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Blockchain and Palm Scanning Integrated System (BPIS) for Workplace Access Control and Contact Tracing

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The coronavirus disease 2019 (COVID-19) pandemic has generated a worldwide threat in terms of healthcare, commerce and social problems. To effectively control the virus spreading, contact tracing has shown its effectiveness in quickly locating all the close contacts of the confirmed cases. However, most existing contact tracing systems for tracking staff and visitors in working areas such as offices, hotels, factories, mining camps and so forth, cannot provide a Contactless, Real-time, Tamper-resistant and Ready-to-share (CRTR) contact profiling service at the entrance and exit access points of the workplace. Lacking this CRTR in contact tracing could lead to delay in locating the close contacts, invasion of user privacy, and inefficient communication with other parties such as government, hospitals and health centres in terms of virus test and quarantine arrangements. To address this issue, this paper designs a novel access control system, namely Blockchain and Palm Scanning Integrated System (BPIS), which leverages the blockchain and Infrared Palm Vein Print (IPVP) verification technology to control the access to enclosed working areas and record the time interval of everyone staying inside. It can assist in identifying and determining the close contacts once there are COVID-19 positive cases inside the area. In the proposed BPIS, the IPVP is applied to control unit access due to its contactless nature, high security, and accuracy, while the blockchain enables keeping records of individual's movements and create contact profiles for real-time monitoring, detecting and sharing, based on smart contracts. The advantages of BPIS lie in its unique CRTR service, and once there are any COVID-19 positive test cases in the working places equipped with the BPIS, the system will be able to immediately locate all the close contacts according to the time intersection with the confirmed cases, thus improving the tracking efficiency and preventing the spread of the virus.

Keywords: Blockchain, Palm vein recognition, Entrance/exit access system, Enclosed working place, Contact tracing system

1. INTRODUCTION AND BACKGROUNDS

The COVID-19 pandemic has resulted in over 206 million confirmed cases and over 4 million deaths globally, at the time of writing [1]. The most important means of controlling the virus and managing the outbreak is to promptly test, track close contacts, isolate, and quarantine, when vaccines and effective treatments are not sufficient to tackle COVID-19. This is supported by the effective tracing system of potential cases and the close contacts of the confirmed cases. In Australia, the government has adopted the "End to End Contact Tracing" system to control the pandemic [2]. This system has proved to be effective in dramatically decreasing the spread of COVID-19. The primary goal of contact tracing is to halt further transmission of the virus when a case is identified. Contact tracing has two purposes: to identify close contacts (downstream contact tracing) and to identify potential

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sources of infection (upstream contact tracing). However, according to the report from the Australian government [2], in certain circumstances, upstream contact tracing may not be possible, this includes where:

- Daily new case numbers are very high, and the contact tracing workforce is under strain. By not performing upstream contact tracing, this will enable staff to concentrate efforts on immediate downstream contact tracing.
- There is evidence of substantial community transmission. If a confirmed case could have acquired their infection from anywhere within the community, then broader public health action is likely to be required to suppress ongoing chains of transmission, and upstream contact tracing may not be an efficient use of finite public health resources.
- When some infected people do not have symptoms, it can be hard for them to realise they have been infected, let alone help with tracing the close contacts of them. Unfortunately, COVID-19 is one of the diseases in which active cases may be asymptomatic or have a delayed incubation period. For those people, generally, the upstream contact tracing is likely to be very difficult or nearly impossible.

Currently, contact tracing is heavily reliant on the recall of the cases being interviewed [3], however this may result in mistakes, errors and omissions. For those who are careless about their daily activities, the tracing process can be extremely difficult and unreliable. To help alleviate this issue, the government has suggested the use of proximity apps, such as COVIDSafe to help with identifying contacts, although the rate of novel contacts identified is currently low. Attendance recording is also important for finding potential close contacts, including through attendance apps. There is also potential to use specialised smartphone download systems to identify locations at which the case or close contact has spent time. Unfortunately, there is scarce evidence on the effectiveness of digital or automated contact tracing [4]. This is mainly due to the lack of trusted data which cannot be tampered with nor altered by any approaches in the current digital environment. For instance, the patient data and information collected and managed by public hospitals, clinics and laboratories could be fraudulently falsified as it is particularly difficult for these organisations to monitor and secure the data [5–7]. In addition, the information collection process at the access spots in many working areas is usually slow, and the collected data is not reliable as the collecting approaches (paper-based and mobile phone-based) could be hacked and altered. To address these issues, blockchain technology can be used as a cloud database that stores hashed data to ensure data security and capability of sharing within a publicly accessible network [8]. On top of that, the palm vein authentication technology can be integrated with the blockchain and used for staff verification, contact data collection, together with access control.

Specifically, palm vein authentication technology uses blood vessel patterns as a personal identifying factor to grant access [9,10]. The vein information is unique and hard to duplicate since veins are internal to the human body and, as a result, this technology offers a high level of accuracy. When a sensor detects a waved hand, it emits infrared light to the deoxidised haemoglobin in the vein vessels, followed by generating a palm vein vessel image [11]. The sensor can capture the image regardless of the position and movement of the palm, which allows the easy application and high accuracy of this biometric authentication technology. Also, the contactless nature of palm vein verification technology ensures hygiene and acceptance by users during the COVID-19 period. Meanwhile, the verified data and access data are collated, hashed and stored into a blockchain as a type of shared database [12], which will ensure the data security and trust in several ways. Firstly, once a data block is stored, it is almost impossible to be altered without the agreement of all the parties on this chain. Secondly, even if an error is found in a blockchain, there will be many blocks acting as references on the chain to correct itself, which further ensures that the data will not be simply altered by any individual [13–16]. The smart contracts and key mechanisms associated with the blockchain can be written and coded in a way to make the communication amongst different parties easier and more secure. Moreover, for the consideration of preventing virus spread, a hand sanitiser will be embedded within this proposed system. As a result, when entrants scan their hands, they would automatically sanitise their hands too. This design corresponds to the Occupational Health and Safety Act and Regulations of Victoria, Australia [17] similar to those in many other governments. That is to say, the safety and health of employees at work will be protected.

In this paper, we propose a Blockchain and Palm Scanning Integrated System (BPIS) to provide work environments, such as offices, mining campsites, factories and hotels, with the Contactless, Real-time, Tamper-resistant and Ready-to-share (CRTR) contact profiling service. It integrates multiple cutting-edge technologies including blockchain, smart contracts, and infrared palm vein print to obtain contact tracing data collection, storage, sanitation, and smart access functions integrated for the COVID-19 pandemic period. Firstly, the system achieves ambient security in relation to control access by using the infrared palm vein print technology, instead of the traditional key card access system, due to sanitation reasons, and mental health considerations. Secondly, the blockchain technology is incorporated in the BPIS to store the entrance/exit information whilst ensuring data security and privacy preservation. The sharing of data only happens when it is necessary for contact tracing with third parties in the instance of a COVID-19 positive case or a close contact enters the facility. The stored data in our system can be tamper-proof due to blockchain implementation. It is trusted information for contact tracing due to the transparency of blockchain.

The remainder of this paper is structured as follows. Section 2 explores existing work in this field. Section 3 introduces the proposed Blockchain and Palm Scanning Integrated System (BPIS). Section 4 reviews several commonly applied access systems and makes a comparison with the BPIS. Lastly, Section 5 presents the conclusion and future study.

2. EXISTING WORK

The lack of a precise mechanism to detect newly infected cases and to predict COVID-19 infection risk is currently one of the greatest challenges for most governments and organisations. To solve this problem, an advanced technology-empowered method is needed to countermine this coronavirus crisis. The various features of blockchain technology, such as decentralisation, transparency, and immutability, can help control this pandemic by early detection of outbreaks, fast-tracking treatment delivery, and protecting user privacy during treatment. This application helps combat the COVID-19 pandemic in terms of clinical trial management, medical supply chain, user privacy protection, data aggregation, contact tracing, donation tracing, and outbreak tracking [18–24].

Blockchain is being applied in innovative ways that are relevant to the current COVID-19 crisis, including tracking medical supplies and infected patients. Khurshid [25] described how blockchain, with its distributed trust networks and cryptography-based security, can provide solutions to data-related trust problems. According to the research outcome from Pham, Tran and Nakashima [26] the abnormal information of target patients can be automatically updated in the blockchain system and shared with hospitals and doctors to achieve real time monitoring. The balance between data collection and privacy assurance can be achieved by using blockchain to collect and examine patient data. Clients can directly control their own information on the blockchain platform. In addition, the health department of governments and healthcare organisations can augment data collection through coronavirus tracking, while clients can ensure that their data will not be exposed or shared. For example, these days, many platforms have been launched that use this technology to aid in sharing the information and valuable data related to COVID-19. Civitas, an app launched by a Canadian startup that engages in blockchain solutions, assists various government officials and local authorities in controlling the COVID-19 outbreak [27]. The advantage of this app is that it can manage clinical trials related to COVID-19 as it anonymously links individuals' identity information through the records of blockchain without disclosing their ID. MiPasa, a blockchain technology-based platform propelled by the World Health Organization (WHO) was launched in March 2020 [28]. It facilitates the whole private information sharing between individuals, local governments, and health institutions. The application of data platform can help the global community rapidly respond to this crisis on a more individualised and compassionate level using an open-source approach.

Garg, Bansal and Padappayil [29] proposed a blockchain-based system to help authorities promote social distancing by allowing only a specific number of individuals in a designated area at any given time. Marbouh, Abbasi and Maasmi [30] proposed, implemented, and evaluated a blockchain-based system with Ethereum smart contracts and oracles to track reported data bound up with the number of new cases, deaths, and recovered cases obtained from trusted sources. Their study can be used to explain the outbreak of COVID-19, so as to prepare for future pandemics. Resiere, Resiere and Kallel [31] described the implementation of medical cooperation using blockchain technology to combat COVID-19, to improve global health by enabling universal access to financing mechanisms and smart contracts. Their work is of great importance in terms of the application of blockchain technology to combat COVID-19.

Based on the previous research regarding the blockchain technology, we propose a novel technology which incorporates the blockchain technology and the door access system to store the entrance and exit information. The information will be used to improve the efficiency when determining the close contact of the confirmed case in the enclosed areas, thus reducing the spread of the COVID-19 virus.

3. THE PROPOSED BLOCKCHAIN AND PALM SCANNING INTEGRATED SYSTEM (BPIS)

3.1 The Overview of BPIS

The proposed Blockchain and Palm Scanning Integrated System (BPIS) is a palm vein print identification system supported by blockchain technology. The appearance of this BPIS assembles the commonly used hand sanitiser station which sprays hand sanitiser when hands are put underneath the spray nozzle. When the entrant puts their hand underneath the palm vein detector, which is placed next to the hand sanitiser sensor, their palm vein would be captured and compared to the registered palm vein image to determine the authorisation of access to the workplace. At the same time, the camera inserted on the top of the machine will record the face of the entrant. The recorded face image as well as the scanned palm vein related personal information would be stored in the profile identification folder within the blockchain database for future investigation.

3.2 The Information Storage System and The Operation of the Blockchain

The blockchain technology has been applied to store the profile identification information of the employees entering and leaving the building, based on the smart contract. The reason for implementing blockchain within the BPIS is to record the access information of the person entering and leaving the workplace and to guarantee the privacy of employees. Their face and palm vein related profile information would be stored as a separate profile identification folder within the blockchain database. As a result, the time interval of the employee staying inside the building can be calculated to determine whether he/she would be identified as the close contact, if there was a confirmed case of COVID-19.

The blockchain enabled system consists of three types of participants: the administration of workplace A, third parties B and employees C. As shown in Figure 2, third parties B represent organisations such as governments, hospitals, healthcare centres and other agents. They would only have access to the entrance/exit record information of the

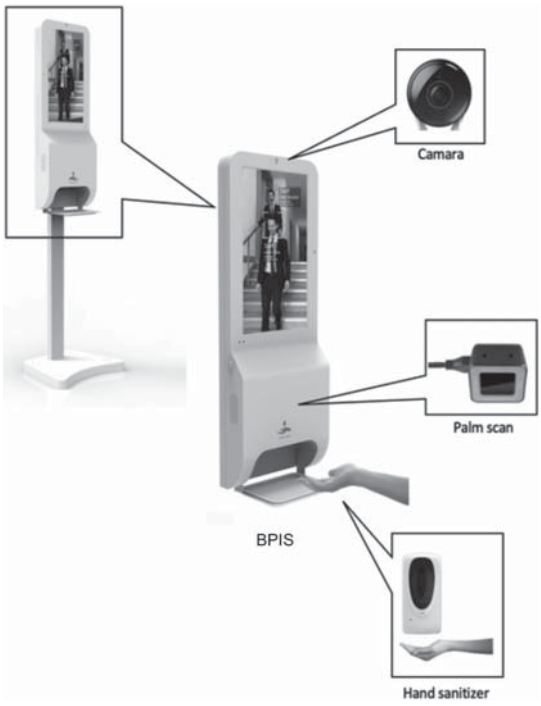

Figure 1 The appearance and the functions of the proposed BPIS.

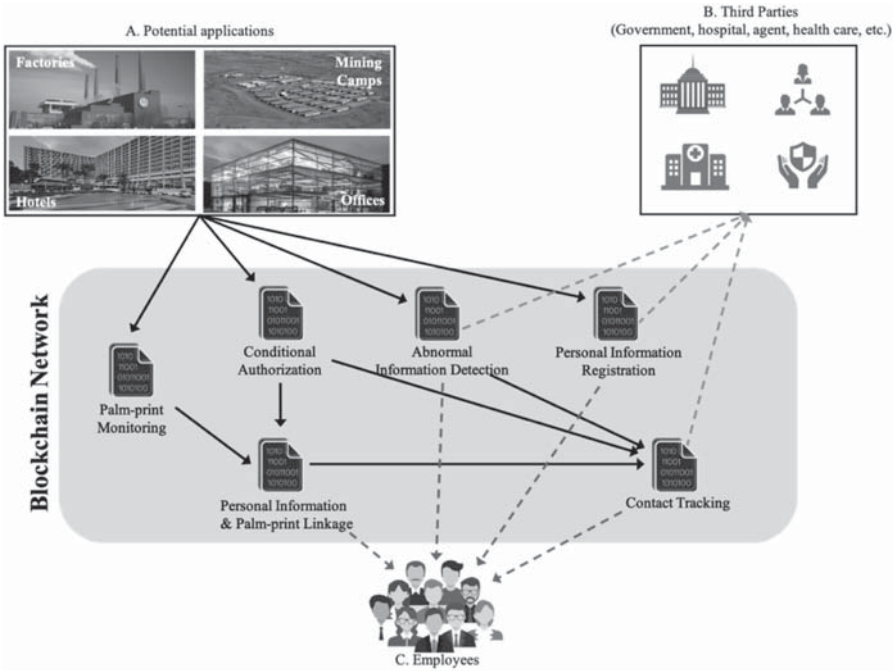

Figure 2 Operation scheme of the blockchain smart contract among three participants: workplace A, third parties B and employees C.

employees C when the confirmed case has been found in A. The reason for sharing information between A and B is to improve the close contact tracing efficiency, thus preventing the spread of the virus. When the confirmed case has been found in the workplace A, the close contacts who stayed in the common workplace in the same period can be identified and tracked as soon as possible. This can help the third parties to provide quarantine advice or policies to stop the virus transmission. Otherwise, when no confirmed case is found in the workplace A, the access information of employees C would not be shared with the third parties B to ensure information privacy.

In our system, smart contracts are introduced as computer programs running across the blockchain network. The working mechanism of the blockchain enabled system has been summarised in Figure 2. Firstly, the administration of the workplace A generates a palm print monitoring contract, and this smart contract is written into the blockchain. The personal information is linked to the palm print when the employees C are recruited, based on the personal information registration

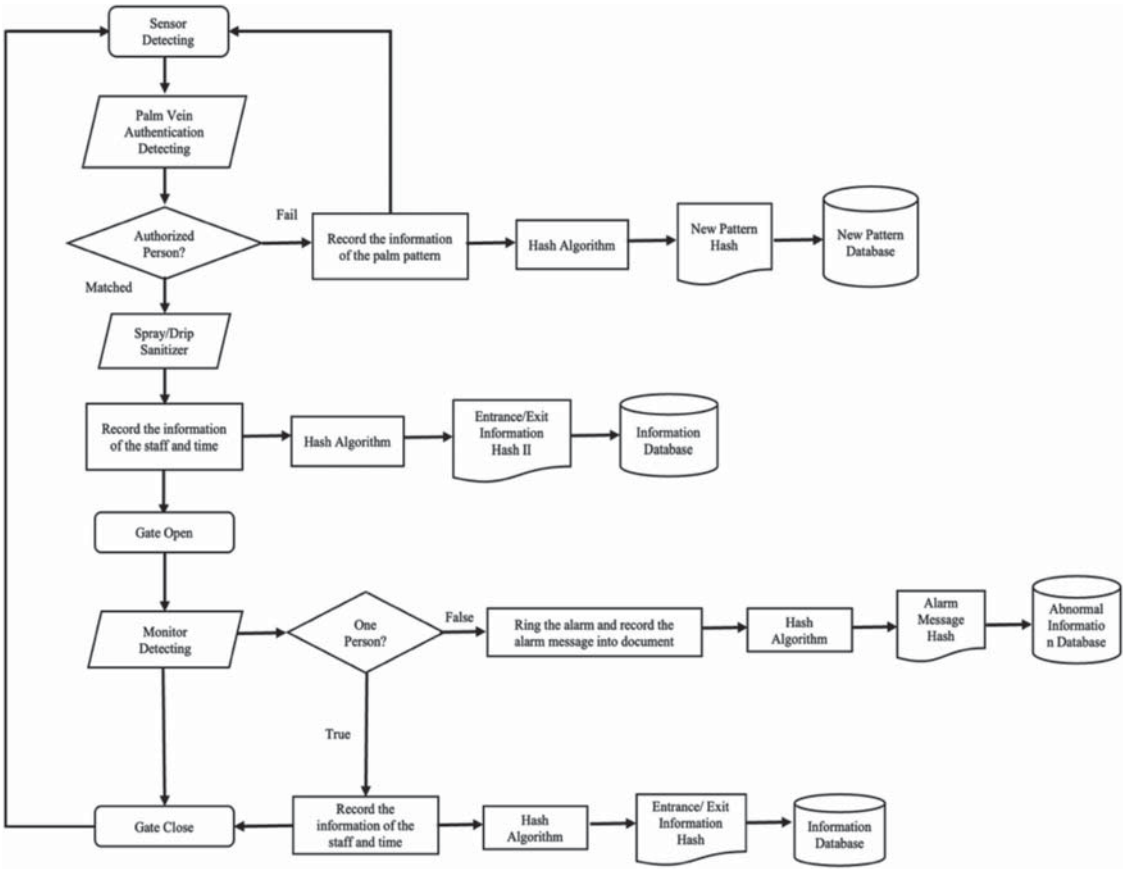

Figure 3 Flowchart of authentication and abnormal information detection.

smart contract in the blockchain system. The workplace administration system A also publishes the complementary smart contract to allow conditional access of the employees C, which is called the conditional authorisation smart contract. The visitors must register their palm vein patterns as well as personal information to pair with the scanned palm print, to gain access to the workplace, similar to the employees C. Based on the abnormal information detection smart contract, the unregistered or unpaired palm prints would be recorded, while not sent to the door access system. Apart from that, once the camera detects and captures that more than one person entered the workplace when only a single palm vein print has been confirmed, they violate the "single palm print, single entry" rule. The access information would be categorised as abnormal information and uploaded to the abnormal datastore for the workplace A or third party to investigate. The mechanism of processing abnormal information detected by the camera monitor is illustrated as Figure 3. Based on the above smart contracts generated by the workplace A, the access information of each employee C who enters or exits the workplace can be stored within the blockchain system. Once the confirmed case has been found in the enclosed working area, the contact tracking smart contract released by third parties B can acquire permission to share the access information of the employees C to determine and track the close contacts of the confirmed case, thus reducing the likelihood of the virus spreading.

The authentication and abnormal information detection flowchart is displayed in Figure 3. When the scanned palm vein print corresponds to the registered palm vein pattern stored in the database, the gate grants access and the monitor camera captures the face of the entrant employee or authorised visitor. If one person has been captured by the camera, the profile information as well as the entrance time would be recorded and written as an information node within the blockchain. However, if more than one face has been detected by the camera, the system will trigger the alarm and record the picture captured by the camera, as well as the scanned palm vein related profile information. The above information would be categorised as abnormal information and stored in the abnormal information database for the workplace A and third parties B to investigate.

The great advantage of implementing blockchain within the smart access system can be summarised as follows:

- The personal data of employees is encrypted, thus protecting their privacy, and ensuring information security.
- The data, including palm vein image and related personal information uploaded into the blockchain is traceable and unchangeable, which ensures the transparency of data. As a result, the tracing process of close contacts of a confirmed COVID-19 positive case can be more reliable and efficient.
- The capital cost of storing information within the blockchain system is much cheaper than maintaining servers to store data by the workplace owner, due to the maintenance cost.

- The implication of blockchain technology is automated through smart contracts, which is discussed in the next section.

As a result, it is a unique approach to applying the blockchain technology into the smart access system to store the personal identification information.

3.3 Smart Contract in The Palm Scanning Integrated System (BPIS)

Smart Contracts (SC) are introduced as computer programs running across the blockchain network. In our system, the smart contracts are based on Ethereum platform. In this section, we illustrate the structure of the smart contract performed by three participants: workplace A, third parties B, and employees C. As shown in Figure 4, the enclosed workplace A uses smart contracts to manage the access information of employees C. Firstly, workplace A creates a pair of Externally Owned Account (A. EOA) keys and the private key (A. EPK). That is intended to initialise the Smart Access System Contract (SASC) and execute smart contract functions. Then, the workplace A deploys smart contract on the Ethereum platform under a corresponding Smart Contract Address (SC.EA). Details on SASC can be accessed by checking SC.EA in the blockchain, and its interface (SC. Interface) can be generated from the Contract JSON JavaScript Signal Interface. To manage the access information of employees C, workplace A releases personal information SC to record the personal information including name, contact details, and possibly age, address, working experiences, family members and so forth. That is to say, workplace A can execute a function to add the personal information of employees C by the Externally Owned Address of employees (C. EOA) along with the encrypted employee data. For the purpose of protecting personal information privacy and security, the sensitive data must be encrypted and stored on blockchain. In this case, only workplace A can decrypt these data. The palm vein monitor SC is used to link the personal information with the captured palm vein image to authorise access control. Using the palm vein monitor SC, the workplace A can execute a function to open the door by comparing the registered and captured palm vein image, along with the encrypted personal information.

The information sharing request initiated by the third parties B can only be allowed when a confirmed case (emergency) has been found in the workplace A to track the close contacts, otherwise the personal information data must be encrypted and confined only to the workplace A. In this way, the privacy of employees registered in this system can be ensured. The abnormal information, including the unpaired palm vein image or the captured face image, would only be shared in this situation to allow the third parties B, such as government departments, hospitals, and healthcare centres to investigate and identify the unregistered entrant. Employees play an important role in this smart contract structure. They must execute the personal information registration SC to allow the workplace A to confirm their identification.

3.4 The Palm Vein Verification Process Through Blockchain and Palm Scanning Integrated System (BPIS)

Infrared palm vein technology is a kind of biometric authentication technology based on palm vein pattern recognition by capturing images of the palm vein pattern beneath the skin. Compared to traditional authentication methods such as ID cards (token-based) and passwords (knowledge-based), biometric recognition is considered more convenient and secure since an individual's biological signatures cannot be easily lost, forgotten, stolen or replicated [32]. The working mechanism of IPVP can be simply explained that the deoxidised haemoglobin in the vein vessels absorb light having a wavelength of about 7.6×10^{-4} mm within the near-infrared area [33]. The blood vessel pattern of the palm is then generated and processed to compare to the stored record of the individual employee to allow access to the building. Compared with the traditional key card access system, IPVP is highly secure, accurate, and hygienic. The contactless nature of this modality is unobtrusive and hygienic compared to touch-based systems and, thus, brings a higher level of comfort and acceptance to users of the IPVP technology. Generally, the whole process of the palm vein verification process can be done in three steps, as shown in Figure 5.

Firstly, when a palm is waved underneath the sensor, deoxidised haemoglobin present in the blood would absorb the near-infrared rays being emitted by the scanner. By detecting blood flowing through the veins, the palm vein pattern is captured and imaged. Then, the captured palm vein image is compared to the pre-registered pattern of the employee to check the authorisation of the scanned palm vein pattern. If the database finds a paired palm vein image, access to the workplace would be granted and time recorded. The related personal information would also be recorded into the blockchain for future investigation for close contacts. Otherwise, the alarm would be triggered, and the scanned palm vein would be categorised as abnormal information and written into the blockchain system.

4. COMPARISON OF THE PROPOSED BLOCKCHAIN AND PALM SCANNING INTEGRATED SYSTEM (BPIS) WITH OTHER COMMONLY APPLIED ACCESS SYSTEMS

Compared with the currently used door access entry systems like key card tapping, password, smart phone APP check in or QR code scan, or a handwritten form, the proposed smart door access system integrates the advantage of each system, as shown in Table 1. This system can allow quick access to the workplace due to the fast reaction of the palm vein verification system. The information of the entrant is accurate because it should be paired to the registered personal information within the blockchain system. Abnormal access has also been considered, such as multiple people trying to enter with a single person hand scan. The automatic hand

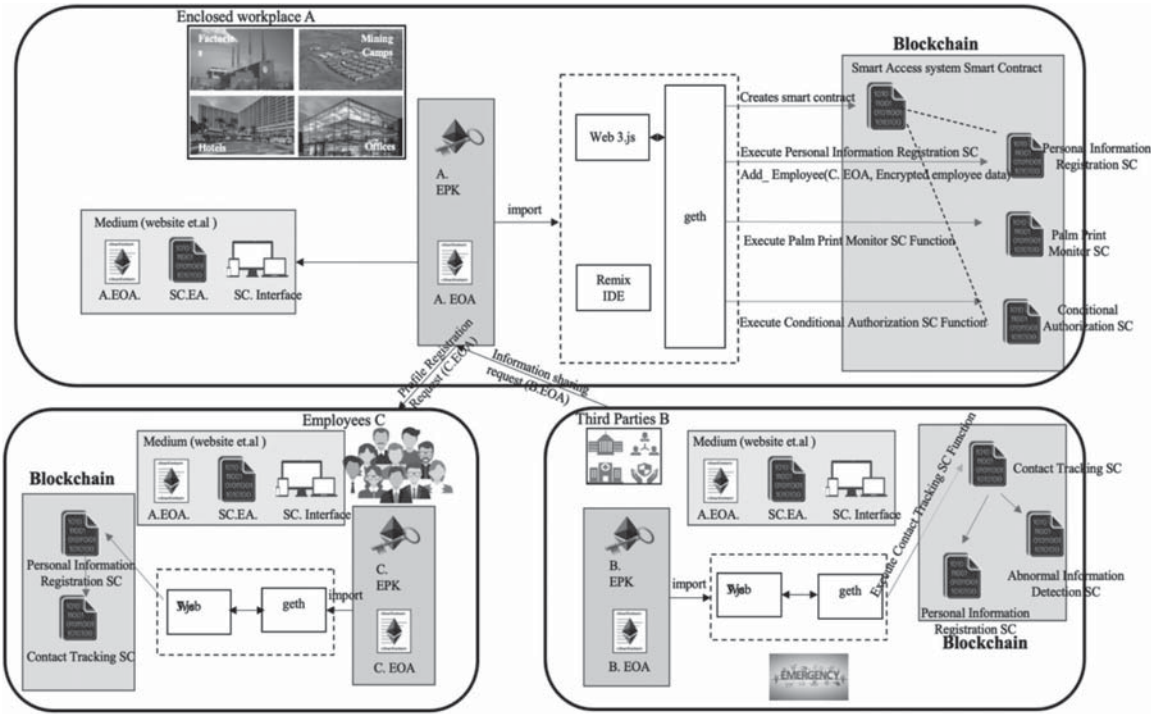

Figure 4 Overview of the BPIS based on the smart contract framework within the blockchain.

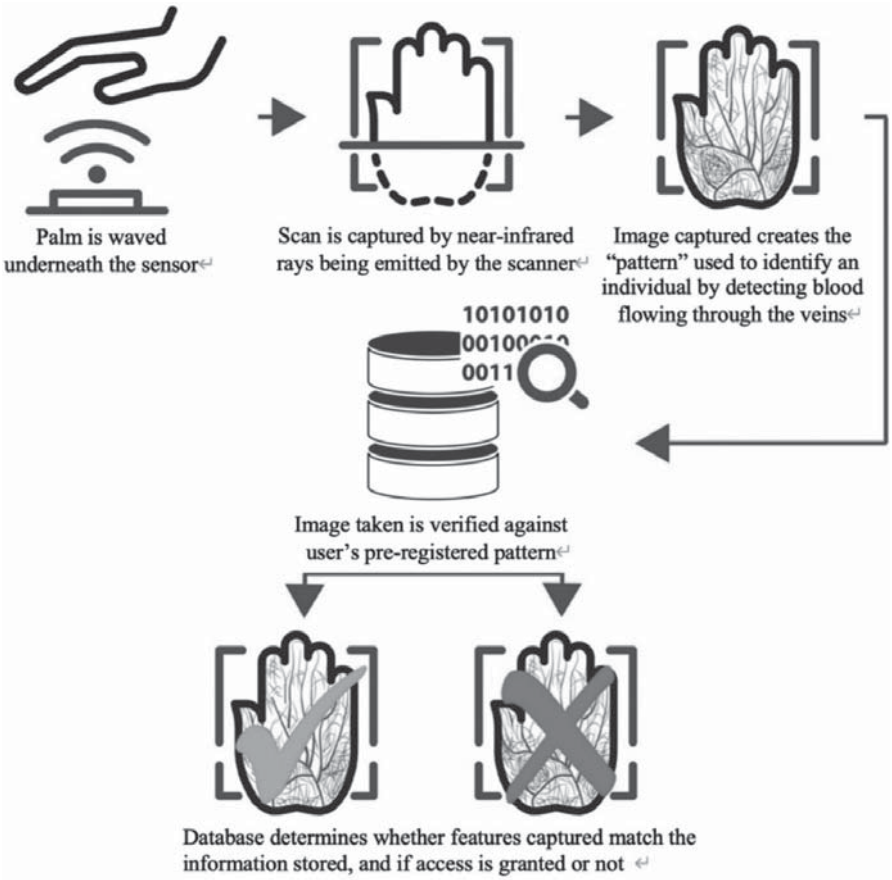

Figure 5 The working mechanism of infrared palm vein verification [34].

sanitiser spray is introduced to ensure the hygiene of entrants to prevent the spread of virus. Apart from that, the proposed smart access system incorporates the blockchain technology for entrant personal information storage. This can facilitate the close contact tracking process, which is specially designed to combat the COVID-19 pandemic.

Table 1 Comparison of different door access systems.

Door access Entry Method	Advantage			Disadvantage			Others
	Convenience	Information accuracy	Sanitisation	Affected by signal	Affected by self-consciousness	Virus spread medium	
Key card	✓					✓	4 May lose the card • May not follow "one person, one tap"
Password	✓					✓	• May forget the password
Smart phone APP		✓	✓	✓			
Handwritten form					✓	✓	• May be affected by bad handwriting
BOIIS	✓	✓	✓				

- Self-consciousness means that the information provided may include fake information.
- "One person, one tap" rule means that a single card tap can only allow the access of one person, not multiple access.

5. CONCLUSION

The Blockchain and Palm Scanning Integrated System (BPIS) has been proposed and designed in this paper, supported by IPVP verification system and the blockchain enabled information storage system. The intention for designing the BPIS is to improve the close contact tracing efficiency once active cases have been confirmed in the workplace. According to current evidence, the COVID-19 virus is primarily transmitted between people through respiratory droplets and contact routes. As a result, the spread of the virus within the enclosed area is much quicker than in an open area, which increases the burden on the government and healthcare centres. To solve this problem, we have designed the proposed BPIS to precisely determine and track the close contacts of the confirmed cases.

In BPIS, the infrared palm print replaced the traditional key card entry system because the contactless nature of IPVP is unobtrusive and hygienic compared to touch-based systems and brings a higher level of comfort and acceptance to users of the technology. The sanitiser spray sensor is also placed besides the palm print capture screen, to achieve the compulsory sanitisation purpose. This design can achieve access control and sanitisation purpose at the same time as soon as the palm is detected by the sensors. As a result, employees' hands are sanitised before entering the common workplace, reducing the likelihood of spreading the virus. The proposed Blockchain and Palm Scanning Integrated System assembles the commonly used hand sanitiser station, to help alleviate the psychological pressure of the entrants because they are less likely to feel their privacy is being invaded. The palm vein pattern image is captured by radiating the palm with near-infrared rays. Then, the captured palm vein image would be compared to the registered palm pattern within the database to determine whether to grant access. The linked profile identification information, as well as the access time, would be written and stored into the blockchain storage system. Once a confirmed case has been found in the workplace, the stored access information would be shared with the government and health care contact tracers to determine, locate, and trace close contacts of the confirmed case. Thus, the spread of the virus can be controlled and prevented.

Declaration of Conflicting Interests

The authors declare that there is no conflict of interests.

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