective and dependable attendance system as it records the exact times of students' arrivals and departures and maintains an accurate attendance log. The system is built and maintained with Arduino, which enables the automated recording of student attendance. To locate and identify faces, the PCA (Principal Component Analysis) technique is employed. The attendance records of the children may be securely tracked by the system in one single spot. The study does not include information on the facial recognition algorithm that was utilized, including the precise methods or models for face detection, feature extraction, and matching. A significant flaw in the article is the lack of comprehensive information on the accuracy and functionality of the attendance automation system.

In order to increase security and dependability, Zhu Zhiguo et al. [11] consider integrating facial recognition using OpenCV and an Efficient Attitude Tracking Algorithm (EATA) in smart door locks. Since face recognition technology eliminates the need for passcodes or keys, door locks with this feature can be a useful security precaution. The experimental findings demonstrate the 94.5% accuracy of the suggested EATA methodology in comparison to baseline techniques, indicating its reliability. The suggested Efficient Attitude Tracking Algorithm (EATA) was shown to have an accuracy of 94.5%, an efficiency of 96.23%, a performance of 97%, and a precision ratio of 95.45% when compared to industry-standard techniques such as ANFIS, FBPCA, JWSC, HCCA, and LBPH.

3. Proposed Methodology

The objective of this project is to integrate deep learning with a Webcam or CCTV camera-based real-time face recognition system for student residence halls. The following stages have been processed by the system in order for it to comply with the particular methods used in this work: Establishing a Facial Database, Capturing Videos, Detecting Face, Recognizing Faces and Save Entry Information.The flow chart in figure 1 shows the completeworkflow.

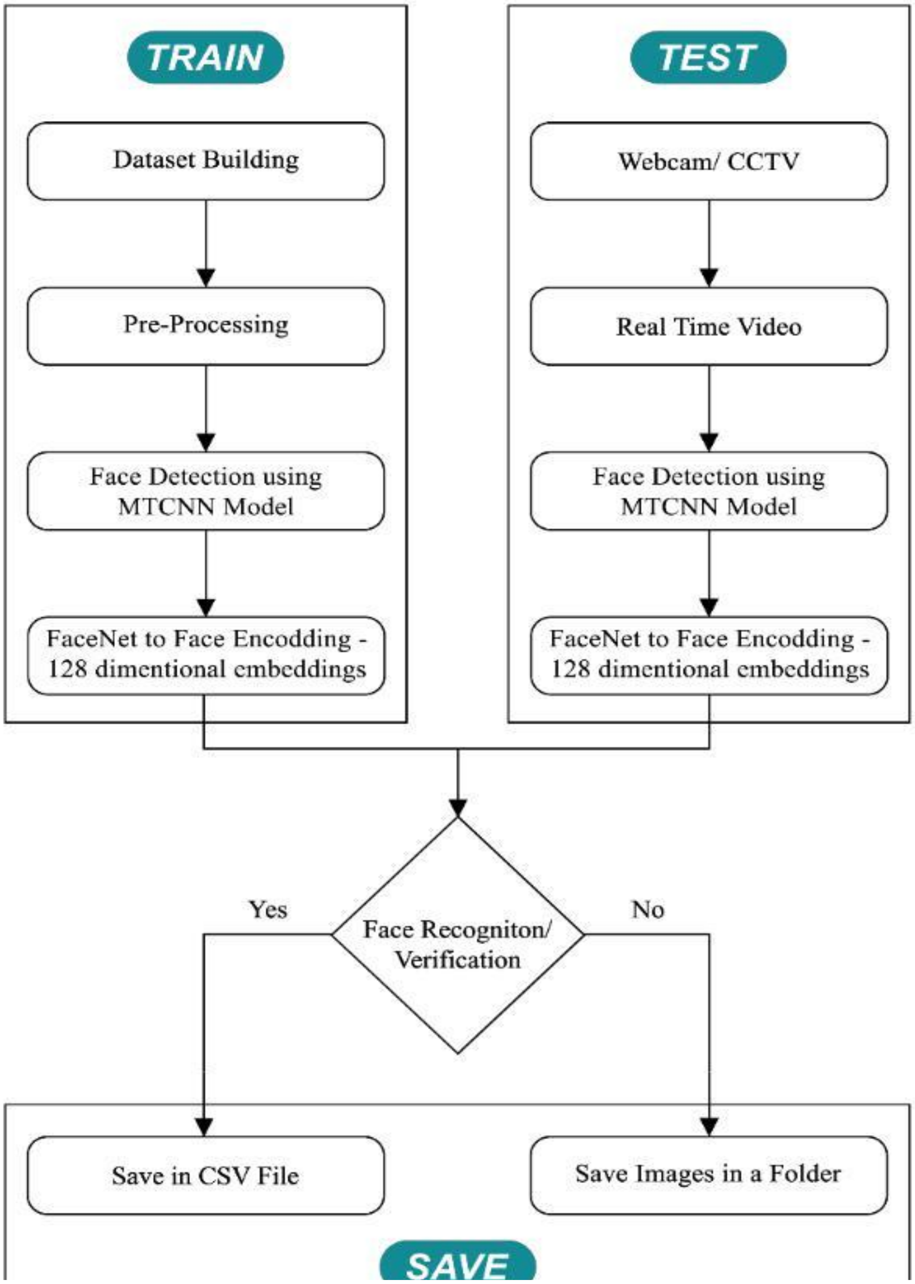

Figure 1: Framework of the Proposed System

3.1 Establishing a Facial Database

The data collection method has been created to enable us to take images of individuals and build our dataset such that it includes images of registered students. In this case, there are 30 students, and the system that gathers student photographs consists of 10 images for each student. The system has 300 photos in total. Deep neural networks cannot be successfully applied without large-scale datasets. By applying a sequence of arbitrary modifications to the training images, the image augmentation method produces training examples that are similar yet distinct, increasing the training dataset's size. Altering the training samples at random can also help the model become less dependent on certain features and increase its capacity for generalization. To improve the predictability of the model, we choose to apply image augmentation to datasets that include random operations during training, resulting in a total of 3000 pictures. where each student has a hundred pictures. Here, we employ a variety of techniques, such as mirror flipping, random fixed ratio cropping, 45° left and right turns, etc. A few examples are shown in figure 2.

Figure 2: Dataset Sample

3.2 Video Recording

As we previously explained, in order to achieve effective detection and recognition, we need a very high-quality camera. Its drivers need to be installed correctly, and it has to be linked to the computer. The video is captured for a short while as soon as the camera is turned on, and then it is further processed to identify faces.

3.3 Face Detection

The system reads the frames after receiving the video. It obtains the frame and transmits it for facial detection once the reading stops. This detection work uses the MTCNN model, which is based on the CNN algorithm, for face detection. Three CNNs make up the network structure of MTCNN; they are seen in figure3, respectively. The MTCNN processing pipeline is as follows: To begin creating the picture pyramid, the test image is first repeatedly scaled to various dimensions. After that, the P-Net is fed the picture pyramid to obtain a huge number of potential face windows and the bounding box regression vectors associated with them. Next, we combine heavily overlapped candidates using non-maximum suppression (NMS). The candidate photos that P-Net has already screened are then further refined by R-Net, which eliminates even more incorrect candidates. The photos are sent to O-Net once R-Net has eliminated a large number of candidates. O-Net's primary job is to produce the final face regression box and the facial key point locations. Many non-face windows are filtered using P-Net and R-Net, and further distinct features are extracted using O-Net. The O-Net output is used as the MTCNN's final detection result.

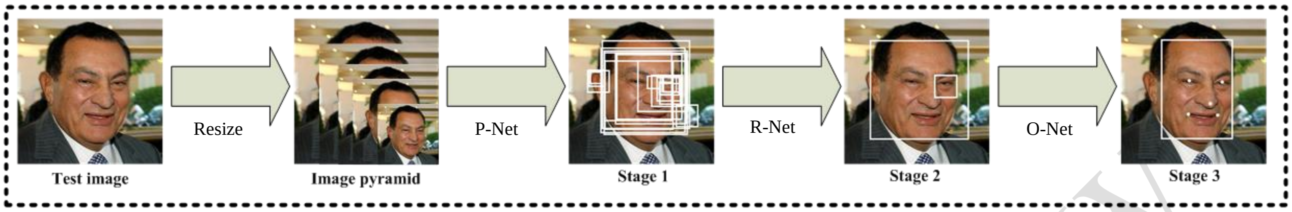

Figure 3: MTCNN network architecture.

3.4 Face Recognition

This, the most essential module in our system, compares test images with training images in order to identify particular students. Many algorithms may be used to carry out the recognition process, however, FaceNet is used in this case. FaceNet uses a triplet-based loss function to directly train its output to be a compact 128-D embedding.FaceNet can use various types of convolutional neural networks as the main body according to requirements, and its main feature is to use the Triplet Loss function for gradient descent. The FaceNet model structure, which is split into five sections, is seen in figure 4. The batch input layer makes up the first component, while the deep CNN structure, which is utilized to extract facial characteristics, makes up the second. After normalizing the features, the L2-Norm is obtained in the third section. In the fourth section, embedding is used to acquire the vector of the face features. In the fifth and final section, the Triplet Loss function is used to compute the training loss. Every optimization aims to reduce the between-class distance while maintaining the within-class distance. Similar faces are mapped to similar areas using the Triplet Loss. Once images are embedded, the processed images are stored in a .pkl file.

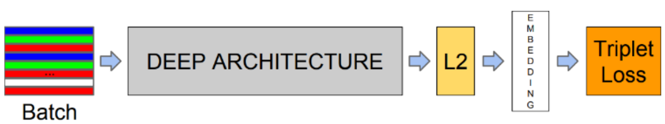

Figure 4: FaceNet model architecture.

3.5 Save the Information

After completing the face recognition module, the student's information is registered. When a face is identified, a CSV file including the name, arrival time, and date of the identified individual is created. A warning will appear and the photos will be saved with the arrival time and date if a face does not match.

4. Result Analysis

The implementation of the Facial Recognition-Based Entry System in student residence halls has had a profound impact on enhancing security and accessibility. In this section, we focus on the key findings and outcomes of this system's deployment, illustrating its effectiveness and its implications for the security and accessibility of these residential spaces. With an average processing speed of less than one second per frame, the system was able to function in real-time. The video frame can identify human names that are recorded in the dataset, and it will automatically show "Unknown" for anyone who is not allowed. The system can perform well in a range of illumination and face orientation situations. Figure 5 presents the outputs of recognition for both known and unknown individuals.

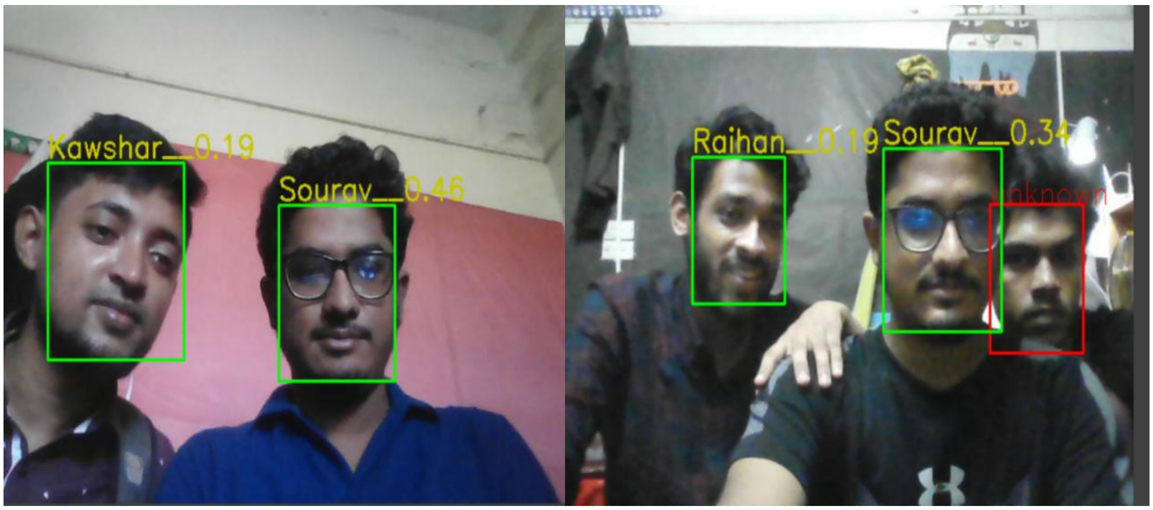

Figure 5: Sample output of the system.

The arrival times and dates of individuals are saved by this system in a CSV file for both known and unknown cases that are shown in figure 6.

	A	B	C
1	**Name**	**Time**	**Date**
2	Sourav	13:02:03	8-Oct-23
3	Sourav	17:10:36	8-Oct-23
4	Sourav	23:16:00	12-Oct-23
5	Sabbir Sir	11:15:10	18-Oct-23
6	Sabbir Sir	11:18:29	18-Oct-23
7	Sourav	11:11:50	1-Nov-23
8	Sourav	11:12:54	1-Nov-23
9	Kawshar	11:13:02	1-Nov-23
10	Sabbir Sir	11:13:04	1-Nov-23

Figure 6: Sample CSV file.

5. Conclusion

Facial recognition-based entry systems have the potential to improve student residence security and accessibility. It can enhance entrance and exit efficiency, and assist in preventing unwanted access to residence halls.The development of a smart hall security system with intelligent face detection and recognition is the main objective of this work. Real-time facial recognition should be possible with the designed technology. Through this research, we were able to learn about a variety of facial recognition techniques. This study presents a real-time face recognition system that combines face detection and recognition, which may be used for any security service. Future research will concentrate on expanding our comprehension of the mistake scenarios, refining the model, and minimizing CPU usage and model size. Additionally, we will investigate how to make the difficulties posed by an unpredictable environment better.

REFERENCE

[1] Taigman, Yaniv, Ming Yang, Marc'AurelioRanzato, and Lior Wolf. "Deepface: Closing the gap to human-level performance in face verification." In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 1701-1708. 2014.

[2] Schroff, Florian, Dmitry Kalenichenko, and James Philbin. "Facenet: A unified embedding for face recognition and clustering." In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 815-823. 2015.

[3] Zhang, Kaipeng, Zhanpeng Zhang, Zhifeng Li, and Yu Qiao. "Joint face detection and alignment using multitask cascaded convolutional networks." *IEEE signal processing letters* 23, no. 10 (2016): 1499-1503.

[4] D. M. Prasanna and C. G. Reddy, "Development of Real-Time Face Recognition System Using OpenCV," *International Research Journal of Engineering and Technology (IRJET)*, vol. 04, no. 12, pp. 791-798, 2017.

[5] Khairuddin, M. H., S. Shahbudin, and M. Kassim. "A smart building security system with intelligent face detection and recognition." In *Iop conference series: Materials science and engineering*, vol. 1176, no. 1, p. 012030. IOP Publishing, 2021.

[6] M. Chauhan and M. Sakle, "Study & Analysis of Different Face Detection," *International Journal of Computer Science and Information Technologies,* vol. 5, no. 2, pp. 1615-1618,2014.

[7] Aydin, Ilhan, and Nashwan Adnan Othman. "A new IoT combined face detection of people by using computer vision for security application." In *2017 International Artificial Intelligence and Data Processing Symposium (IDAP)*, pp. 1-6. IEEE, 2017.

[8] Raghuwanshi, Anshun, and Preeti D. Swami. "An automated classroom attendance system using video based face recognition." In *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, pp. 719-724. IEEE, 2017.

[9] Wang, Jiakailin, Jinjin Zheng, Shiwu Zhang, Jijun He, Xiao Liang, and Sui Feng. "A face recognition system based on local binary patterns and support vector machine for home security service robot." In *2016 9th international symposium on computational intelligence and design (ISCID)*, vol. 2, pp. 303-307. IEEE, 2016.

[10] Soniya, V., R. Swetha Sri, K. Swetha Titty, R. Ramakrishnan, and S. Sivakumar. "Attendance automation using face recognition biometric authentication." In *2017 International Conference on Power and Embedded Drive Control (ICPEDC)*, pp. 122-127. IEEE, 2017.

[11] Zhu, Zhiguo, and Yao Cheng. "Application of attitude tracking algorithm for face recognition based on OpenCV in the intelligent door lock." *Computer Communications* 154 (2020): 390-397.

[12] Chunming Wu and Ying Zhang, “MTCNN and FACENET Based Access Control System for Face Detection and Recognition,” *Automatic Control and Computer*

Sciences, vol. 55, no. 1, pp. 102–112, Jan. 2021, doi: https://doi.org/10.3103/s0146411621010090.

[13] Jin, Rongrong, Hao Li, Jing Pan, Wenxi Ma, and Jingyu Lin. "Face recognition based on MTCNN and Facenet." (2021)

[14] M. R., R. Y., R. R. and S. A., "Smart Home Security System using IoT, Face Recognition and Raspberry Pi," *International Journal of Computer Applications*, vol. 176, no. 13, pp. 45–47, Apr. 2020, DOI: https://DOI.org/10.5120/ijca2020920105.

[15] Mahler, Michael A., Qinghua Li, and Ang Li. "SecureHouse: A home security system based on smartphone sensors." In *2017 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, pp. 11-20. IEEE, 2017.

[16] Dhanisha, G., J. Monika Seles, and dan E. Brumancia. "Android interface based GCM home security system using object motion detection." In *2015 International Conference on Communications and Signal Processing (ICCSP)*, pp. 1928-1931. IEEE, 2015.

[17] Nayyar, Chetana, B. Valarmathi, and K. Santhi. "Home security and energy efficient home automation system using arduino." In *2017 International Conference on Communication and Signal Processing (ICCSP)*, pp. 1217-1221. IEEE, 2017.

[18] Rao, Bandi Narasimha, and Reddy Sudheer. "Surveillance camera using IOT and Raspberry Pi." In *2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA)*, pp. 1172-1176. IEEE, 2020.

[19] Chowdhury, Md Nasimuzzaman, Md Shiblee Nooman, and Srijon Sarker. "Access control of door and home security by raspberry pi through internet." *Int. J. Sci. Eng. Res* 4, no. 1 (2013): 550-558.

[20] Das, Arundhati, MameetaPukhrambam, and Ashim Saha. "Real-time robust face detection and tracking using extended haar functions and improved boosting algorithm." In *2015 International Conference on Green Computing and Internet of Things (ICGCIoT)*, pp. 981-985. IEEE, 2015.

[21] Viola, Paul, and Michael Jones. "Rapid object detection using a boosted cascade of simple features." In *Proceedings of the 2001 IEEE computer society conference on computer vision and pattern recognition. CVPR 2001*, vol. 1, pp. I-I. Ieee, 2001.

[22] Cordiner, Alister, Philip Ogunbona, and Wanqing Li. "Face detection using generalised integral image features." In *2009 16th IEEE International Conference on Image Processing (ICIP)*, pp. 1229-1232. IEEE, 2009.

[23] Chen, Shigang, Xiaohu Ma, and Shukui Zhang. "Adaboost face detection based on haar-like intensity features and multi-threshold features." In *2011 International Conference on Multimedia and Signal Processing*, vol. 1, pp. 251-255. IEEE, 2011.

[24] Zhang, Dong, Stan Z. Li, and Daniel Gatica-Perez. "Real-time face detection using boosting in hierarchical feature spaces." In *Proceedings of the 17th International Conference on Pattern Recognition, 2004. ICPR 2004.*, vol. 2, pp. 411-414. IEEE, 2004.

[25] Singh, Aruni, Sanjay Kumar Singh, and Shrikant Tiwari. "Comparison of face recognition algorithms on dummy faces." *The International Journal of Multimedia & Its Applications* 4, no. 4 (2012): 121.

[26] Lee, Kuang-Chih, Jeffrey Ho, Ming-Hsuan Yang, and David Kriegman. "Video-based face recognition using probabilistic appearance manifolds." In *2003 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2003. Proceedings.*, vol. 1, pp. I-I. IEEE, 2003.

[27] Aggarwal, Gaurav, AK Roy Chowdhury, and Rama Chellappa. "A system identification approach for video-based face recognition." In *Proceedings of the 17th International Conference on Pattern Recognition, 2004. ICPR 2004.*, vol. 4, pp. 175-178. IEEE, 2004.

[28] Barr, Jeremiah R., Kevin W. Bowyer, Patrick J. Flynn, and Soma Biswas. "Face recognition from video: A review." *International journal of pattern recognition and artificial intelligence* 26, no. 05 (2012): 1266002.

[29] Viola, Paul, and Michael J. Jones. "Robust real-time face detection." *International journal of computer vision* 57 (2004): 137-154.

[30] Osuna, Edgar, Robert Freund, and Federico Girosit. "Training support vector machines: an application to face detection." In *Proceedings of IEEE computer society conference on computer vision and pattern recognition*, pp. 130-136. IEEE, 1997.

[31] Chen, Duan-Sheng, and Zheng-Kai Liu. "Generalized Haar-like features for fast face detection." In *2007 International Conference on Machine Learning and Cybernetics*, vol. 4, pp. 2131-2135. IEEE, 2007.

[32] D Deshmukh, A., Mahender G Nakrani, D. L Bhuyar, and U. B Shinde. "Face recognition using OpenCv based on IoT for smart door." In *Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University Rajasthan, Jaipur-India*. 2019.

[33] Sagar, Saurav, Ujjwal Choudhary, and Rinky Dwivedi. "Smart home automation using IoT and Raspberry Pi." In *Proceedings of the International Conference on Innovative Computing & Communications (ICICC)*. 2020.

[34] Zhang, Kaipeng, Zhanpeng Zhang, Zhifeng Li, and Yu Qiao. "Joint face detection and alignment using multitask cascaded convolutional networks." *IEEE signal processing letters* 23, no. 10 (2016): 1499-1503.