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Embedded Low Power Blockchain Traceability Solution for University Classroom Attendance

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***Abstract*—** The emergence of artificial intelligence and decentralized applications has made it possible to set up efficient systems in terms of traceability. The combined technologies are used in several fields such as fintech, industry 4.0, smart agriculture, etc. Their application can also impact educational and academic fields. There is growing interest in leveraging blockchain technology to securely store and retrieve student records. This paper proposes a new smart system that uses deep learning and blockchain technologies to store and manage student attendance. It relies on an embedded platform based on a camera and a Raspberry PI platform that uses artificial intelligence for face recognition and on the blockchain for secure data storage. Evaluating the resulting model on the Labeled Faces in the Wild (LFW) benchmark yields an impressive accuracy rate of 0.9938 with a standard deviation of 0.00272. Moreover, the proposed system provides a complete and accurate record of the entire student learning process, and, thus, reduces the risk of falsified educational records. It also provides potential benefits to future employers by giving them access to large amounts of verified and systematically accumulated data, allowing them to identify and hire qualified students.

***Keywords*—** Face recognition; Blockchain; Embedded System; Raspberry; Automatic attendance; Education; Smart attendance system.

1. INTRODUCTION

The rapid development of technology has slashed the volume of work manually assumed by a human. Many jobs have the potential for automation as in the case of monitoring and control of attendance in industrial, medical or academic contexts. The manual monitoring of screens is a tedious task because of the large amount of information that circulates. It is therefore certainly advantageous to automate this procedure using image processing systems, capable of not only extracting useful information from videos, but also interpreting and saving it in an immutable way that guarantees traceability. This application, which was once specific to the financial sector, is becoming more and more common. Indeed, blockchain is used not only in fintech but also in the medical field [1-3], the agricultural field [4, 5], the industrial field [6], the sports field and, broadly speaking, in social contexts [7].

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In the context of academia, participation in a seminar or a classroom course is a commitment of time in exchange for knowledge and skills. This information can only be acquired if the student is present. Additionally, in order to identify students in need of assistance, many universities have found it necessary to track student attendance.

Seminar organizers could also use this technique for punctuality, attendance, etc. This information might then be used to identify students, and, subsequently, decide which participants to re-invite. Tracking the actual attendance of participants at a seminar provides organizers with a reliable basis for awarding certificates of attendance. It provides sponsors with a reliable report on the participation of sponsored candidates. Since the attendance counts in mark assignment and can affect the results of the students, this information is considered of critical importance and should not be tampered with in any form or way. Even after, the fact of it being saved, a solution is needed to guarantee that the information saved will not later be modified and any addition or manipulation should be detected and the file renderer invalid. We should also be able to track the manipulator in case that happens and be able to retrieve the original file in that case.

In the Tunisian educational system, one could argue that the curriculum is overloaded with information that must be delivered to students throughout the academic year. It falls upon the teachers to convey a significant amount of material and explanations within a limited timeframe. This is why every minute of each class session is crucial. However, during each session, approximately 10-15 minutes are squandered on the roll call process. Professors must audibly call out each student's name and wait for the student to respond, confirming their presence, or they waste even more time waiting for a response if the student is absent. This procedure is inefficient and results in a considerable amount of time being wasted, time that could be better spent educating the bright minds of tomorrow.

The proposed attendance process in this paper applies advanced technology, including artificial intelligence and blockchain enabling traceability and immutability. Our paper consists of four parts. We begin with a state of the art on the university classroom attendance. In Part II, we detail the blockchain technology. In Part III, we propose our implemented approach and the Facial Recognition Implementation. The results of the work are revealed in Part IV. The paper is closed with a conclusion and some perspectives.

2. RELATED WORKS

There are various methods available to monitor attendance in different settings, such as schools, companies and hospitals, where it is essential to record the entry and exit time of attendees. Some of the popular methods used for attendance-taking are paper-based registries, radio frequency identification, biometric systems, and web-based systems. However, these attendance monitoring systems have their own limitations. Currently, the attendance system used in many universities is generally manual [8]. Before starting their lessons, instructors enter classrooms to teach students who have already arrived. During the teaching and learning process, instructors collect attendance data through paper documents. The attendance data gathered from these documents are then collated by the academic administration. However, these methods may not be ideal for larger classes, as it would be time-consuming for educators to call out every student's name to validate their attendance. This could potentially waste valuable time that could be used for more efficient teaching. Amidst the rapid technological progress, several researchers have proposed more intelligent methods.

The objective of the research in [9] is to propose an approach for managing attendance in educational settings through a presence system based on RFID technology. The proposed system leverages sensors to capture data, which is read by RFID tags attached to students' cards. The system's primary aim is to simplify the task of tracking student attendance for both lecturers and students. As students enter the classroom, their RFID tags will be scanned, and the collected data will be transmitted automatically to a centralized database. A number of campuses have already begun to automate their attendance systems relying on fingerprint technology. However, this method is time-consuming as users have to scan their fingerprints one by one, resulting in queues during peak hours. Similarly, barcode technology, which assigns a unique code to each card, also suffers from delays as the reader must be aligned with the card. This causes queues and further time inefficiencies [10].

The Turkish Near East University has implemented a web-based attendance monitoring system that requires students to log in and use a "click event" method to register their attendance on the University's web server. Wang Meilin et al. [11] proposed a double signature-based attendance (DSBA) system that ensures real-time operations and traceability in higher education institutions. Similar monitoring systems have been applied in manufacturing execution systems to manage manufacturing workshops.

In the suggested system outlined by [11], the focus is on automating the monitoring of the user's device location and screen interactions within a specified time frame dedicated to a subscribed conference session. This involves employing AI-driven analytics, leveraging custom mathematical models and JavaScript Machine Learning Libraries, to make informed decisions based on the gathered data. This analytical approach aids conference organizers in evaluating attendee performances. Furthermore, the transition of data from the web 2.0 database to the blockchain is facilitated through the implementation of a smart contract. The users are only permitted to access data from the blockchain, while the administrator is responsible for publishing data to the blockchain from the web 2.0 backend. By sending data to the blockchain in record mode, it becomes possible to retrieve flattened data objects from the blockchain in a manner similar to querying data from the MySQL database. This ensures that the data could be easily queried and accessed from the blockchain (see Fig. 1).

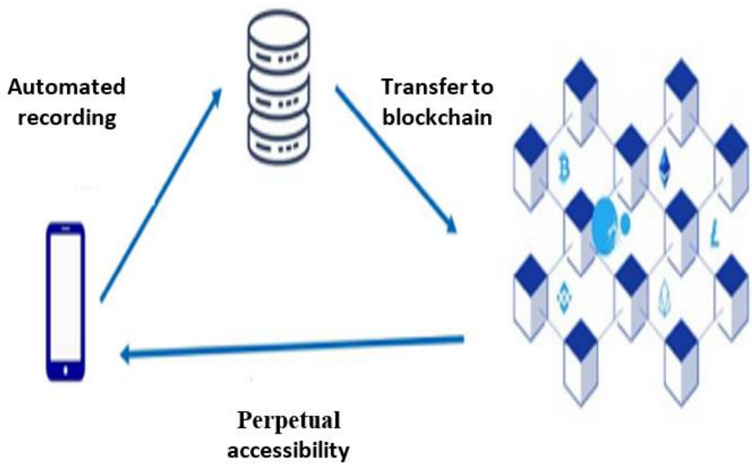

Fig. 1. Illustration of the functional requirement of Web2/3 application.

Furthermore, certain intermediate educational establishments employ cameras that are equipped with facial recognition technology to monitor the conduct of individual students. These cameras are capable of identifying specific behavior patterns, such as writing, reading, speaking and paying close attention [12]. In recent times, there has been a significant transformation in the utilization of information technology. The coming years are expected to bring a wide-scale integration of blockchain-based data storage systems as the current cloud-based data storage solutions are centralized, thereby necessitating trust in the service providers [13-15]. However, with decentralized cloud-based data storage, user data is not stored in a central server but is rather distributed across the nodes of the blockchain. The authors in [16] propose a private blockchain framework, wherein student attendance is tracked using QR code, mobile phones and a teacher's laptop. Fig. 2 illustrates the framework for student attendance registration.

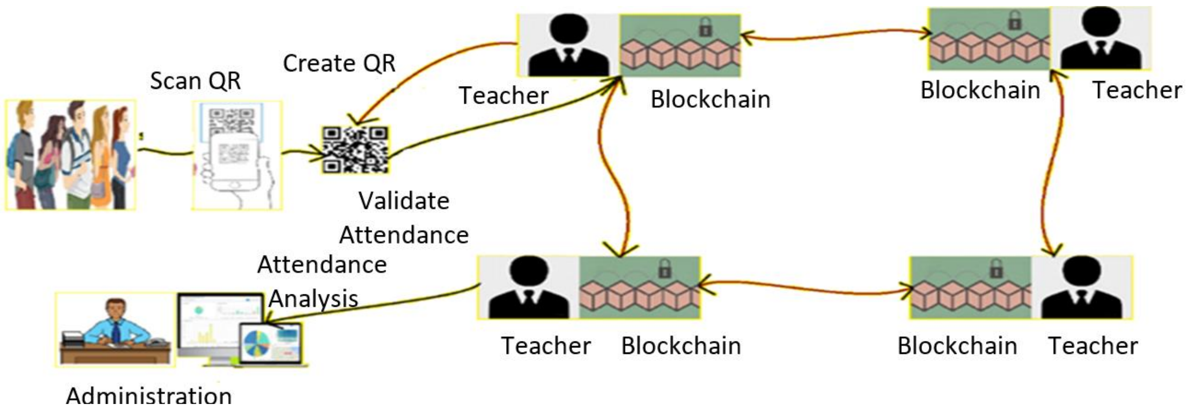

Fig. 2. Smart attendance system using IOT and blockchain.

To ensure the security of data storage, the authors in [17] used a decentralized blockchain technology allowing the university to establish its own blockchain and set its own operating rules. The solution relies on the NVR (Network Video Recorder) unit and a smart contract for attendance registration.

The authors in [18] describe a blockchain-based solution for student attendance management, which uses facial recognition technology for attendance tracking. Advantages of this system include increased accuracy and efficiency in attendance tracking. However, implementing this system may raise concerns about privacy and data protection. It also requires significant investment in facial recognition technology and blockchain infrastructure. In [19], the authors propose a vision face recognition attendance monitoring system for surveillance using deep-learning technology. The authors achieved a maximum recognition accuracy of 74% when running the real-time surveillance algorithm. This work was an attempt to overcome the lack of a robust and user-friendly facial recognition system. The use of blockchain technology has also been suggested for various purposes in higher education, including document storage and security for educational certificates, as well as the potential use of crypto currency for payments, as mentioned in [20, 21]. Additionally, Shah et al. [22] proposed utilizing blockchain for transcript storage, incorporating machine learning to predict student success. Authors in [23] provide a detailed plan for implementing blockchain to store and retrieve students' transcripts using Python lists, although a working prototype is still in development. In the system proposed by [24], facial recognition technology is employed, utilizing a Convolutional Neural Network (CNN) for face detection in images. Deep metric learning is then applied to generate facial embeddings, and a K-Nearest Neighbors (K-NN) algorithm is utilized for classifying students' faces. Through this methodology, the computer is capable of identifying and recognizing faces. Experimental results indicate that the system successfully identified the faces of attending students, with the corresponding attendance data being automatically recorded. The attendance recording system is implemented as a web-based application for accessibility and convenience. Raspberry Pi 3 model B+ is utilized by students to mark their attendance, while the Raspberry Pi NoIR v2 camera, connected to the Raspberry Pi, captures their images. The attendance data is then processed using face recognition algorithms on a computer and added to the database. The system architecture is illustrated in Fig. 3.

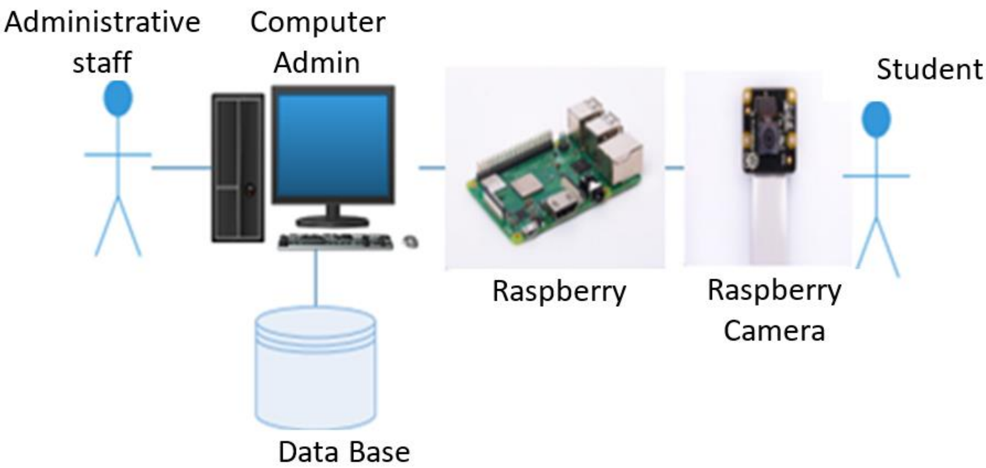

Fig. 3. Centralized student attendance system design.

The researchers in [25] introduced a university classroom automatic attendance system, combining two deep learning algorithms: MTCNN (Multi-Task Cascaded Convolutional Neural Networks) for face detection and Center-Face for face recognition (see Fig. 4). Notably, the face recognition model achieved an accuracy rate of 98.87%.

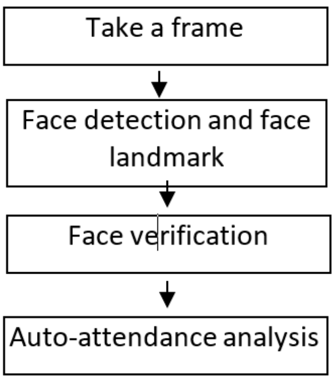

Fig. 4. Algorithm of the automatic attendance system.

Based on recent research in this area, many potential solutions could still be improved to control student attendance. Indeed, many of the proposed solutions are not secure or do not exploit a decentralized solution. Other proposals are based on solutions requiring computer-based architectures. But among the constraints of an embedded solution is the low power aspect. In this context, an embedded solution that combines the decentralized and low-power aspects for monitoring student attendance is proposed. Thus, the reliability and the integrity of the solution will be guaranteed. This solution can be applied in universities and can be extended in the security fields. Table 1 represents a comparison of our approach with the different state-of-the-art.

The significance of our work is substantiated by a comprehensive comparison, as presented in Table 1 of the manuscript. Unlike many existing approaches to student attendance tracking, which predominantly rely on centralized databases or traditional computer systems, our proposed solution leverages embedded hardware, specifically the Raspberry Pi. This deliberate choice addresses several limitations associated with traceability, embedded aspects, and cost considerations in existing methods.

Table1. A comparison of the proposed approach with state-of-the-art approaches.

Ref.	Blockchain	Technology	Embedded	Data Base	Low power
[9]	No	RFID	No	Yes	No
[10]	No	Fingerprint, barcode	No	Yes	No
[11]	Yes	Smartphone	No	Yes	No
[16]	Yes	QRcode	No	Yes	No
[17, 18]	Yes	Webcam, video	No	Yes	No
[23]	No	Webcam	Raspberry PI	Yes	Yes
Our approach	Ethereum	Webcam	Raspberry PI	Yes	Yes

Our work distinguishes itself by not only showcasing cost-effectiveness but also highlighting the inherent advantages of utilizing embedded systems and blockchain technology. The reliance on centralized databases or general-purpose computers, as observed in other approaches, introduces limitations in terms of reliability and traceability. In contrast, our embedded hardware-based approach ensures a more robust and secure system for attendance tracking.

3. BLOCKCHAIN OVERVIEW

3.1. Characteristics

Blockchain is a distributed ledger technology that enables secure and transparent data transactions without the need for a centralized authority. It is characterized by a number of features, including decentralization, immutability, security, transparency and consensus. These features make blockchain an ideal platform for managing and sharing data across various industries, including finance, healthcare, supply chain and education [26].

One of the main advantages of blockchain is its security features. The technology uses cryptographic algorithms to secure data, ensuring that it cannot be altered or deleted once it has been added to the blockchain. The use of cryptographic algorithms and a distributed network of nodes makes blockchain resistant to hacking, tampering and other forms of cyber-attacks. Another advantage of blockchain is its transparency. Once data has been added to the blockchain, it is visible to all participants in the network. This makes it easier to track and verify transactions and reduces the risk of fraud and corruption. Additionally, blockchain's transparency can improve accountability. Decentralization is another key feature of blockchain. Instead of relying on a central authority to validate transactions, blockchain uses a network of nodes to achieve consensus on the state of the ledger. This means that no single entity has control over the blockchain, making it more resistant to censorship, corruption and other forms of centralization [27].

Immutability is another feature of blockchain that makes it an attractive platform for managing and sharing data. Once data has been added to the blockchain, it cannot be altered or deleted. This provides a high degree of integrity and authenticity to the data, making it easier to verify and trust. There are two main types of blockchain: public and private. Public blockchains, such as Bitcoin and Ethereum, are open to anyone and can be used to create decentralized applications. Private blockchains, on the other hand, are only accessible to a specific group of users, making them more suitable for confidential data management. Private blockchains can be used to create closed networks for specific use cases, such as supply chain management, where data privacy is critical [28]. Evidently, blockchain technology offers a range of advantages, including security, transparency, decentralization, immutability and consensus. These features make it an ideal platform for managing and sharing data in a secure and efficient manner. As the technology continues to evolve, it is likely that we will see novel applications of blockchain in various industries, including education, where it can be used to manage student records and improve transparency and accountability in the education system.

3.2. Use Cases of Blockchain

Blockchain technology is poised to revolutionize diverse sectors, encompassing health, agriculture, and education, as highlighted by [29] (Fig. 5). Specifically, in the healthcare industry, blockchain holds the potential to securely and efficiently manage patient data. The implementation involves storing patient records in the blockchain, creating a secure platform for seamless data sharing among healthcare providers. This not only diminishes errors but also enhances patient outcomes. Additionally, blockchain can play a pivotal role in tracking the supply chain of pharmaceutical products, assuring the authenticity and safety of drugs.

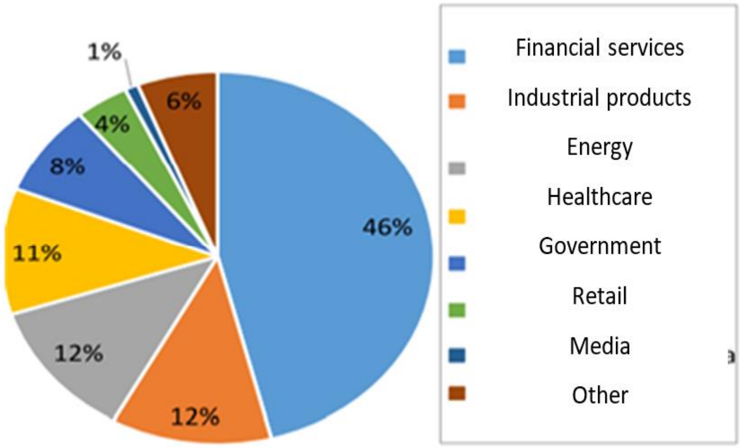

Fig. 5. Blockchain use cases [29].

In agriculture, for example, blockchain can be used to track food products from the farm to the kitchen. Farmers can use blockchain to verify the authenticity of their products and prove their compliance with quality and safety standards. Consumers can use blockchain to verify the authenticity and safety of the food they buy, reducing the risk of food fraud and contamination [30].

Additionally, blockchain can facilitate secure sharing of health data between different healthcare providers and improve the efficiency of processes such as insurance claims management and drug supply chain management. Some ongoing projects are exploring the use of blockchain for health data management, clinical trials management, and even for incentivizing healthy behavior using blockchain-based reward systems. While there are still challenges to be addressed, the potential benefits of blockchain in eHealth make it a promising area for further research and development. In the education sector, blockchain can be used to manage student records, including transcripts, certificates and diplomas. This provides a secure and tamper-proof platform for data sharing between universities and other educational institutions. Blockchain technology offers a multitude of applications, extending its utility to verifying the authenticity of degrees and certificates, thereby mitigating the risk of fraud and enhancing the credibility of educational qualifications. In the realm of universities, blockchain can be employed in a remote voting system that prioritizes security, anonymity, irreversibility, accessibility, and user-friendliness. This innovative approach enables voters to cast their ballots for their chosen candidates without the necessity of being physically present [13]. Furthermore, researchers can leverage blockchain to securely and transparently share their research findings, fostering collaboration with peers globally. Universities can also utilize blockchain for managing accreditation and ranking systems, establishing a secure and tamper-proof platform for transparent data sharing. This not only enhances the integrity of educational institutions but also contributes to a more transparent and trustworthy academic ecosystem.

4. PROPOSED APPROACH

4.1. System Architecture

Blockchain technology has become increasingly popular in the education sector, and its potential uses are numerous. One innovative use involves the use of blockchain and deep learning algorithms to create a secure and reliable platform for classroom attendance tracking. This can be achieved using a Raspberry Pi, a low-cost and low-power (less than 6 watts) credit-card-sized computer that can be easily integrated into the existing classroom infrastructure. Using a camera connected to the Raspberry Pi, deep learning algorithms can be used to analyze images of the classroom and identify students based on their facial features. This allows for real-time monitoring of classroom attendance without the need for manual input, thereby reducing the risk of errors and fraud. As shown in Fig. 6, in each classroom of every department, a camera attached to a Raspberry Pi running the software script will be installed facing the entry door. The combination of the camera and the Raspberry Pi will constitute our node. This node, like the other nodes, will be linked via Ethernet to the university local area network and the internet. The attendance data can be securely stored on a blockchain network, ensuring that the data is tamper-proof and transparent. This provides a reliable and secure platform for tracking attendance, which can be useful for both students and teachers.

For students, the attendance data can be used to track their progress and ensure that they meet the required attendance criteria. For teachers, the data can be used to identify students who may be struggling with attendance and provide appropriate support. The incorporation of the Raspberry Pi in our research holds significant importance, aligning with the specific requirements and goals of our proposed system. The Raspberry Pi 3 model B serves as an embedded platform, chosen deliberately for its robust features and capabilities. First, the aim of our application is to process facial recognition data locally at the periphery, reducing the dependence on centralized IT resources. The Raspberry Pi, with its Quad Core A.2 GHz 64-bit CPU and 1 GB RAM, provides substantial processing power to handle the computational demands of facial recognition. This local processing ensures efficiency and minimizes the need for external servers, contributing to the decentralization aspect of our proposed system.

Secondly, the Raspberry Pi offers a range of peripherals, including 4 USB ports, an RJ45 port, and an HDMI port. These peripherals are crucial for seamless integration with cameras and other components, facilitating the core functionality of our system. The ability to connect multiple peripherals makes the Raspberry Pi a versatile and suitable platform for applications demanding various inputs and outputs. Furthermore, our research involves the deployment of the Ethereum blockchain, and the Raspberry Pi can act as a node in this decentralized network. Its affordability, ease of deployment, and quick setup make it a practical choice for implementing and testing our proposed solution.

In the comparison with other available platforms such as ARDUINO Uno, Mega, 32-nucleo STMs, ML 507 FPGAs, and Raspberry Pi, the Raspberry Pi emerged as the most suitable option that can deliver a reliable and efficient system meeting our application needs. The decision to choose the Raspberry Pi over other platforms is based on its cost-effectiveness, deployment convenience, and ability to support both facial recognition and blockchain functionalities. Additionally, the low power consumption [7] of the Raspberry Pi is a crucial factor, ensuring continuous and energy-efficient operation. This aligns with our research's sustainability objectives and practical considerations, emphasizing the feasibility and real-world applicability of our proposed system.

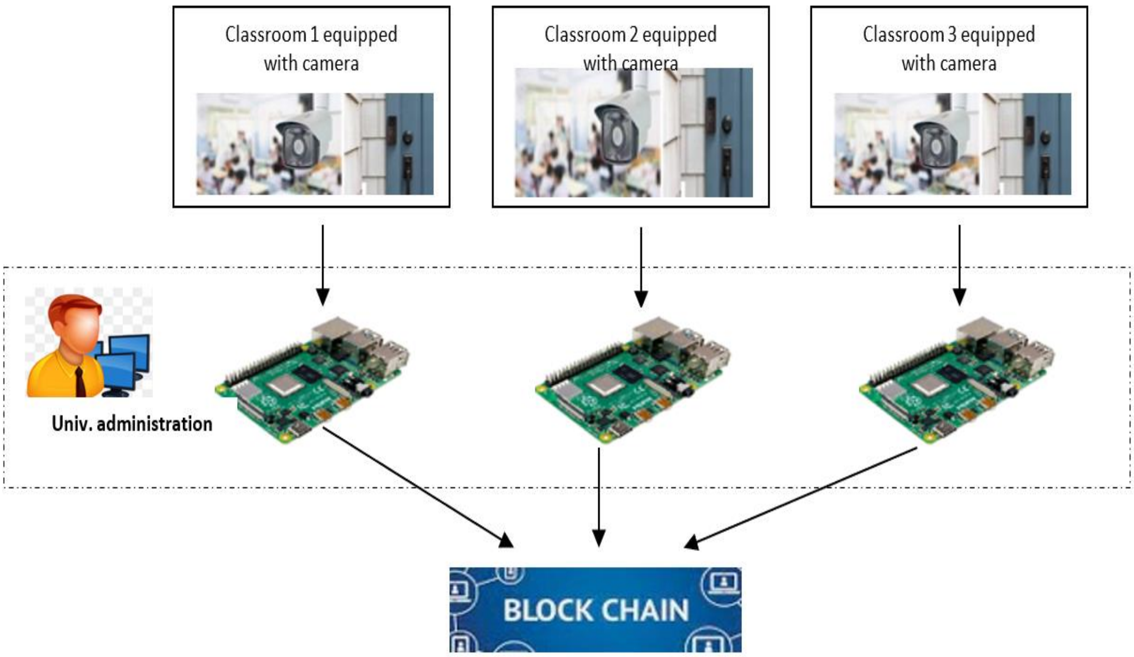

Fig. 6. The proposed student attendance approach.

4.2. Software Model

The software has a few basic requirements, irrespective of the details of the image detection and recognition.

a) Student image repository: This will be the source of images that the software would use to train itself to recognize the students already known. It is organized as follows: Department→year → class. Example: GE→ GE3→ EIE1→ 1 student_name.jpg as shown in Fig. 7. The program extracts the names, last names and ID numbers of students and crops the pictures to just the size of the face.

b) Schedule of every classroom: When setting up the software, the classroom and the department are fixed. The program then investigates that classroom schedule and keeps watch over the current time. If it matches a session, the software then makes a list of the students taking their names and IDs from the image labels in the student pictures directory and begins to detect and recognize students. The program flowchart is presented in Fig. 8.

c) Facial Recognition Implementation

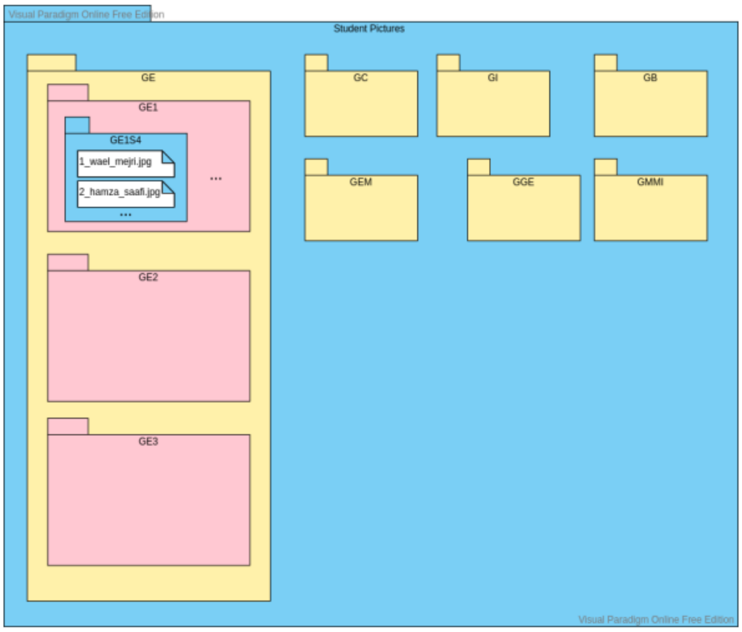

Fig. 7. The student image repository.

4.2.1. CNN and Resnet

This research is based on a deep learning approach utilizing convolutional neural networks (CNNs). Despite significant progress made in CNN research, these models are often limited in their real-world application due to computing and memory constraints [31].

A significant factor driving the development of ConvNets is their high accuracy in classifying images based on abstract concepts that are difficult to understand. One of the key advantages of CNNs is their architecture, which eliminates the need for manual feature extraction. Instead, the system is trained to extract features using convolutions of image data with filters, generating invariant features that are passed on to the next layer. These features are further convoluted with different filters to produce more invariant and abstract features until the final output (e.g., the face of the student), which is invariant to occlusions. The convolutional layer is the essential building block of the CNN architecture. According to MathWork, CNNs use 2D convolutional layers to convolve learned features with input data, making them highly effective in processing 2D data, such as images. CNNs extract features directly from images, and these features are learned during network training on a collection of images, rather than being pre-trained. Automated feature extraction is the key feature that makes CNNs highly accurate and well-suited for computer vision tasks, including object and image classification.

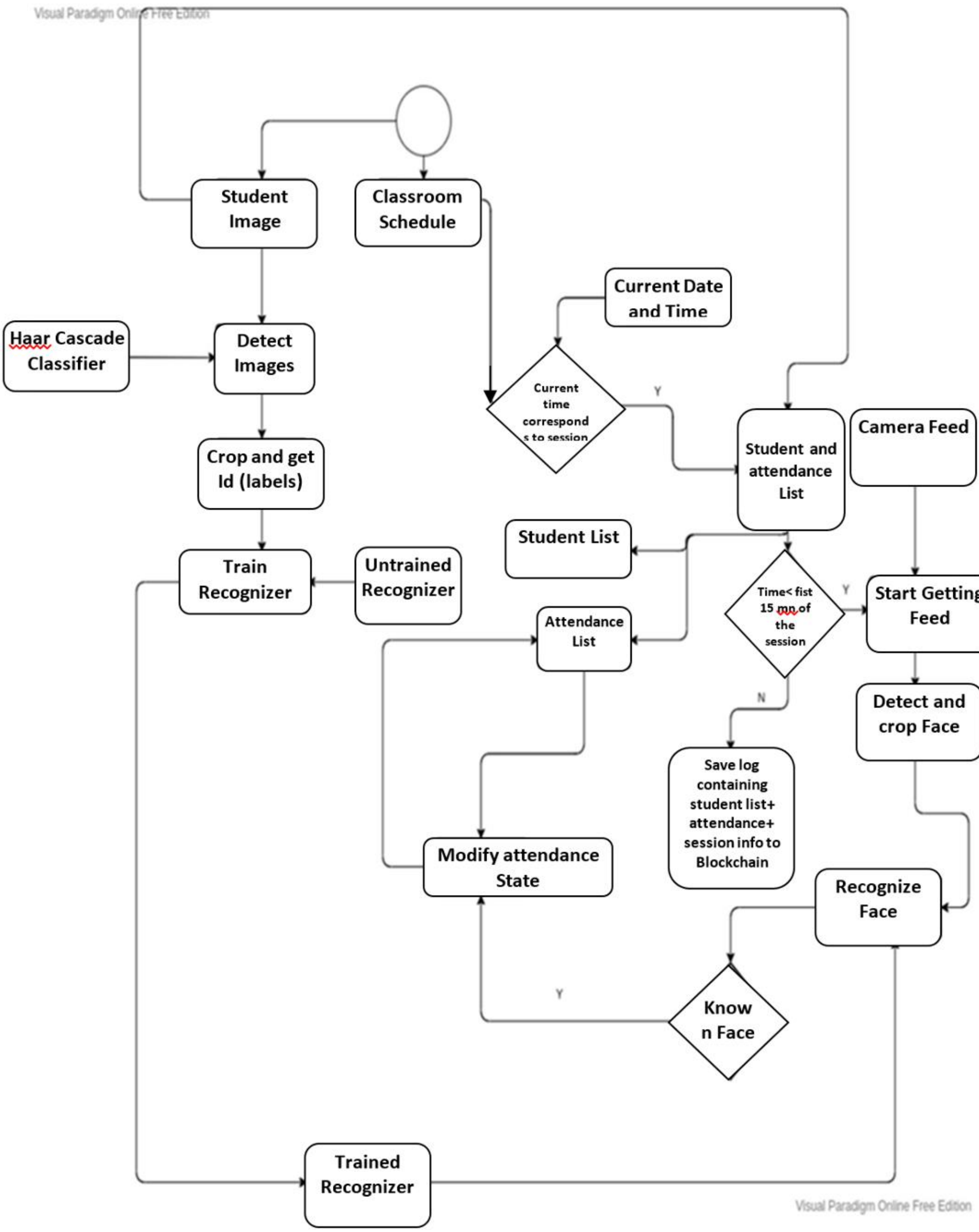

Fig. 8. Software flowchart.

4.2.2. Dlib face recognition Resnet

Dlib is a comprehensive C++ toolkit that offers machine learning algorithms and tools for building complex software solutions to tackle real-world problems. This powerful toolkit is widely used across different domains, such as robotics, embedded devices, mobile phones and high-performance computing environments in both industry and academia. Its open-source licensing model enables users to use it free of charge in any application [32]. The model being described is a ResNet network that contains 29 convolutional layers. The modified version of the ResNet-34 network, as presented in [33], has undergone adjustments with the removal of several layers and a reduction in the number of filters per layer. Training of this network was initiated from scratch, utilizing a dataset comprising approximately 3 million faces. This dataset is a composite of various datasets, including FaceScrub [34], the VGG dataset [35], and a substantial collection of images sourced from the Internet.

Ensuring data quality was imperative, leading to a cleanup process involving the removal of labeling errors. Specifically, certain data from VGG was filtered out through a combination of repeated training of the face recognition CNN, followed by graph clustering methods and manual review to iteratively refine the dataset. In the end, around half of the images originated from VGG and FaceScrub, resulting in a dataset containing 7,485 individual identities. Importantly, measures were taken to avoid any overlap with identities present in LFW (Labeled Faces in the Wild).

4.3. Blockchain Solution

Following the detection and recognition of students and in order to guarantee the traceability and immutability of data, the blockchain solution is applied. One way to benefit from the advantages of the blockchain while paying the minimum per transaction is to store only the hash of the data in the blockchain. This will ensure the reliability of the data. In our context, smart contracts will be deployed to store information on the blockchain. For this purpose, an application proposed by Jung Winter [36] is exploited to save the hash of the attendance file as shown in Fig. 9. Heni et al. designed an emotional educational system based on face recognition of autistic learners [37]. The choice of the Ethereum blockchain is due to two main reasons. Ethereum is an authorization blockchain. It uses a robust consensus, the PoW.

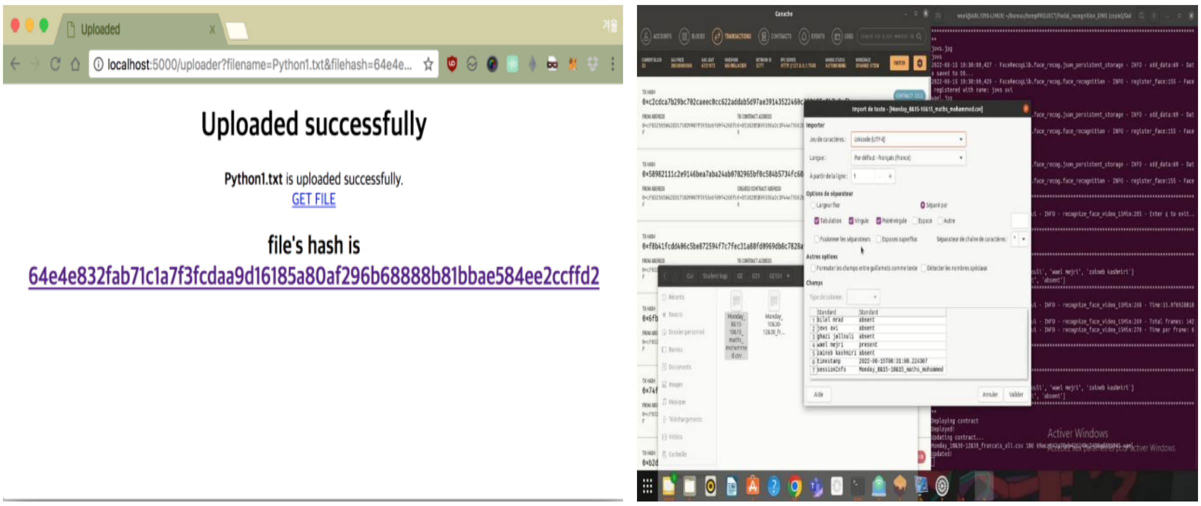

Fig. 9. Hash generation of the student attendance files.

While working offline, the following software tools will be used:

- Truffle: a "framework" development environment for blockchains using the Ethereum Virtual Machine (EVM).
- Ganache: Ganache is used to set up an Ethereum blockchain to test Solidity contracts.Metamask: a software crypto-currency wallet used to interact with the Ethereum blockchain, allowing users to access their Ethereum wallet via a browser extension or mobile application
- Nodejs: a runtime environment that includes everything needed to run a program written in JavaScript.

4.4. Security Measures

In addressing the paramount concern of ensuring the security of university attendance data, we have implemented a robust security framework centered around blockchain technology. The utilization of blockchain serves the dual purpose of enabling traceability and providing inherent security features. Specifically, the security of user information is guaranteed through the generation of a unique public and private key pair using the ECDSA (Elliptic Curve Digital Signature Algorithm). This key pair establishes a secure connection utilized within the smart contract to validate the identity and authorization of the user. The legitimacy and integrity of the certificate data are rigorously verified by cross-referencing the content of the registered certificate with the public key used for signing. This meticulous verification process safeguards against any potential forgery, ensuring the authenticity of the attendance records.

In the context of our decentralized system tailored for university attendance, a two-tier security approach is paramount. The first layer involves the encryption of all stored data, including attendance records, during the transactional process. This encryption serves as a robust safeguard, fortifying the protection of sensitive academic information against unauthorized access. Furthermore, to bolster the security of our Ethereum-based platform, we have incorporated the Keccak-256 hash-based consensus mechanism. This mechanism plays a pivotal role in converting the entered data, adding an additional layer of security to the overall system. The Keccak-256 hash-based consensus mechanism ensures the tamper-resistant nature of the data, enhancing the system's resilience against potential vulnerabilities and affirming the integrity of the attendance records.

The distributed nature of attendance records across the network acts as a robust defense against unauthorized alterations, ensuring the immutability of data through Ethereum's consensus mechanisms. Cryptographic techniques [38, 39], including the use of public and private key pairs, hashing, and digital signatures, play a pivotal role in guaranteeing the integrity and authentication of attendance entries. Furthermore, the implementation of smart contracts automates key processes, reducing the need for human intervention and fortifying the system against potential errors or fraud. The transparent nature of the blockchain allows for a comprehensive audit trail, providing visibility into all transactions. To enhance security further, sensitive attendance details are encrypted during storage, adding an additional layer of protection to our system.

5. RESULTS AND DISCUSSION

The training of the network commenced with weights initialized randomly and incorporated a structured metric loss aiming to project all identities into non-overlapping balls with a radius of 0.6. The loss function employed is essentially a pair-wise hinge loss, covering all pairs within a mini-batch, and incorporates hard-negative mining at the mini-batch level.

In our use case, students are required to present themselves in front of the webcam, as depicted in Fig. 10. In the scenario of multiple faces in a classroom, the webcam is strategically positioned at the entrance of the classroom. As students enter the class, each one is expected to stand in front of the webcam for identification and attendance purposes. This setup ensures a streamlined and systematic process, leveraging facial recognition technology to accurately capture and record the attendance of individuals in a classroom setting. Considerations for face accessories, such as glasses or facial hair, are incorporated into the student's dataset to accommodate diverse appearances.

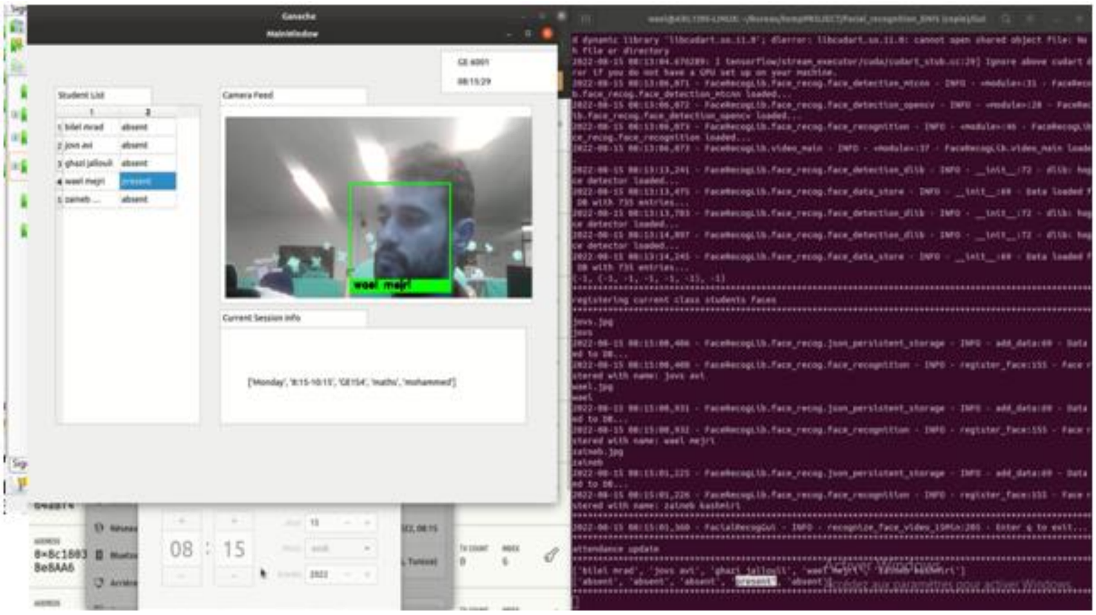

Fig. 10. Recognition results.

The resultant model achieved an impressive accuracy rate of 0.9938, with a standard deviation of 0.00272, as evaluated on the LFW benchmark.

The results of this application are currently being validated. In fact, when utilizing Ganache, the platform automatically generates a distinct set of private and public keys for each account. Each account is endowed with a balance of 100 ETH. Ether (ETH) serves as the transaction currency on the Ethereum platform and is employed for experimental purposes in conjunction with the simulated node role.

An analysis of the cost associated with the functions executed within our smart contract, deployed on the blockchain, is detailed in Table 2. The analysis reveals that the functions exhibit a low cost in US dollars.

In Table 2, we provide a detailed breakdown of cost metrics parameters. Notably, our transaction cost falls within the range of 0.27 to 1.2 USD, showcasing a cost-effective implementation.

Table 2. Transactions cost.

Smart contract transaction	Cost in ETH (10-3)	Cost [USD]
New Classroom	0.54	1.24
New student	0.33	0.75
Student's presence	0.12	0.27

The affordability of the Raspberry Pi, priced under 50 USD, further underscores the economic viability of our approach compared to alternatives. Crucially, our system achieves an impressive accuracy rate of approximately 98%. This high level of accuracy is a testament to the efficacy of our solution in real-world scenarios, where precise attendance tracking is essential.

Fig. 11 shows the deployment of smart contracts under Ganache as well as the cost of the operation.

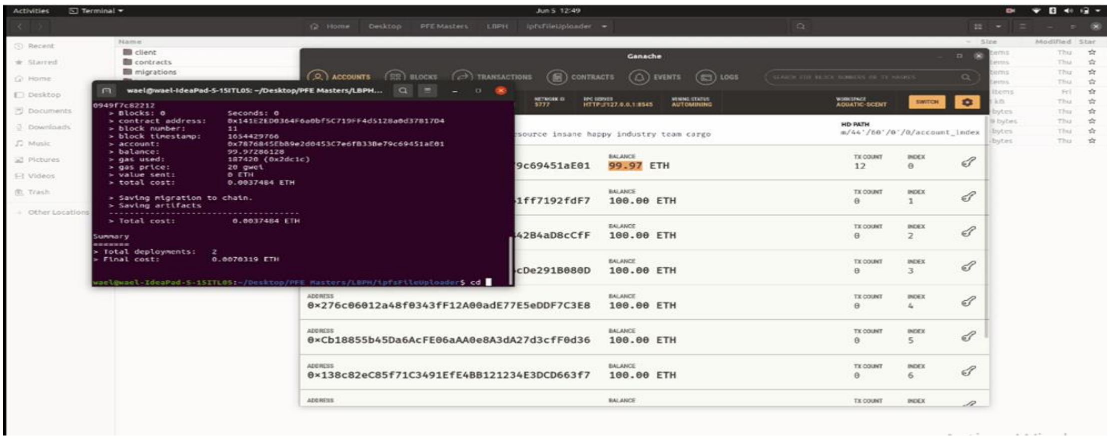

Fig. 11. Smart contracts deployment on Ganache.

The low power factor [40] has become an important issue, especially for blockchain, which consumes a lot of energy (GigaWatts). Indeed, one of the reasons why blockchain, and especially Ethereum, have been decried is for its use of PoW consensus, which is characterized by a high consumption. In this context, Ethereum in its version 2.0 shifted from using PoW to PoS consensus. This change has certainly decreased the power of the encryption algorithms, but it has minimized the consumption while keeping the reliability necessary for the blockchain. Subsequently, our application has been implemented on a resource-constrained platform. In this context, the Raspberry PI platform has been chosen for its low power. It offers the possibility to process the video stream of webcams. Moreover, the video acquisition application does not present strict constraints in terms of real time since it only requires a minimum of frames per second. As the raspberry is a low power board with a power consumption of less than 6W [7], it could represent a good alternative for blockchain applications. Previous studies [7] have shown that it is possible to save 61% of energy with the Raspberry compared to the Xeon processor. The latter has a power of 3.5 Ghz with 6 processor cores that run in parallel.

Moreover, Privacy is carefully preserved in the blockchain thanks to a sophisticated encryption process involving the use of public and private keys. Each user of the blockchain has his or her own pair of keys, the public key being visible to everyone, while the private key is strictly confidential and known only to the user. When a transaction is carried out, it is secured using the sender's private key, ensuring that only authorised recipients can access the transaction details. This advanced encryption technology strengthens user confidentiality and helps to establish a secure environment within the blockchain, where personal information remains protected.

The presented system for university attendance tracking using blockchain and facial recognition on a Raspberry Pi platform has certain limitations. First, the reliance on facial recognition technology may encounter challenges in diverse lighting conditions, and the system's accuracy may be affected by variations in individual appearances. Additionally, the implementation on a Raspberry Pi, while energy-efficient, might face scalability issues for larger institutions with extensive attendance data. Finally, the minimalist proposed approach presented in this paper has been developed for a limited number of students.

To enhance the presented system for university attendance tracking, addressing its limitations involves the implementation of advanced facial recognition algorithms resilient to diverse lighting conditions and individual variations. Scalability challenges on the Raspberry Pi platform can be mitigated by exploring more powerful hardware solutions or adopting distributed computing approaches. A hybrid approach integrating facial recognition with other attendance tracking methods, continuous system optimization, and adaptation for varied institutional settings can collectively contribute to a more versatile and reliable system. Pilot testing in diverse educational environments and collaboration with institutions can provide valuable feedback for refining the system's accuracy, scalability, and overall effectiveness, ensuring its applicability across a broader spectrum of educational settings.

Facial recognition of veiled women presents specific challenges due to the coverage of the face. To meet these challenges, several approaches are explored [31, 41, 42]. So, it is essential to study the extent to which a computer system can identify a veiled person and recognize him or her on the basis of the characteristics of the eyes and the uncovered part of the face.

6. CONCLUSIONS

The combination of blockchain and deep learning technologies has the potential to transform classroom attendance tracking, making it more efficient, reliable and secure. The use of inexpensive and readily available hardware, such as the Raspberry Pi, makes this technology accessible and scalable, providing a useful tool for educators and students. The implementation of this embedded platform for face recognition to confirm student attendance provides a safe and secure environment. This system is based on a decentralized application that stores an incorruptible version of the various saved data.

The resulting model yields an accuracy rate of 0.9938 with a standard deviation of 0.00272 on the LFW (Labeled Faces in the Wild) benchmark. The proposed work used low resolution embedded cameras connected to a Raspberry Pi. This low power, low resource algorithm was deployed in each node of the blockchain to keep data from each department. This data is linked in order to automate the processes of absence and attendance monitoring, and, therefore, minimize the risk of errors by optimizing the objectivity of the system. This work could be improved by adding other data to be decentralized, such as the management and storage of diplomas and registrations. It would also be important to succeed in linking different systems, each based on a decentralized application.

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