IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received 3 October 2024, accepted 17 November 2024, date of publication 22 November 2024, date of current version 16 December 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3504858

RESEARCH ARTICLE

Enhanced Efficiency in SMEs Attendance Monitoring: Low Cost Artificial Intelligence Facial Recognition Mobile Application

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This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea Government (MSIT) (No. NRF-2023R1A2C1008134).

ABSTRACT The distributed work model, which allows people to work from multiple physical places, has gained significant popularity in recent years, particularly since the outbreak of the COVID-19 epidemic. Despite the potential advantages of cost reductions associated with office space and flexible working environments, this model presents difficulties in effectively controlling and monitoring employee work activities. Applying advanced technologies in human resources can enable organizations to address these challenges effectively. However, SMEs face challenges in adopting advanced technologies such as AI and facial recognition due to financial constraints, lack of technical expertise, and concerns about cost-effectiveness. The paper focuses on developing a low-cost attendance monitoring mobile application that utilizes real-time facial recognition and location analysis for SMEs. We try to enhance the real-time registration and identification flow with the camera of employees' mobiles by handling large data streams and integrating the system with a cloud-based solution. First, the AI facial detection module uses the camera on mobile devices as input devices to ensure the flexibility of face recognition data input. The AI Engine layer is built by applying a deep learning-based facial recognition model that was trained using a large dataset of collected employee faces. Employees' facial identities using the Resnet34 model integrated Additive Angular Margin Loss function to identify employees' facial identities. The facial recognition model is designed to operate in real-time, with the ability to detect and identify employees as they check in and out of the workplace. Finally, we demonstrate an experimental prototype on a mobile phone application using React Native, NodeJS, and Python. The mobile application is designed to operate on both iOS and Android platforms, ensuring widespread accessibility for SMEs. The experimental findings provide empirical evidence that our system exhibits accuracy and efficiency in the tasks of facial identification and personnel matching. This research will serve as a valuable reference for executing strategies that are appropriate for SMEs.

INDEX TERMS SMEs attendance monitoring, artificial intelligence, facial recognition, mobile application, cloud computing.

The associate editor coordinating the review of this manuscript and approving it for publication was Zhe Jin.

I. INTRODUCTION

Distributed work blended paradigm encompasses on-site teams at one or more office sites and remote employees working from home, in coworking spaces, in public areas, or while traveling. The distributed work model has gained significant popularity in recent years, particularly since the outbreak of the COVID-19 epidemic. Despite the potential advantages of cost reductions associated with office space and flexible working environments, enterprises' lack of direct supervision might challenge monitoring employee performance. Timekeeping and payroll are two interdependent activities of significant importance. Hence, the absence of a systematic and rigorous approach to the timekeeping process is bound to impede production and company operations.

Traditionally, corporations and organizations have relied on manual timekeeping methods for tracking employee attendance, such as sign-in/sign-out sheets, attendance registers, and badge-swiping systems. These processes often require significant time from security personnel and employees, leading to inefficiencies, especially during peak hours when many individuals are checking in or out. Manual methods are prone to human error, resulting in mistakes that can affect payroll and attendance records. Additionally, they lack real-time data, hindering management's decision-making about staffing and resource allocation. Security risks, such as buddy punching, can also arise in these systems. Moreover, the administrative burden of maintaining accurate attendance records diverts resources from other important tasks. Occasionally, errors may occur when the influx and egress of individuals surpass the cognitive ability of the security personnel or sentinel. Moreover, this phenomenon elicits discomfort for employees due to the presence of skepticism or perceived challenges. To address these challenges, many organizations are now exploring automated attendance monitoring solutions, like facial recognition technologies, which can streamline the process, enhance accuracy, and improve overall efficiency in the workplace.

Applying advanced technologies in human resources management (HRM) can enable organizations to address these challenges effectively. In recent years, there has been a proliferation of attendance management systems that utilize facial recognition technology. These systems aim to address the challenges that come with manual attendance, including time constraints, proxy attendance, and data administration. Existing research and products have highlighted the widespread adoption of sophisticated attendance-tracking technologies, such as biometric systems and advanced access control solutions, in large organizations. However, the utilization of these technologies in the Small and Medium Enterprise (SME) sector remains limited, as previous works highlight the challenges SMEs face in adopting advanced technologies such as Artificial Intelligence (AI) and facial recognition due to factors like financial constraints, lack of technical expertise, and concerns over cost-effectiveness [1], [2], [3]. There is a research gap in the availability of cost-effective, scalable, and user-friendly attendance tracking solutions specifically tailored to the unique requirements of SMEs. This research aims to address these gaps by developing and deploying an AI-powered, low-cost mobile application for attendance monitoring that is specifically designed to meet the needs and constraints of SMEs.

The research focuses on developing a low-cost attendance monitoring mobile application that utilizes real-time facial recognition and location analysis for SMEs. We try to enhance the real-time registration and identification flow with the camera of employees' mobiles by handling large data streams and integrating the system with a cloud-based solution. In our research, we focus on developing AI computing-intensive solutions specifically optimized for the resource-constrained environment of smartphones. Unlike data centers or large-capacity servers that can leverage extensive computational resources, smartphones operate under significant limitations in processing power, memory, and battery life. Our proposed solution addresses these challenges by implementing advanced algorithms that prioritize efficiency and minimize resource consumption while maximizing performance.

The contribution of our approach lies in the utilization of a cloud-based architecture where the AI model procedures are executed centrally on a shared server. This design ensures sophisticated AI tasks are executed in the resource-constrained environment of smartphones, thereby enhancing user experience and providing real-time processing capabilities. The main findings can be illustrated in the following manner:

- Developing a low-cost attendance monitoring mobile application incorporating AI-based facial recognition and analysis techniques.
- Building experimental prototypes as a mobile phone application and testing performance.

The rest of the research is structured as follows. Section II provides an overview of technologies related to AI-based facial attendance systems in human resource management systems (HRMS). Section III discusses the proposal and research model experiment setup. In Section IV, the implementation and result are presented. Section V will present the performance and evaluation. The conclusions and future work aiming to improve the results are discussed in Section VI.

II. RELATED WORKS

A. ATTENDANCE MONITORING MODULE IN HRMS

In the contemporary company environment, the extent of technological integration significantly influences the outcomes and expediency of establishing a competitive market position. The rapid and ongoing evolution of technology necessitates organizations to engage in continuous innovation concerning technology, consumers, and markets [4]. The prioritization of human resources (HR) transformation should be regarded as a critical objective for firms. Enterprises have the potential to enhance their operational efficiency by using the significant advantages associated with using digital technology platforms in HRM [5]. Integrating digital technology into HR procedures can potentially enhance employee attitudes and engagement within SMEs [6]. A HRMS refers to a collection of software programs that are utilized to effectively manage human resources and the associated procedures that occur across the whole employee lifecycle [7].

HRMS has garnered significant attention and has been the subject of much research in prior studies. The utilization of HRMS enables organizations to gain comprehensive insights into their personnel, ensuring adherence to evolving labor standards and adapting to emerging work arrangements during the COVID-19 pandemic, population aging, climate change, and the dynamic landscape of Industry 4.0 [7]. Human resource management positions can be categorized into four distinct groups: the recruitment work group, the compensation and bonus work group, the administrative work group, and the training and development workgroup. The group of jobs compensation and bonus workgroup demands the most significant allocation of time and human capital. In HRMS, the payroll management module is the process of disbursing employee salaries by collecting data on employee attendance, computing earnings, and statutory deductions. The data is extracted from timekeeping and attendance modules associated with employees to facilitate the computation of automatic deposit and manual cheque-writing functionalities. Research in Zimbabwe's tourism and hospitality industry found that it significantly enhances organizational efficiency and HR functions [8]. The time and attendance module collects standardized data on employee work-related efforts and hours worked.

In the past, the process of monitoring and managing the ingress and egress of individuals in a business necessitated dependence on manually recorded logbooks maintained by the security personnel. The task of maintaining high levels of focus and attentiveness, as well as accurately documenting information, poses a significant challenge for human security officers. The traditional method of timekeeping involves the manual verification and documentation of employees' daily working hours. Monthly, human resources staff encounter difficulties managing the substantial volume of timekeeping documents required to accurately record and calculate employee work hours. Executing the task necessitates a substantial allocation of time, exertion and the utilization of both people and material resources inside the organization or business entity. In addition, manual recording and calculating methods frequently result in avoidable errors within the employee timekeeping procedure. Instances of employee bias and the falsification of timekeeping records. There is a requirement to enhance equity in the timekeeping procedure for employees. Numerous timekeeping methods utilizing AI technology have emerged in response to the limitations of traditional timekeeping approaches. These novel methods aim to address conventional practices' drawbacks and cater to this domain's evolving demands. These technologies can be demonstrated as follows: fingerprint recognition [9], [10], [11], voice recognition [11], [12], [13], iris recognition [14], [15], and facial recognition [16], [17], [18], [19]. Nevertheless, most of these technologies necessitate staff engagement and device configurations, such as the utilization of fingerprint readers and iris readers. Moreover, within the framework of the distributed working model, wherein individuals or departments operate from various places and adhere to flexible schedules, the task of monitoring and regulating employees' working hours becomes intricate. The presence of attributes in this operational framework poses challenges for the organization in terms of maintaining regular attendance and tracking time daily due to the reliance on stationary equipment.

In the context of enterprise environments, Odewole and Kadel [20] proposed a smart attendance system that leverages the relationship between the Media Access Control (MAC) address of users' devices such as smartphones, the Received Signal Strength (RSS), and the Angle of Arrival (AoA) of the wireless signal at the enterprise's Wireless Access Point (WAP). The proposed system aims to provide a faster, more efficient, and more secure attendance monitoring solution than previous methods like RFID, biometrics, and Bluetooth-based systems. It utilizes the IEEE 802.11a Wi-Fi standard, which offers better performance in terms of speed, capacity, and range than earlier standards. The system is designed around the Raspberry Pi platform, which monitors the wireless signals' MAC addresses, RSS, and AoA. The authors present a comprehensive smart attendance system leveraging advanced Wi-Fi technology and signal metrics to enhance the efficiency and robustness of attendance monitoring.

Espinosa et al. [21] focus on applying facial recognition technology to solve problems in the operations of Archempress Fruit Corporation. This company is one of the growing bananas exporting companies, but it still uses a manual timekeeping system, causing some difficulties in management and operation. The researchers have studied the facial recognition system's methods of detecting, tracking and recognizing faces. From there, they proposed to build a facial recognition system to automate the process of timekeeping and salary payment for employees. This system will accurately record the time in/out of employees and integrate with the salary payment system, helping the company increase productivity, reduce costs and manage more effectively.

Núñez et al. [22] present the construction of a time control system and attendance for enterprises using facial recognition technology based on artificial neural networks and machine learning. The authors leveraged technologies such as Raspberry Pi and Python to implement this system. The authors built a model of a facial recognition system using Raspberry Pi and an artificial neural network architecture with a faulty back transmission method to extract knowledge from input data. The algorithms are implemented in Python, and the results show high accuracy in classifying and identifying people. This research has successfully applied AI, machine learning, and artificial neural network technologies to build an effective time management system and presence list for businesses.

Some research gaps need further exploration to improve the efficiency and applicability of facial recognition technology based on the time and attendance management system. First, it is necessary to conduct a detailed evaluation of the performance and accuracy of the facial recognition system in real-world conditions, with many people, different angles and environments. Tests need to be conducted thoroughly to ensure high reliability, even in difficult situations such as poor lighting, different viewing angles, or partial facial occlusion. In addition, it is necessary to study solutions to improve security and privacy for users. Ensuring the safety of facial data and compliance with regulations on personal data protection is extremely important. Considering appropriate authentication and authorization mechanisms, such as using passwords, PINs, or additional authentication factors, is also a noteworthy direction. Expanding the system's functionality and integrating it with other HR management applications is also a trend that needs to be studied. Evaluating the ability to integrate this system with HR management software, such as salary management, performance evaluation, and job assignment, will help improve the system's utility and comprehensiveness. In addition, the utilization of these technologies in the SME sector remains limited, as previous works highlight the challenges SMEs face in adopting advanced technologies due to financial constraints, lack of technical expertise, and concerns over cost-effectiveness. The research focuses on developing a low-cost attendance monitoring mobile application that utilizes real-time facial recognition and location analysis for SMEs.

B. ATTENDANCE SYSTEM BASED ON FACE RECOGNITION

Face detection is a process that analyzes an image or video frame to identify facial regions, their position, and size [23]. The process involves the identification of things as facial features that are present in images or video sources through the utilization of machine learning techniques. The concept of face recognition is distinct from that of face detection, as they are defined in disparate manners. The process involves the verification and identification of a facial image by comparing the alignment of facial landmarks with those stored in a pre-existing database [24]. Facial recognition is regarded as a subject of investigation within the domain of computer vision and as a discipline within the realm of human biometrics [25].

Face recognition algorithms are classified as either template-based or geometry-based algorithms. Template-based methods can be constructed with statistical techniques such as Support Vector Machines (SVM) [26], [27], [28], Principal Component Analysis (PCA) [28], [29], [30], Linear Discriminant Analysis (LDA) [31], Kernel methods [32], Trace Transforms [33], [34], etc. Geometric feature-based methods involve the analysis of facial features and their corresponding geometric relationships. This approach is alternatively referred to as feature-based techniques. Numerous studies have pursued the investigation of the interconnections of components within a component and the overall face, to deduce the most significant aspects. Several methodologies employ the visual sense or an amalgamation of various variables, among other aspects. This category encompasses many Hidden Markov Model approaches, which are widely recognized in the field of face recognition for their prominent feature processing capabilities. The shape-based approach uses morphological techniques in conjunction with machine learning models to accurately identify the precise locations of facial regions within the image. Every image is seen as a vector with several dimensions. The utilization of this method is frequently employed in the process of extracting a feature space from picture segmentation. The sample image is being compared to the training set. The verification task involves comparing two facial images to determine whether they depict the same individual. The identification task involves comparing and recognizing a provided facial image about a pre-existing database of facial images. Recently, Kurutach et al. [35] proposed to use face attribute recognition as a task to improve face alignment performance using deep learning CNN.

In recent years, there has been a proliferation of attendance management systems that utilize facial recognition technology. These systems aim to address the challenges that come with manual attendance, including time constraints, proxy attendance, and data administration [36], [37], [38]. Kakarla et al. [39] introduced a real-time attendance system with a face recognition-based approach. This system was designed utilizing a pre-trained model and the Dlib library, enabling accurate identification of student faces inside the captured frame. Sultan et al. [40] presented a web-based application designed to facilitate an online attendance system. This application allowed users to conveniently access the system interface through any browser, irrespective of the terminal being used. The training phase of the model was conducted using SVM. The server application incorporated the Open-Source Computer Vision (OpenCV) library for face recognition. Aljaafreh et. al [41] constructed various models to improve the face recognition capabilities of an attendance system. These models included Support Vector Classifiers (SVC) and Neural Networks, namely Tuned SVC with RBF Kernel, SVC with linear kernel, Simple NN, and CNN. The purpose of this research was to assess and optimize the performance of these models in the context of face recognition of the attendance system. The highest levels of accuracy achieved by the optimized SVC model were observed to be 0.99334. Bhattarai et al. [42] proposed a novel approach that integrates the eigenface, fisher face, and local binary patterns histograms (LBPH) algorithms. The objective of this integration was to enhance the accuracy of time attendance systems. The LBPH Extension (FELE) algorithm demonstrated a remarkable accuracy rate of 100%, surpassing other existing methods in performance. Munlin [43] built a smartphone attendance monitoring application. The detection algorithm was a single-shot detector-based convolution network (RCNN). In addition, the researchers employed the YOLOv3 algorithm for the purpose of face detection.

Furthermore, they utilized Microsoft Azure, namely the face API, to conduct face identification tasks, which involved the utilization of a face database. The technology has demonstrated a high level of accuracy in face detection and performance. Previous research has predominantly focused on the development of systems within the realm of classroom management [44], [45], [46]. Hence, it is imperative to develop a facial recognition attendance system that can seamlessly integrate with the HRMS.

Facial detection and recognition are increasingly popular and widely applied machine learning techniques. Facial recognition algorithms can be divided into two main categories: template-based and geometry-based. Sample-based methods use statistical techniques such as SVM, PCA, LDA, kernel methods, while geometry-based methods analyze the features and geometric relationships of faces. In recent years, many attendance management systems have applied facial recognition technology to address the limitations of manual attendance management methods. Research has proposed models such as SVM, Neural Networks, LBPH, etc., to improve the accuracy of this system. The existing literature has primarily focused on developing facial recognition-based attendance systems within classroom management, overlooking the specific needs and constraints of small businesses. Additionally, most of the proposed solutions have been designed for large enterprises, needing more cost-effectiveness and user-friendliness required by resource-constrained SMEs.

This research aims to address these gaps by developing an AI-powered, low-cost mobile application for attendance monitoring that is specifically designed to meet the needs of small and medium-sized enterprises.

III. PROPOSED RESEARCH MODEL AND EXPERIMENT SETUP

A. RESEARCH METHODOLOGY

This research presents an approach to improve the efficiency of the SMEs' attendance monitoring application. Also, the research model incorporates the utilization of face recognition based on deep learning for attendance tracking and monitoring. We take camera images from mobile, desktop, or laptop as input data for the system. Subsequently, the input data will undergo pre-processing to achieve normalization and standardization before proceeding with the face recognition procedure. The typical procedure for face recognition is designed with three primary stages: face detection, feature extraction, and face matching. The identification process is considered complete when the facial features captured in the recorded image correspond to those of an individual stored within the database. The system will extract and store attendance information and employee location data. At this time, the process of attendance and timekeeping has been finalized. In this research, we try to enhance the system's registration and identification flow with the mobile camera in real-time. Our application can ensure the flexibility to handle large data streams smoothly from cameras, enabling speed and ease of use by integrating the attendance identification system into the cloud database for updating and reporting operations real-time.

B. RESEARCH MODEL

In our designed framework, individuals take a photo in our application (mobile/desktop with webcam/factory device or laptop camera) upon first registration as an employee. Every employee must have their facial data duly registered within the system. This photo will be saved in the Face cloud database for automated training in the training server, enabling further utilization in the face recognition procedure. Employees can perform daily attendance directly on a device installed at the company door, both on a mobile phone or computer with an internet connection and sharing location. The proposed prototype attendance application is presented in Fig. 1.

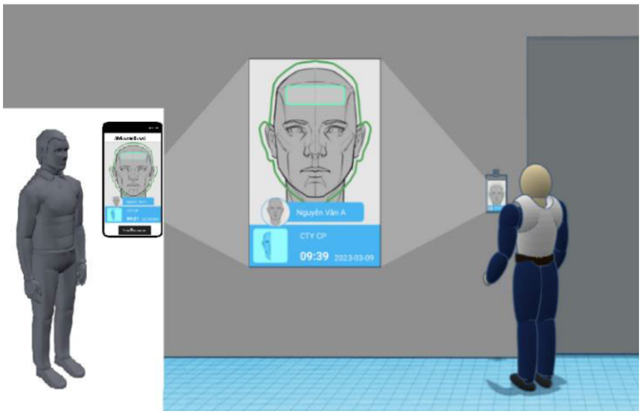


FIGURE 1. Proposed prototype attendance application.

The proposed system architecture for the face attendance system is presented in Fig. 2. Our system has two main layers including APP UI and AI ENGINE. In the APP UI, employees must choose the check-in option in each session to start the timekeeping process. The primary purpose of the front-end application is to capture video from the user's device and transmit it to the API Gateway. Video streams from the camera of the factory device, mobile app, or website on the desktop/laptop will be sent to the API gateway. The video frames are encoded in Base64 format and sent to the API Gateway endpoint as the request payload.

The remaining procedures will be executed centrally on the system's shared server to reduce the application's footprint and guarantee efficient image processing. The API Gateway is the entry point to our cloud infrastructure. It receives the API requests from the front-end application and forwards them to the appropriate designed services for processing. The API gateway triggers a middleware function, which handles the incoming API request and initiates the facial recognition process.

The middleware function utilizes the recognition service, which manages computer vision and deep learning service, to perform facial recognition on the provided video frames.

The middleware function processes the results from recognition, which includes the detected faces and their associated metadata, including bounding boxes and confidence scores. The middleware function then prepares the response to be returned to the front-end application. Finally, the processed response is sent back to the front-end application through the API Gateway using the same API protocol. This cloud-based architecture leverages the scalability and reliability of cloud services to handle the facial recognition workload, offloading the computational and storage requirements from the front-end application.

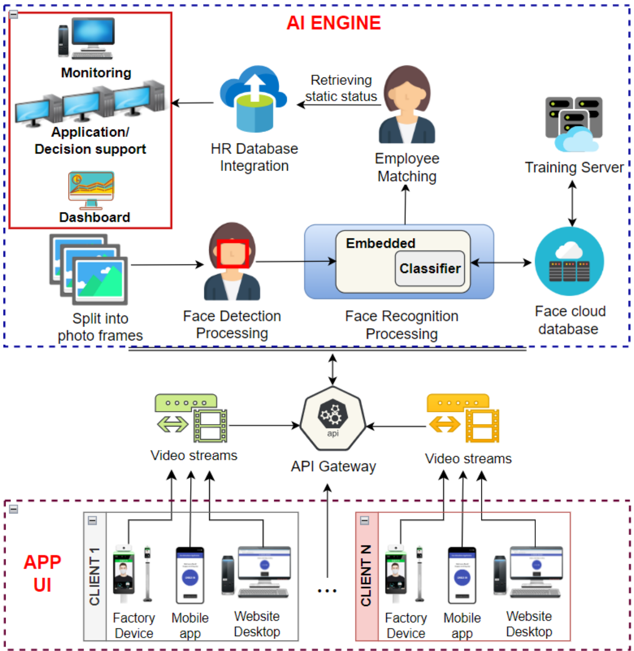


FIGURE 2. Proposed system architecture.

The facial image will be transferred to the AI Engine layer. The face detection procedure involves inputting the face image into the program to analyze and interpret the subject's facial structure. Essential elements to consider encompass the interocular distance, the depth of the orbit, the vertical dimension from the glabella to the mention, the morphology of the zygomatic arches, and the configuration of the labial auricular. Our proposed model can ascertain prominent facial features that can be utilized to differentiate individuals within the primary database. The system will proceed to transform the image into data and subsequently engage in the process of facial recognition. The process involves transforming a photographic image depicting a human face into a collection of digital data derived from the distinctive characteristics and attributes of the individual's facial structure. The facial traits will undergo processing through algorithms and formulas, generating distinct facial data for everyone. The subsequent phase involves doing a comparative analysis with the pre-existing facial database. The facial recognition algorithm is constructed by utilizing the Resnet and ArcFace models.

Finally, a database was constructed to facilitate the storage of facial information. The identification process is accomplished once the recorded face is successfully matched with an image stored in the database. If this condition is not met, the system will notify the Human Resources personnel, prompting them to either enroll new users or make necessary modifications to the existing data. The recognition data will be stored in the HR Database Integration and shown in a dashboard format to facilitate decision-making by the Head or Manager.

In addition, in our designed framework, individuals capture their photo using our application—whether on a mobile device, desktop with a webcam, or factory device. The system has the ability to extract location data based on the device's ID for factory devices or the IP address for laptops and mobile devices. This method allows us to confirm that employees are in the appropriate location when checking in, further reinforcing the integrity of the attendance monitoring process. Furthermore, the integration of location data allows the system to detect any anomalies or unusual movements within the workplace. Finally, the combined facial recognition and location data can provide valuable insights into employee attendance patterns and workday routines, which can help identify optimization opportunities, such as adjusting work schedules, improving resource allocation, or identifying potential productivity bottlenecks. This dual approach significantly mitigates the risk of fraudulent check-ins and improves overall reliability.

This facial recognition time attendance monitoring system design offers both cost savings and flexibility. In terms of cost savings, the system leverages centralized processing on a common server, minimizing hardware requirements for client devices such as mobile applications, factory equipment, or desktop computers. This approach eliminates the need for powerful hardware, reducing overall investment costs. Furthermore, the system allows employees to use personal devices or existing computers at the factory or office instead of purchasing specialized timekeeping devices, resulting in additional savings. Cloud deployment also helps avoid the costs of on-premises server hardware and maintenance. Regarding flexibility, this system design supports various employee devices, including mobile applications, factory devices, and desktop or laptop computers, facilitating easy integration into various working environments. The scalability of a centralized server-based processing system allows it to be adapted to suit an organization's needs without major infrastructure changes. Additionally, the modular design, featuring an independent user interface layer and AI engine layer, provides the flexibility to upgrade system components in the future without impacting overall operations.

The schematic representation of the proposed methodology is illustrated in Fig. 3. The process of time attendance with face identification is the following:

- Employees will start the flow by choosing the check-in option on the APP UI. They should be in front of the camera device or use their mobile phone application.

- The APP will auto-send the real-time video stream through the gateway to the AI Engine. AI Engine will split the video stream into several photo frames and choose the best quality frame.

- From then, the photo frame will be sent to face detection and face recognition through pre-processing, feature extraction, and classifier steps.

- AI Engine will identify if the employee exists in the employee database or not. If not, another alert to check and upgrade, modify, or add employee information to HR Management. If AI Engine can recognize employee information, the timekeeping and attendance will be stored and analyzed to make the report.

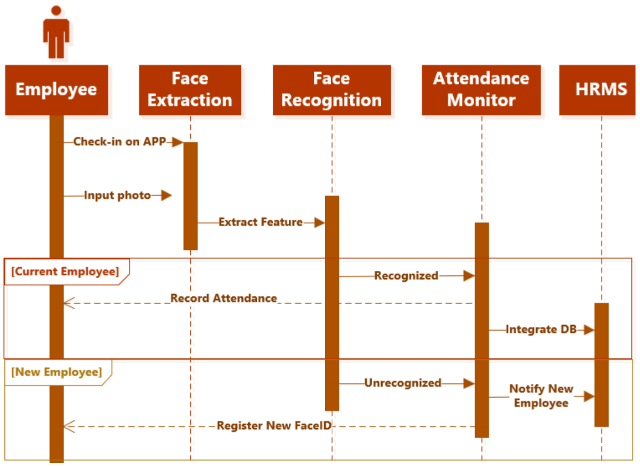


FIGURE 3. Sequence diagram of attendance monitoring system.

The real-time processing of facial images allows for instantaneous recognition without requiring users to remember passwords or carry physical tokens. This can lead to a more seamless experience, particularly in high-traffic environments where time efficiency is crucial. We also incorporate user feedback mechanisms within the app to continuously improve the authentication process based on real user experiences. This approach aims to enhance the convenience and reliability of the system, ensuring it meets the needs of our target user base.

C. DESIGNED AI ENGINE

AI Engine will split the video stream into several photo frames and choose the best quality frame. Next, the face detection procedure involves inputting the face image into the program to analyze and interpret the subject's facial structure. Generally, face recognition is the process of identifying or verifying one or more faces in an image. Face recognition usually consists of three main steps: detecting a face in an image, feature extraction, and face matching. The schematic representation of the proposed methodology for face recognition is illustrated in Fig. 4.

1) FACE DETECTION PROCEDURE

Face detection is the task of detecting the presence of a human face without comparing the differences between faces.

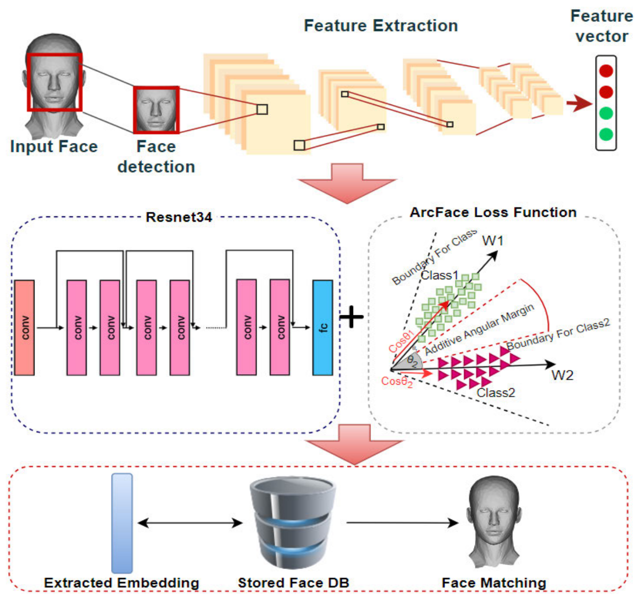


FIGURE 4. Workflow of face recognition.

In our work, a Multi-task Cascaded Convolutional Network (MTCNN) is used for face detection and face alignment. MTCNN is an effective neural network to detect faces and identify the position of these faces introduced in 2006 [47]. The structure of MTCNN consists of three cascaded CNNs and simultaneously works for face detection and identification, namely P-Net, R-Net, and O-Net. The cascaded architecture of MTCNN allows for efficient face detection and alignment. The P-Net rapidly generates many candidate regions, which the R-Net then refines, and finally, the O-Net provides accurate facial landmark localization and face classification. Its multi-task approach enables it to handle multiple tasks simultaneously and efficiently, making it a popular choice for real-time face-related applications. Each CNN network plays a different role. To improve the accuracy of the model when recognizing, the MTCNN library is used to enhance the image, specifically as follows: Normalize according to the normal distribution of pixels of the image; Create images with skew angles of 20 degrees (left, right); Shift the image by width; Shift the image by height; Flip the image horizontally.

Image processing is converting an image into a digital form and performing certain operations to get helpful information from that image. An image is defined as a two-dimensional function, $F = (x, y)$ where x and y are the spatial coordinates, and the amplitude of F at any pair of coordinates (x, y) is called the intensity of the image at that point. When the x, y and amplitude values of F are finite, we call it a digital image. In other words, an image can be identified by a two-dimensional array explicitly ordered by rows and columns. The digitized image consists of a finite number of elements, each of which has a specific value at a particular location. The result is a feature vector representing the location of the face.

2) FACE RECOGNITION PROCEDURE

The main idea of face recognition is that the more similar two images are (of the same person), the smaller the distance between them. Conversely, the further apart the two images are, the larger the distance should be. The distance used is Euclidean distance - Norm standard between input image $u(x_1, y_1)$ and image stored in database $v(x_2, y_2)$. The Euclidean distance is calculated in the formula (1) below:

$$EU\,(u, v) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)}^2 \quad [48-49] \tag{1}$$

$$\begin{cases} EU\,(u, v) \leq T \rightarrow Same \\ EU\,(u, v) > T \rightarrow NotSame \end{cases} \tag{2}$$

With this approach, in the formula (2), we define a threshold T. We will compare the distance $EU\,(u, v)$. If the distance is below the threshold, we will take those images as output.

Embedding feature vectors such that features of the same person have a smaller distance and features of different people have a considerable distance. In our work, we use the Resnet34 model as our embedding model to embed the images into a vector. Resnet34 is a state-of-the-art image classification model, structured as a 34-layer convolutional neural network and defined for Image Recognition. However, RestNet is different from traditional neural networks in the sense that it takes residuals from each layer and uses them in the subsequent connected layers. Then crop the face out of the image and put it into the Resnet Network, obtaining a 128-dimensional feature vector used to represent the face. This feature vector can be used for face clustering, similarity determination, and classification.

After that, we use the Additive Angular Margin Loss (Arcface) loss function to identify employees' facial identities. A typical CNN used for classification includes feature extraction and classification. During training, the model will learn unique facial features and create feature embeddings during feature extraction. Instead of using Euclidean distances, Arc Face calculates geodesic distances within the hypersphere space is the space in which all distances are measured in rails. The line obtained between two points is called a geodetic line. Describes the shortest distance between points, also known as geodetic distance. Arcface has a better geometrical interpretation than the supervision signals. Arcface θ cos $(+m)$ maximizes decision boundary in angular space. Compared to multiplicative angular margin and additive cosine margin, Arcface can obtain more deep features. ArcFace loss does not have this shortage, and the result seems much better. All points are closer to the center, and there is an evident gap between identities. Consequently, the previously mentioned requirements for intra-class compactness and inter-class separability are met.

D. RESEARCH ENVIRONMENT

Empirical evidence demonstrates that many SMEs face obstacles when allocating resources to invest in information technology (IT) infrastructure. These challenges stem from a variety of factors. Modern IT systems often demand substantial financial investments in hardware, software, cloud, and expert IT management services. SMEs may need to enhance their financial capacity to cover these expenses adequately. The IT market is significantly growing, with various technological choices and solution offerings. This situation can complicate decision-making processes and lead to resource allocation towards unsuitable solutions. Additionally, it's important to note that numerous SMEs may require assistance managing and implementing IT projects. These difficulties arise due to limited technological understanding or a need for more suitable human resources.

This research centers on developing a facial recognition-based time attendance system tailored for small and medium-sized enterprises. Hence, opting for a research environment equipped with a moderately configured infrastructure, utilizing open-source software or cloud services, can effectively mitigate the initial financial outlay for enterprises. This research will serve as a valuable reference for the execution of strategies that are appropriate for SMEs.

We used our computer as the leading hardware of the system where we pre-process raw images, extract image features, build recognition programs, and a mobile application. We also built our computer as a primary server for the process flows of the system. The primary server contains all relevant resource records and handles all queries for a domain. There is a cloud server as the secondary server. The secondary server contains zone file copies that are read-only and cannot be modified.

The computer used has the following specifications:

- Operating System: Ubuntu 20.04.5 LTS
- Processor: AMD® Ryzen 7 5800 × 8-core processor × 16
- Memory: 128.0 GB RAM
- Graphics: NVIDIA Corporation TU106 [GeForce RTX 2060 Rev. A]

Prototyping and programming software used during our research development stage can be presented as follows:

- Coding environment: Visual Studio, an integrated development environment (IDE) from Microsoft, is used in our research. We developed AI functions and main programming in Visual Studio because it provides capabilities to create compiled, both native code and managed code. Visual Studio supports Python programming in the Face Recognition Module and Node.js, React Native in our Web-app and mobile application. Visual Studio Code allows us to use a development environment through a container through our remote Linux Subsystem. Moreover, there are class libraries to support our face recognition algorithms.
- Database: PostgreSQL, an open-source relational database management system emphasizing extensibility and SQL compliance, is used as our database management engine. All registration data, user data, face data, and transaction data are built in the form of a relational

database. This data will be processed, extracted, and visualized in the interface of the application through the database connection API mechanism.

- Developing Mobile Application: React Native is a framework designed to address the performance issues of hybrid applications and the challenges of writing multiple native languages for each mobile platform. Expo is a framework to build React Native apps on iOS and Android, SMEs can reduce the recompilation costs of native applications by utilizing Hot Loading, which allows for rapid modifications to the source code without the need to rebuild the application from scratch. This feature helps them quickly and intuitively trace their code, minimizing the time spent on building and running the application.

IV. IMPLEMENTATION RESULTS

A. RESEARCH DATASET

Deep learning recognition models need massive amounts of training data as well as validated data and testing data to acquire and upgrade accuracy and speed. In this work, we would prefer to create our dataset to evaluate the performance of the AI attendance in real-time to use other readily available datasets online. At first, we captured a face captured under different variations such as illumination, scale, expression, and background in different light conditions and angles. After that, we continued to crop the face in each image and standardize all the raw images. During this pre-processing, we also labeled images with a border that fully encloses a digital image, known as a bounding box, to generate our training dataset. On the other hand, we also built an automatic function to extract facial data from the camera of our mobile application. When users use our application, they will have a button to take their own photos when registering or checking attendance actively. The input image is fed into face detection models, which will be carefully presented in the next part. If the accuracy of our detection module is greater than 85%, the face with border image will be sent to the output folder. This procedure will help the system can also save time and generate research datasets in the operating time of the application. In our research, we created a dataset containing 1000 images from 10 individuals.

The samples were captured under different variations such as illumination, scale, expression, and background. Besides that, we also use a face dataset LFW [50], which is widely recognized in the field, and is frequently employed for the face verification task. It comprises a substantial collection of 13,233 photos, representing 5,749 distinct individuals, which have been retrieved from news programs for trained models and validated face recognition models.

B. AI ENGINE IMPLEMENTATION

The input of almost any face detection algorithm is an image. Because we always only have a face image of a timekeeper session and the image condition and quality are good, in this model, we use hand-crafted filters to search and locate faces in the image. This method is speedy and effective under near-ideal conditions. The algorithm's output is an image area containing a rectangular face that can be represented by 4 points (or 2 points and length and width) along with the probability that the face is in that image area. Pseudocode 1 is designed to display the found corresponding box on the image with a frame specifying the position of the face and the ratio defining the classification of that frame.

Pseudocodes 1 . Face Detection

```
    Input: A set of images of people faces needs to detect
    Output: Detected face in blue rectangle
1. Split the video stream into several photo frames
2. Pre-process pyramid of frames
      Resizing image (224, 224)
      Convert color (cv2.COLOR_BGR2RGB)
      Compute integral image
      Normalized image
3. Utilize the face-detection model to facilitate the accurate delineation of facial regions inside an image
     Detect face detect_faces(img_rgb)
     Drawing detection box x, y, w, h = detection["yaw angle, roll angle "]
     Detected_face = img[int(y):int(y + h), int(x):int(x + w)]
4. Return detected face
```

The sample result of our face detection processing can be shown in Fig. 5 below. Because there is only a face image of a timekeeper session and the image condition and quality are good, the detection process's output is an image area containing a yaw angle and roll angle face that can be represented by several points along with the probability that the face is in that image area. And even if the captured image is tilted or skewed, our application can still auto-capture and accurately detect the face area, as shown in Fig. 5.

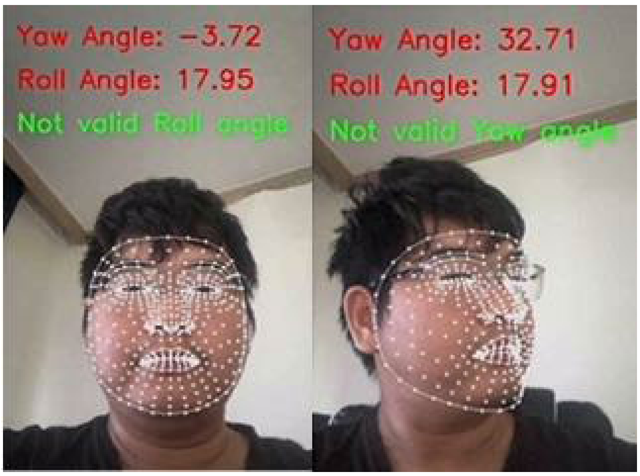


FIGURE 5. Auto-detected face when valid roll and yaw angle.

After detecting the face in the frames, the next step is to extract the important features so that the recognition model can be built to identify the object. Data feature extraction is a crucial step to effectively represent facial information that can be used for face recognition tasks. The digitized image consists of a finite number of elements, each of which has a specific value at a particular location. The result is a feature vector representing the location of the face. The feature extraction process is presented in Pseudocodes 2.

Pseudocodes 2 . Feature Extraction

Input: A set of images of people that have been labeled
Output: The feature list has been packed according to the label of each person in the dataset

```
1. Pre-process image data
      img_pixels = image.img_to_array(img)
      img_pixels = np.expand_dims(img_pixels, axis = 0)
2. Process feature
      For image dataset_images:
         image = preprocessing (bbox, landmark, size = "224,224")
         bbox, landmark = SSD (image)
         append list image
      Return image list as set of face images aligned to the ratio 224 × 224
3. Extract feature of photo frame and store them in database
      For labeled in dataset: Detect face:
         images: list images in each folder
         For image in images:
            image = preprocessing (size = "224,224")
            bbox, pred = SSD (image)
            feature = modelResNet.get_feature(bbox)
            list_feature.append(feature)
            list_label.append(folder)
4. Return list feature, list label
```

The essential concept underlying face recognition is that the proximity between two photographs depicting the same individual diminishes as their similarity increases. The vector similarity of two different images of the same person is high. However, the distance is small, and the similarity of two different images is low, but the square of the distance is significant. After we detect and crop the face, we can process it through the face arc model, generating two embedded features. Once we get the two embedding vectors, we should be able to calculate the cosine similarity or squared distance between them and determine if the two images belong to the same person. The calculation allows us to return many similar results and search for many vectors simultaneously by searching and giving the top frame with the smallest distance. Face recognition is presented in Pseudocodes 3.

The processing time of our system only takes 1-3 seconds to process and complete the timekeeping per one employee Fig. 6 shows the recognition result of the experiment.

C. FACE ATTENDANCE MOBILE APPLICATION

The implementation of a mobile application for the attendance system offers significant convenience to users due to its ability to accommodate frequent mobility and flexible working hours. Initially, the Mobile Application was developed using the React Native framework in conjunction with the Expo development tool. React Native is well recognized as a prominent framework utilized by developers for the purpose of constructing mobile applications that are compatible across several platforms. Fig. 7 illustrates the initiation of the Expo React Native by running the Yarn command. The QR

Pseudocodes 3 . Face Recognition

Input: A set of images of people that have been detected and extracted feature
Output: Identify each person in the dataset

```
1. Training ResNet34 Model
      Input image into keras layers (shape = (112, 112, 3))
      x = tensorflow.keras.layers
      Add image to keras layers
      model = training.Model
      Normalized image
      return model
2. Block1(x, filters, kernel_size = 3, stride = 1, name = None, conv_shortcut = True):
      bn_axis = 3
      if conv_shortcut:
         shortcut = add_tensorflow_keras_layers
         (layer_arguments)(x)
      else: shortcut = x
3. Stage 1: stack1(x, filters, blocks, stride1 = 2, name = None):
      x = block1(x, filters, stride = stride1, name = name + '_block1'
   For i in range(2, blocks + 1):
      x = block1(x, filters, conv_shortcut = False, name = name + '_block' + str(i))
   return x
4. Stage n
      stack_fn(x):
         x = stack1(x, 64, 3, name ='conv2')
         x = stack1(x, 128, 4,name ='conv3')
         x = stack1(x, 256, 6, name ='conv4')
         return stack1(x, 512, 3, name ='conv5')
5. Theta and Marginal target logit calculation
6. Identify
      If cosine similarity or squared distance is below the threshold:
         Return face matching
```

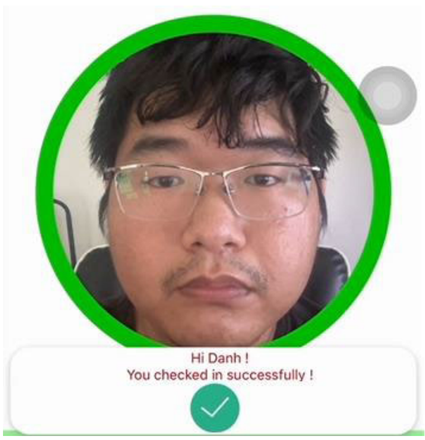


FIGURE 6. Identifying information by face recognition.

Code provided can be utilized to facilitate the installation and execution of the application.

FIGURE 7. Run the expo react native by yarn start block.

After scanning the QR code, Expo will build the JavaScript bundle, as present in Fig. 8. Users just need to wait up to 30 seconds for the installation application to complete.

FIGURE 8. Build the JavaScript bundle in expo.

The main screen of the application is shown in Fig. 9. We designed the interface to be as simple as possible to prevent employees from spending too much time logging in and then being able to time attendance every day. The description of the main interface of the application, including features for employees and visitors, is presented below:

1) FOR EMPLOYEES

Time Attendance Button: This button allows employees to perform attendance quickly and conveniently. Our application is aimed at older users and employees who may not be familiar with using the application. With just one button employees just need to press this button to start the attendance process. After pressing, the system will ask the employee to scan his/her face. When the face is scanned, the system will automatically determine the time and apply the previously set rules to classify the action as "Check-in" or "Check-out". The interface will display a confirmation message after the scanning process is complete, letting employees know that the operation has been successfully performed. This feature not only saves time but also minimizes errors in the attendance process, bringing maximum convenience to employees.

Time Attendance History: This feature provides employees with an overview of their attendance history. Employees can view their check-ins and check-outs, specific times, and total hours worked. Employees can access their timekeeping records for the past three months for various purposes, including tracking working hours, reporting errors, calculating income, self-evaluating performance, and ensuring compliance with company regulations. This feature enhances transparency and efficiency in the timekeeping process, enabling better work management and compliance with company regulations.

Register for New Employee: This feature allows managers or authorized employees to register information for new employees. Necessary information such as name, location, start date, and other contact information can be entered. The interface will guide you step by step to ensure the information is entered correctly.

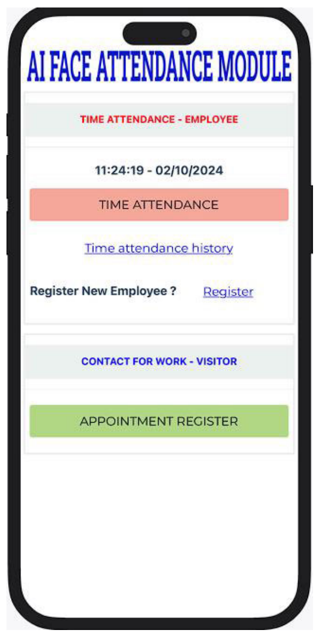


FIGURE 9. Main screen of face attendance mobile application.

2) FOR VISITORS

Appointment Register: This feature allows visitors to easily register for an appointment in advance. Visitors can select a specific date and time, as well as the person they want to meet. The interface will ask for personal information such as name, phone number and reason for visit. Once completed, the visitors will receive a confirmation of their appointment, making it easier to manage the reception of guests.

Each of these features is designed to create an easy and efficient user experience, suitable for the needs of both employees and visitors. The interface is designed to be intuitive, featuring clear buttons and easy-to-understand instructions, which facilitate user familiarity and application use.

After selecting the time attendance button inside the application, individuals are required to position themselves in front of the camera device or utilize the mobile phone application. The AI Engine will identify if the employee exists in the employee database or not. If not, another alert to check and upgrade, modify, or add employee information to HR Management. At this time, new employees can also register by themselves. Fig. 10 shows the registration process for new employees.

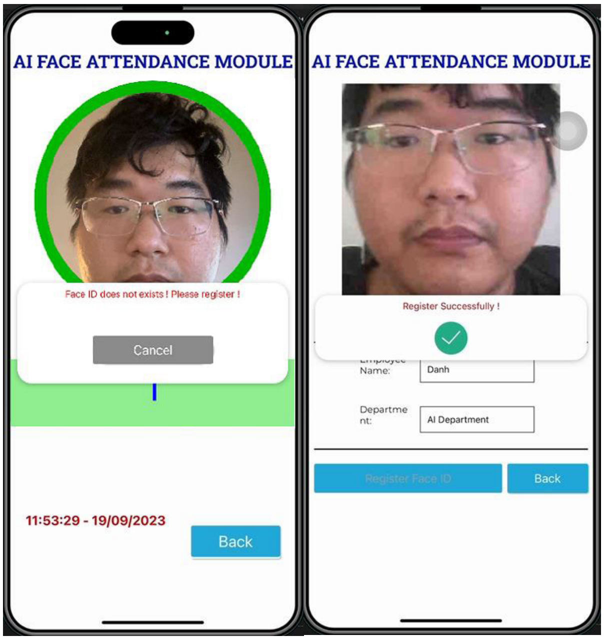


FIGURE 10. Use Case of employee not registered.

In the case of the employee existing in the employee database, the user must wait for the application to process. Normally, the processing time is 1 to 3 seconds. The system will go through a process of converting the image into a digital format, after which it will proceed with the task of facial recognition. The process involves transforming a photographic image of an individual's face into a collection of digital data, which is derived from the distinctive characteristics of the person's facial structure. The facial traits will undergo processing using algorithms and formulas, with everyone possessing distinct facial data. The subsequent phase involves doing a comparative analysis with the pre-existing facial database. The identification process is considered complete when the facial features captured in the recording correspond to an image stored within the database. Fig. 11 shows the current state of the check-in process, indicating its successful completion.

Our attendance application facilitates employees in monitoring their attendance records, working hours, instances of tardiness, instances of leaving early, duration of breaks,

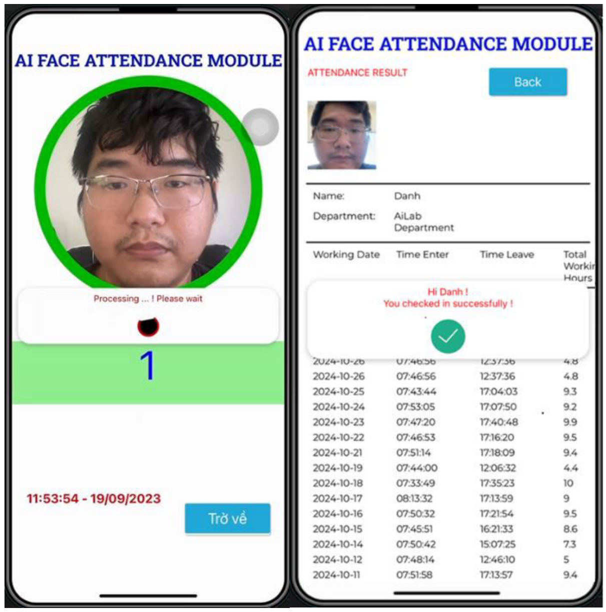


FIGURE 11. Check in successfully.

and instances of absence. The time attendance history screen is depicted in Fig. 12. Additionally, it can be utilized to guarantee adherence to labour requirements pertaining to the verification of attendance.

FIGURE 12. Time attendance history screen.

Our application will save all recognition data, encompassing the employee's name, status, time of check-in, and recorded image, as depicted in Table 1. Employees can access their timekeeping records for the past three months for various purposes, including tracking working hours, reporting errors, calculating income, self-evaluating performance, and ensuring compliance with company regulations. This feature enhances transparency and efficiency in the timekeeping pro-

TABLE 1. Time attendance history screen.

Registration Image	Recognition Image	Location	Attendance Date
		AI-SUNV	2023-09-05
		AI-SUNV	2023-09-05
		AI-SUNV	2023-09-05
		AI-SUNV	2023-09-05
		AI-SUNV	2023-09-05
		AI-SUNV	2023-09-05
		AI-SUNV	2023-09-05
ctn.	ctn.	ctn.	ctn.

cess, enabling better work management and compliance with company regulations.

Employers and human resources personnel can oversee and track their employees' working hours, track instances of tardiness and early departures, and locations, record the duration of breaks, and keep tabs on absenteeism. The improved attendance tracking application provides several benefits. It aids in the management of labor expenses by mitigating instances of excessive payments resulting from compensating staff for non-working hours. Moreover, it eliminates the occurrence of transcribing errors, misinterpretations, and deliberate inaccuracies that can occur with manual attendance recording.

The Time Attendance History can provide a comprehensive view of employee attendance records. This table allows HR managers, supervisors, and authorized personnel to access and review the historical attendance data for individual employees or an entire team. Users can easily select the specific employee whose attendance history they want to review from a dropdown list or search bar. The screen allows users to filter the attendance data by a specific date range, such as a week, month, or custom date selection. We also provided the feature of integrating the mobile application with existing HR management systems to provide SMEs with a more seamless and comprehensive attendance-tracking experience. This integration would eliminate the need for manual data entry and ensure the secure storage of employee attendance data.

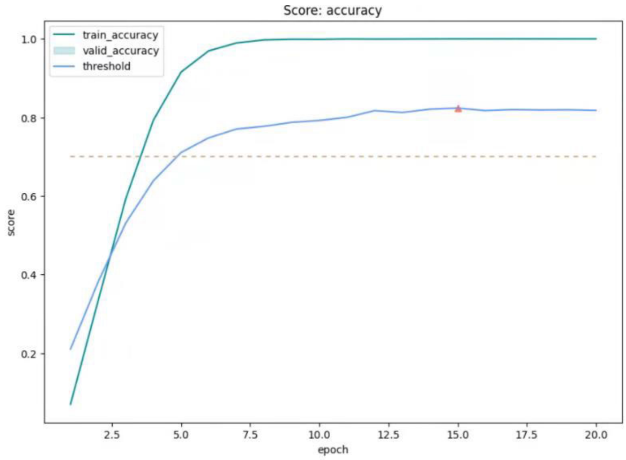
V. PERFORMANCE EVALUATION AND DISCUSSION

We use the accuracy metric and loss metric to evaluate the face recognition model in of AI engine. The assessment of a classification model's performance can be achieved through the utilization of accuracy as a measurement method. The metric is commonly represented in the form of a percentage. Accuracy refers to the measure of forecasts in which the predicted value matches the true value. The binary nature of a specific sample is characterized by its true or false values. During the training phase, accuracy is frequently plotted and monitored, with its value typically being linked to the overall or final accuracy of the model. In Fig. 13 (a), there is an increase in accuracy during the training of 20 epochs. The loss function, commonly referred to as the cost function, incorporates the probability or level of uncertainty associated with a prediction by quantifying the extent to which the prediction deviates from the actual value. This provides a more comprehensive perspective on the model's performance. In contrast to accuracy, loss is not represented as a percentage. Instead, it is computed as the cumulative sum of errors produced for each sample inside the training or validation sets. In Fig. 13 (b), there is an increase of loss during the training of 20 epochs.

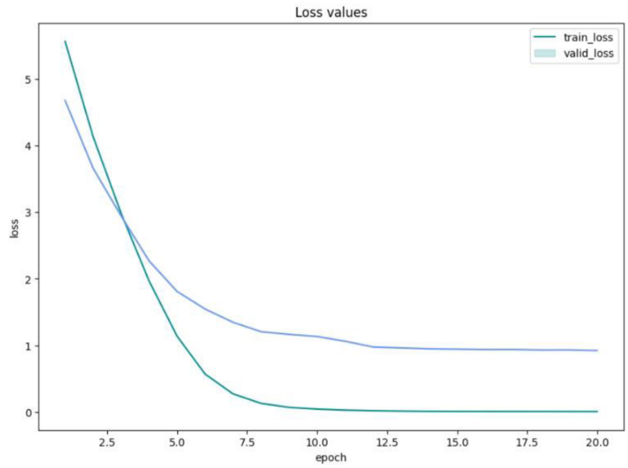
The accuracy of the model's recognition results is 92%. In Fig. 14, we present a result of celebrity recognition according to the test dataset of the LFW dataset [50].

We use the accuracy metric and loss metric to evaluate the face recognition model in of AI engine. The assessment of a classification model's performance can be achieved through the utilization of accuracy as a measurement method.

The metric is commonly represented in the form of a percentage. Accuracy refers to the measure of forecasts in which the predicted value matches the true value. The binary nature of a specific sample is characterized by its true or false values. The proposed system is an electronic attendance mobile application that utilizes Face ID, a facial recognition technology, to determine the working and off-shift hours of employees accurately. First, the mobile camera system employs an automated process to scan facial features and afterwards conducts a comparative analysis against a pre-existing database to ascertain and validate the pertinent information of each employee. The system can record and store all instances of check-in and check-out, as well as shift start and end times, in the database. It can subsequently transfer this data to the human resource management software (if integrated) or send it to the user's email as reports. The process of listing is executed in a fully automated manner. The improvement in attendance time is higher when compared to traditional systems of attendance and timekeeping. Table 2 displays a sample of specific details on the identity and duration of attendance records. The process of recording employee attendance has been substantially expedited, with the time required for this task reduced to a mere 1 to 3 seconds. The duration of attendance can be as low as 0.33 seconds.



(a) Increase of accuracy



(b) Decrease of loss

FIGURE 13. Time attendance history screen.

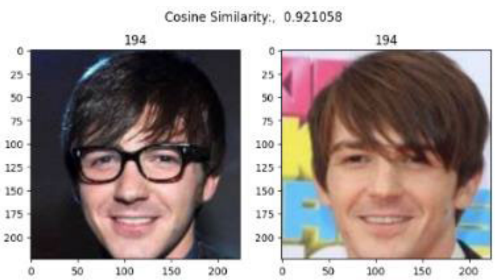


FIGURE 14. Face recognition results.

This table demonstrates the efficiency of the improved attendance tracking system, which has significantly reduced the time required to record employee attendance data. The ability to capture attendance details within a matter of seconds has streamlined the data collection process and improved overall productivity, thereby reducing the cost of time associated with manual attendance tracking.

Our attendance monitoring mobile application can help the organization maintain regular attendance and track time daily without relying on stationary equipment, especially in the framework of the distributed working model.

TABLE 2. Improved attendance system: An sample of reduce cost of time.

ID varchar	**EmployeeName** varchar	**Status** varchar	**Cost of Time** numeric
id0037	Thai Hong Danh	Allowed	2.6217322
id0038	Thai Hong Danh	Allowed	2.6217322
id0039	Thai Hong Danh	Allowed	0.3119781
id0040	Thai Hong Danh	Allowed	0.9330031
id0041	Thai Hong Danh	Allowed	0.9259998
id0042	Thai Hong Danh	Allowed	0.9330031
id0043	Thai Hong Danh	Allowed	0.9269997
id0044	Thai Hong Danh	Allowed	0.9209999
id0045	Thai Hong Danh	Allowed	0.9380003
id0046	Thai Hong Danh	Allowed	0.9159998
id0047	Thai Hong Danh	Allowed	0.9240002
ctn.	ctn.	ctn.	ctn.

Our face recognition-based attendance mobile application implements improvements to address usability concerns. Firstly, the attendance workflow should be streamlined by minimizing the number of steps required for employees to authenticate using the face recognition feature, providing clear on-screen instructions, and ensuring a rapid and responsive process with minimal delays. The real-time processing of facial images allows for instantaneous recognition without requiring users to remember passwords or carry physical tokens. This can lead to a more seamless experience, particularly in high-traffic environments where time efficiency is crucial. We also incorporate user feedback mechanisms within the app to continuously improve the authentication process based on real user experiences. This approach aims to enhance the convenience and reliability of the system, ensuring it meets the needs of our target user base. Secondly, our application has user feedback and error handling mechanisms to indicate the status of the attendance process, providing user-friendly error messages. Thirdly, the user interface design is optimized, adopting a clean and intuitive visual layout, using clear interactive elements, and ensuring accessibility for users with diverse needs. Fourthly, our application has user onboarding and support resources, including detailed guides, in-app guidance, and responsive help channels. By implementing these manners, our face recognition-based attendance mobile application can address the identified usability concerns and drive broader employee adoption and satisfaction.

The proposed cloud-based application can help reduce costs and adapt to the needs of SMEs in the following ways. First, by utilizing the cloud infrastructure, such as Google Cloud or Amazon Web Services (AWS), SMEs can avoid the upfront capital expenditure and ongoing maintenance costs associated with setting up and managing their own on-premises server infrastructure. Our proposed model can dynamically scale the system's computing and storage resources based on the workload. This is particularly beneficial for SMEs, as their facial recognition and attendance monitoring requirements may fluctuate with the number of employees or the number of locations. The cloud-based architecture can automatically scale to handle increasing demand without SMEs needing to invest in additional hardware. Our cloud-based architecture allows SMEs to access the facial recognition system from multiple locations and devices, such as mobile apps, websites, and factory devices. This flexibility is particularly valuable for SMEs with distributed operations or remote employees, as it enables access to a centralized attendance monitoring system from anywhere. We also provided the feature of integrating the mobile application with existing HR management systems to provide SMEs with a more seamless and comprehensive attendance-tracking experience. This integration would eliminate the need for manual data entry and ensure the secure storage of employee attendance data.

In our research, we focus on addressing several critical constraints that SMEs encounter when adopting advanced technologies, including AI and facial recognition. Previous works have highlighted challenges such as financial constraints, lack of technical expertise, and concerns over cost-effectiveness, which significantly hinder the integration of these technologies into the SME sector. To specifically address these challenges, our proposed solution is the development of a low-cost attendance monitoring mobile application that utilizes real-time facial recognition and location analysis. This application is designed to be accessible and affordable for SMEs, allowing them to streamline attendance monitoring without incurring significant costs. Our cloud-based architecture plays a crucial role in this solution. By executing AI model procedures centrally on a shared server, we ensure that sophisticated AI tasks can be performed without placing heavy demands on the smartphones used by employees. This design not only enhances user experience but also provides real-time processing capabilities while minimizing the need for high-performance hardware. Consequently, SMEs do not need to invest in costly infrastructure or complex systems, making our solution more attractive. Additionally, our approach allows for flexibility in technical expertise. The system is designed to be adaptable, enabling businesses to train the AI model on their actual data. This customization ensures that the solution meets the specific requirements of each SME, effectively addressing the varying levels of technical knowledge and resources available. In summary, our research offers a practical framework that empowers SMEs to implement advanced AI technologies cost-effectively, thereby overcoming the barriers that have historically limited their access to such innovations.

VI. CONCLUSION

The distributed work models, popular since COVID-19, present challenges in controlling employee activities. Our research aims to address these by developing a low-cost worker attendance mobile application that includes real-time face detection and recognition with relatively high accuracy. First, the AI Face Detection Module will be integrated into the camera on mobile devices to ensure the flexibility of face recognition data input. To handle large data streams smoothly from cameras, an automatic streaming flow enables speed and integrates the attendance identification module into the information system for updating and reporting operations. Finally, we demonstrate an experimental prototype on a mobile phone application using React Native, NodeJS, and Python. System performance is relatively good, with fast detection time for straight face shots and good image quality. This system can help managers monitor diligently, look up information, update errors, and export attendance files. Experimental results prove that our system has a high accuracy of 92% and fast processing speed when recognizing, identifying, and matching employees' faces. Our application eliminates the occurrence of transcribing errors, misinterpretations, and deliberate inaccuracies that can arise with manual attendance recording. The comprehensive attendance data stored in the HR database allows for more effective oversight and management of employee work schedules, enabling supervisors to monitor working hours, identify patterns of tardiness or early departures, track break durations, and keep close tabs on absenteeism.

The research focuses on developing a low-cost attendance monitoring mobile application that utilizes real-time facial recognition and location analysis for SMEs. We try to enhance the real-time registration and identification flow with the camera of employees' mobiles by handling large data streams and integrating the system with a cloud-based solution. In our research, we focus on developing AI computing-intensive solutions specifically optimized for the resource-constrained environment of smartphones. Unlike data centers or large-capacity servers that can leverage extensive computational resources, smartphones operate under significant limitations in processing power, memory, and battery life. Our proposed solution addresses these challenges by implementing advanced algorithms that prioritize efficiency and minimize resource consumption while maximizing performance.

The contribution of our approach lies in the utilization of a cloud-based architecture where the AI model procedures are executed centrally on a shared server. This design ensures sophisticated AI tasks are executed in the resource-constrained environment of smartphones, thereby enhancing user experience and providing real-time processing capabilities. The API Gateway serves as the entry point to our cloud infrastructure, receiving API requests from the front-end application and forwarding them to designated services for processing. The API Gateway triggers a middleware function that handles incoming requests and initiates the facial recognition process. This middleware utilizes the recognition service, which manages the computer vision and deep learning tasks required for facial recognition on provided video frames. It processes results, including detected faces and their associated metadata, such as bounding boxes and confidence scores, before preparing the response for the front-end application. Finally, the processed response is sent back through the API Gateway using the same protocol. This cloud-based solution leverages the scalability and reliability of cloud services to efficiently handle the facial recognition workload, offloading computational and storage requirements from the front-end application.

Our research also contributes to the field by establishing a framework applicable to various applications, such as mobile health monitoring, real-time language translation, and augmented reality—all requiring efficient AI processing on handheld devices. By demonstrating the feasibility and effectiveness of our solution in a resource-constrained environment, we aim to pave the way for further innovations in mobile AI applications.

Our proposed solution aligns with the constraints and needs, offering cost-effective scalability, flexibility, and reduced IT complexity for SMEs looking to implement an efficient and low-cost attendance monitoring system. Future studies may implement deep learning models to improve accuracy and develop mobile-based AI applications.

AVAILABILITY OF DATA AND MATERIALS

Please contact the corresponding author for data requests. The coding environment employed is Visual Studio, encompassing Python programming capabilities alongside Node.js and React Native. The database management system in use is PostgreSQL. Developing mobile applications uses Expo as a framework for building React Native applications. We have published the resources of the article on GitHub [51] and an introduction for our Attendance Monitoring System: AI Facial Recognition Based (**Video Abstract**) [52].

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