Face Recognition-Based Surveillance System in Mining Industry

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Abstract—Access control in mining construction areas is crucial for the operations of mining companies. This access control functions to secure and restrict unauthorized parties from mining activities. Violations of access rights in the mining industry result in significant losses for companies. This access control can also be utilized to record employee attendance, serving as input for the contract work system commonly applied in mining areas. Closed-circuit television (CCTV) is commonly used to monitor activities; however, the current use of CCTV still requires direct human observation, which may result in important events being overlooked. The functionality of these CCTVs can be enhanced to manage access rights and monitor employee attendance to support company operations through face recognition methods. In this study, a system design was carried out through a research approach to determine the technology to be used in the system. The development of a face recognition-based access control system was conducted based on system engineering methodology. This development includes system requirements analysis, the design of a face recognition-based access control system, implementation, and system performance evaluation. The resulting system was tested through simulation processes based on actual field conditions, and the test results showed that the system could recognize faces registered in the dataset and identify subjects not registered in the dataset with an accuracy of 60%, precision of 96%, recall of 58%, and an F-score of 72%. Additionally, the system was able to connect to a database to store face recognition results and then display them on an employee attendance monitoring dashboard. The delay between the face recognition system and actual time ranged from 2-4 seconds and was still tolerable.

Keywords—access control, face recognition, mining construction, face recognition system.

I. INTRODUCTION

Mining is a sector that necessitates robust access management to regulate entry to activities and facilities within the mining area. The mining area is a private and secret area where people who can access and exit the place are people who have authority. Unauthorized people are prohibited from entering. Violations of access rights in mining areas, whether through vandalism, theft of facilities, or theft of mining products, can result in substantial losses for management and negatively impact mining productivity. Notable cases of access rights exploitation in mining areas, such as the news that occurred in Pangkal Pinang City and PT Pama Persada Nusantara, are among several incidents that have led to significant financial losses, amounting to hundreds of millions of rupiah.

Biometric technology emerges as a leading solution to address access rights management issues, offering a unique and secure authentication method that ensures only authorized individuals gain access. However, biometric technology is not without its vulnerabilities, including the potential for biometric attribute forgery and privacy concerns. Face recognition technology is considered more reliable and secure than other biometric models [1] due to its non-intrusive nature and high accuracy in identifying individuals. This reliability makes face recognition a popular choice for achieving security and authentication goals in access rights management systems, despite ongoing privacy security issues.

Face recognition technology can be effectively utilized as a supporting tool in access rights management systems within mining construction. By employing face recognition technology for biometric authentication, mining workers with authorized access to construction areas undergo an authentication process to ensure precise access control. This method facilitates the supervision of construction security, preventing unauthorized access. Consequently, the identification of workers using face recognition is essential.

Moreover, the implementation of face recognition technology at mining sites presents several challenges, such as ensuring the security of devices and the readiness of the installation environment. Cameras in mining areas are typically installed at elevated positions to mitigate the risk of device theft and damage during operational activities. Therefore, the design of a face recognition-based access control system in mining industrial areas must consider the strategic placement of cameras at higher positions.

II. RELATED WORKS

Research on video analytics-based face recognition systems has been extensively conducted with specific objectives and methods. The use of video analytics technology enables the application of machine learning technology into video management devices, such as cameras, encoders, and routers [2]. One notable study on the implementation of face recognition for attendance systems was conducted by [3], titled “In-Browser Attendance System using Face Recognition and Serverless Edge Computing.” This research focused on the challenges of attendance during the Covid-19 pandemic, comparing various online attendance methods used by schools, companies, and industries. The study analyzed the pros and cons of each method. Face detection and face recognition were chosen for their reliability and difficulty to deceive, using Tiny YOLO v2 and FaceNet. The developed attendance system included a student portal, attendance page, and a dataset of user faces. This system achieved a remarkable 99.38% accuracy on the LFW dataset [3].

Another significant study by [4], titled “Integrated access control monitoring system based on face video detection,” explored the application of face video detection for access control systems. The complexity of image data processing and identification procedures impacted the accuracy. This research aimed to enhance management information, face feature monitoring, and face recognition in access control systems. The developed system integrated image processing, computer vision, machine learning, and calculation technologies to improve accuracy. Proposed methods included block matching on face video features and a face anti-deception algorithm for authentication. The system achieved an accuracy of 0.932 in 100 iterations, compared to traditional methods that only reached 0.684 [4]. These results demonstrate the greater accuracy of Qian Zhai’s method.

Wang M. and Deng W. conducted a comprehensive study in 2018 titled “Deep Face Recognition: A Survey,” which discussed the use of DCNN (Deep Convolutional Neural Networks) in face recognition technology. This research compared several DCNN-based face recognition techniques with various testing parameters. The findings revealed that the accuracy of DCNN-based face recognition methods exceeded 97% [5]. The study also examined the development of loss functions used in various face recognition methods. Newly developed loss functions, such as L2 Softmax, Arcface, and Cosface, showed significant improvements. These loss functions refined existing face recognition methods, providing valuable insights into the effectiveness of DCNN in face recognition.

Research on the face recognition system for employee attendance conducted by Ferry Cahyono et al. in 2021 entitled "Face Recognition System using Facenet Algorithm for Employee Presence" which discusses the use of face recognition as a system for recording employee attendance. The study [6] the Facenet and Openface facial recognition models to record attendance for 15 sample people. The accuracy calculation reaches the maximum level by comparing the detection results with registered workers.

The facial recognition system leverages Deep Learning techniques, including Facebook's DeepFace, which achieves an accuracy of 97.35% [7]. Another example is DeepID, which offers slightly better accuracy at 97.45% with a standard deviation of 0.26% [8]. In 2015, FaceNet has 99.63% accuracy [9] after being trained on a proprietary dataset [10]. Additionally, Openface is a model derived from DeepFace and GoogleNet, redesigned and refined using the CASIA and FaceScrub datasets [10].

Another algorithm for face recognition is ArcFace. This algorithm was developed by Microsoft Research and is one of the most accurate facial recognition algorithms today. ArcFace uses the ResNet-50 architecture as its backbone and adds a special layer called "additive margin loss" to improve facial recognition performance. This layer helps the algorithm to better distinguish similar faces. Arcface has several advantages such as high accuracy, the ability to recognize faces in various conditions (changes in expression, lighting, and viewing angles), and high speed. In Arcface there is an exact correspondence between angles and arcs in the normalized hypersphere so that it can directly optimize the geodesic distance margin [11].

III. METHODOLOGY

The methodology for the design and development of the system is illustrated in Figure 1. The system comprises input datasets for training and CCTV stream inputs for inference, several subsystems, and outputs in the form of an attendance dashboard.

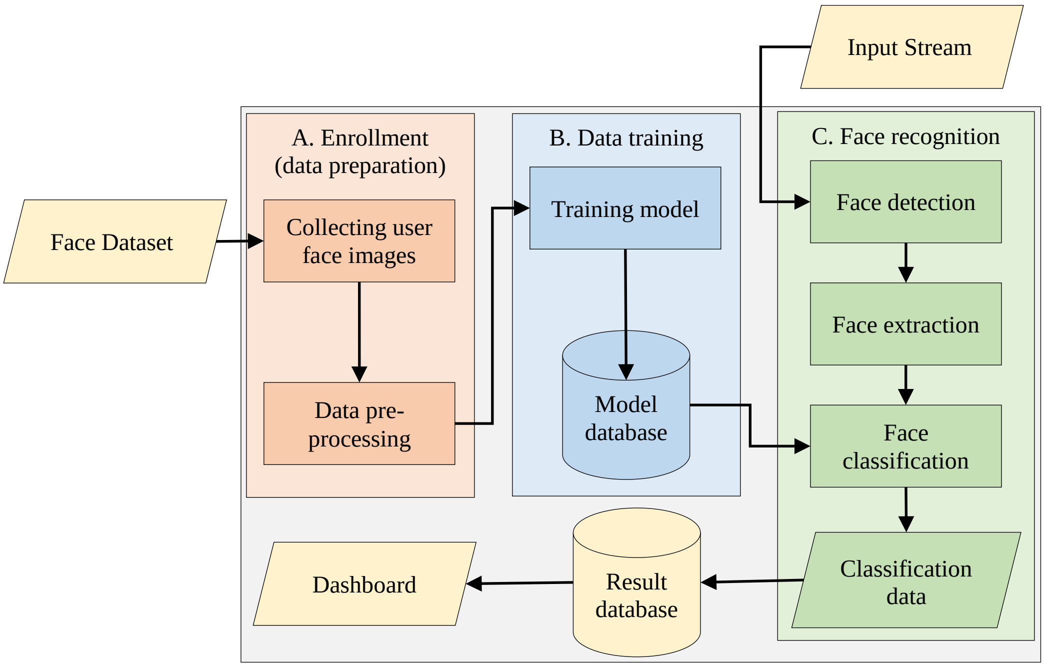

Figure 1. Framework of the developed system.

A. Enrollment (Data Preparation)

The worker dataset is collected asynchronously by requesting the mining construction company to send videos of workers' faces according to the specified procedures. The collection process is conducted via a Google Form containing the procedures and a link for uploading the videos. The most important procedure to adhere to is that the entire face plus the body up to the shoulders must be in the frame, then while recording, the worker poses by facing right, left, up, down slowly. After collection, the dataset is processed to focus the images on the faces using a face detection algorithm. The preprocessing algorithm aims to prepare the construction worker dataset for face recognition. The preprocessing stage involves face detection on the collected dataset and feature extraction on the detected faces.

B. Data Training

After data preprocessing is completed, the collected face photos (there are 23 workers in total) undergo feature extraction for each subject in the dataset. This extraction process constitutes the model training stage for the dataset. The extracted face features of each subject are stored in a database for comparison during face recognition.

C. Face Recognition

The face recognition system in this study use ArcFace algorithm anda receives input in the form of real-time video captured through a camera using RTSP (Real Time Streaming Protocol) run on OBS Studio to reduce delay. When a subject appears in the input video, the system performs face detection to process the detected face in the video framew. The detected face is then extracted for its features and compared with the face features stored in the system's database. If the comparison between the real-time captured face features and one of the stored face features is sufficiently close, the system will display the name of the recognized subject along with a confidence score and then send this data to the face recognition results database. Conversely, if the detected face does not closely match any of the stored face features, the subject in the camera frame will be identified as an unknown subject.

IV. EXPERIMENTS

A. Experimental Setups

Testing was conducted using a dataset of 23 individuals who visited the SCCIC laboratory.

Table 1. Hardware Specifications in the Testing Environment

No.	Name	Description	Specifications	Image
1	CCTV	CCTV is used as a sensing tool for video input in the system environment.	• **Type:** Fixed IP Camera • **Sensor:** 1/3 inch • **Resolution:** 4 MP (2688 × 1520) • **Framerate:** 30 fps	

No.	Name	Description	Specifications	Image
2	PoE Switch	PoE is used to transmit video input data from CCTV to the operating system and provide power to the CCTV using PoE.	• **Model:** Gigabit PoE Switch • **Forwarding Rate:** 14.88 Mpps • **Cache:** 1.5 Mbits	
3	Computer	The computer is used to process input received from CCTV and execute the face recognition program.	• **Processor:** Intel i5 3.4 GHz • **RAM:** 4 GB • **Storage:** 1TB • **Graphics card:** NVIDIA GeForce MX130 2 GB • **Operating System:** Windows 10 (64-bit)	
4	Cat 5e Cable	Cat 5e cable is used to support the connection between hardware components in the system.	• **Type:** Cat 5e, • **Standards:** IEC 60332-3-25	

Figure 2 and 3 are the documentation of hardware installation in the testing environment:

Figure 2. Hardware Installation in the Testing Environment.

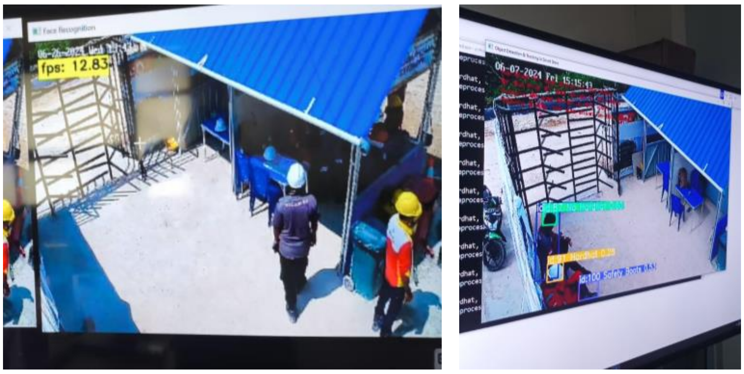

Figure 3. Hardware Installation in the Mining Industry Environment.

B. Simulation

Testing was also conducted by simulating several scenarios that occur in the system usage environment and reenacting them in the testing environment. The testing scenarios included workers passing through the gate/entrance of the mining construction area, workers having discussions, and workers sitting and resting.

The system's ability to recognize faces of subjects in the dataset was tested on 17 out of 23 subjects in the dataset and 3 individuals not registered in the dataset. Six registered subjects faced scheduling and availability issues for system trials. Testing was conducted by capturing image frames when the subject entered the video frame and their face was detected for a duration of 5 seconds at 30 FPS. This resulted in 150 sample frames for each subject and a total of 3000 frames used as the basis for evaluating the face recognition algorithm.

In this test, all subjects registered in the dataset were correctly detected, and all unregistered subjects were identified as 'unknown,' although the time required for the system to recognize faces after detection varied. The results for registered subjects were as follows: 3 subjects were recognized within 1 second after face detection, 9 subjects within 2 seconds, 2 subjects within 3 seconds, 2 subjects were initially identified as unknown for 2 seconds before being correctly recognized, and 1 subject was misidentified as another person for 2 seconds before being correctly recognized.

For unregistered subjects, the results were as follows: 2 subjects were identified as 'unknown' within 2 seconds, and 1 subject took 3 seconds to be identified as 'unknown' after face detection. Based on these results, the performance of the face recognition algorithm was measured.

Table 2. Performance Evaluation Results of the Algorithm.

True Positive	1560
False Positive	60
True Negative	240
False Negative	1140
Accuracy	60%
F-score	72%
Recall	58%
Precision	96%

From this evaluation, it is evident that the face recognition algorithm performs well, particularly in terms of precision. Out of 3000 image frames, the algorithm accurately recognized faces in 1560 frames. The system's algorithm failed to recognize faces in 1140 frames or took time to accurately recognize faces, which is also supported by the accuracy of recognizing subjects in the dataset and unregistered subjects.

The evaluation of the algorithm indicates that the duration for face recognition should be improved. This could impact the system's ability to recognize faces of workers moving quickly or running.

Figure 4. Display of Detected and Recognized Faces.

In this testing process, the system demonstrated its ability to detect and recognize faces of subjects in the dataset and display the confidence score of the face recognition results. The system was also able to detect faces and recognize unregistered subjects as 'unknown.'

Figure 5. Recognition of Unregistered Subjects.

C. Simulation of Activities in the Mining Industry Environment

Scenario testing was conducted to determine the appropriate usage scenarios for the final system environment. Based on various activities performed by mining construction workers, several scenarios were simulated in the laboratory to test the system's suitability in different scenarios.

The first scenario involved testing the system at the gate/entrance area for workers. In this simulation, CCTV was directed to capture video of workers' faces as they passed through the laboratory entrance under various conditions to review system limitations, such as wearing helmets and not wearing helmets, as well as when multiple workers passed through the entrance simultaneously. The results of this test can be seen in the following image.

Figure 6. Simulation Test Results at the Gate/Entrance Area.

As shown in the image, the system can recognize workers' faces as they pass through the gate area while wearing construction helmets. Based on these results, the system's usage scenario at the gate/entrance of the mining construction area yielded good results. The system was also able to detect and recognize the faces of subjects while they were walking. The second testing scenario involved workers discussing and talking in the construction area. In this scenario, CCTV was directed towards the discussion or meeting area. The results of this scenario test are shown below.

Figure 7. Simulation Test Results in the Discussion Area.

As seen in the image, one subject's face was not detected because it was turned away from the CCTV video capture. Based on these results, installing the system in the discussion area is not recommended due to the potential for subjects to turn their faces away from the camera, resulting in undetected faces. The system also experienced a decline in performance in detecting and recognizing faces when subjects moved their faces downward and sideways.

The third testing scenario involved users sitting and resting in the mining construction area. In this scenario, CCTV was directed towards the workers' rest area. The results of this scenario test are shown below.

Figure 8. Simulation Test Results in the Rest Area.

As seen in the image, the system was only able to recognize the face of one subject. Another subject in the video frame was identified as 'unknown' despite being registered in the database, and one subject was not detected at all. Based on these results, using the system in the workers' rest area scenario is deemed ineffective due to the possibility of subjects turning their faces away from the camera, making it difficult for the system to detect and recognize workers' faces. From the test results conducted, the detection results are considered good for various scenarios such as entering the gate and discussing with the camera conditions located above the head like the original conditions in mining. The detection capability in all these scenarios aims to monitor who is in a mining area and the location of the presence detected through the camera location.

V. CONCLUSION

The face recognition-based access control system for the mining construction case study was developed for use in the mining construction environment. The system implementation includes dataset collection, software development, and hardware installation. The system was then evaluated by simulating activities on the ITB campus based on observed activities in the mining area. The test results showed that the system could recognize faces registered in the dataset and identify subjects not registered in the dataset with an accuracy of 60%, precision of 96%, recall of 58%, and an F-score of 72%. Additionally, the system was able to connect to a database to store face recognition results, which were then displayed on an employee attendance monitoring dashboard. The delay between the face recognition system and actual time ranged from 2-4 seconds and was still tolerable.

ACKNOWLEDGEMENT

We hereby express our deepest gratitude and appreciation to the Research and Innovation Funding for Advanced Indonesia (RIIM) of the National Research and Innovation Agency for providing financial support for this research. This support has enabled us to conduct this research effectively and achieve the expected results. We also extend our thanks to all parties who have assisted in the research process. We hope that the results of this research will make a meaningful contribution to the advancement of science and technology in Indonesia.

REFERENCES

[1] L. Li, X. Mu, S. Li and H. Peng, "A Review of Face Recognition Technology," in IEEE Access, vol. 8, pp. 139110-139120, 2020, doi: 10.1109/ACCESS.2020.3011028.

[2] V. Kulkarni and K. Talele, "Video Analytics for Face Detection and Tracking," 2020 2nd International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), Greater Noida, India, 2020, pp. 962-965, doi: 10.1109/ICACCCN51052.2020.9362900.

[3] D. Yadav, S. Maniar, K. Sukhani and K. Devadkar, "In-Browser Attendance System using Face Recognition and Serverless Edge Computing," 2021 12th International Conference on Computing Communication and Networking Technologies (ICCCNT), Kharagpur, India, 2021, pp. 01-06, doi: 10.1109/ICCCNT51525.2021.9580042.

[4] Q. Zhai, "Integrated access control monitoring system based on face video detection," *2022 2nd International Conference on Consumer Electronics and Computer Engineering (ICCECE)*, Guangzhou, China, 2022, pp. 580-585, doi: 10.1109/ICCECE54139.2022.9712709.

[5] Wang, Mei, and Weihong Deng. "Deep Face Recognition: A Survey." arXiv preprint arXiv:1804.06655v9, last revised August 1, 2020. https://arxiv.org/abs/1804.06655.

[6] F. Cahyono, W. Wirawan and R. Fuad Rachmadi, "Face Recognition System using Facenet Algorithm for Employee Presence," 2020 4th International Conference on Vocational Education and Training (ICOVET), Malang, Indonesia, 2020, pp. 57-62, doi: 10.1109/ICOVET50258.2020.9229888.

[7] Y. Taigman, M. Yang, M. Ranzato and L. Wolf, "Deep-face: Closing the gap to human-level performance in face verification", CVPR, 2014.

[8] Y. Sun, X. Wang and X. Tang, "Deep learning face representation from predicting 10000 classes", CVPR, 2014b.

[9] Florian Schroff, Dmitry Kalenichenko and James Philbin, "Facenet: A unified embedding for face recognition and clustering", Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 815-823, 2015.

[10] B. Amos, B. Ludwiczuk and M. Satyanarayanan, "Openface: a general-purpose face recognition library with mobile applications", CMU-CS-16-118 CMU School of Computer Science, 2016.

[11] J. Deng, J. Guo, J. Yang, N. Xue, I. Kotsia and S. Zafeiriou, "ArcFace: Additive Angular Margin Loss for Deep Face Recognition," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 44, no. 10, pp. 5962-5979, 1 Oct. 2022, doi: 10.1109/TPAMI.2021.3087709.