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SMART SENSOR BASED TOUCHLESS FINGERPRINT SYSTEM

Abstract

his paper introduces a touchless fingerprint recognition system, offering a hygienic alternative to conventional touch-based systems. The primary objective is to develop and evaluate a comprehensive solution that addresses hygiene-related concerns and mitigates the risks associated with disease transmission, particularly in the context of the ongoing Covid-19 pandemic. The proposed system utilizes a state-of-the-art touchless sensor to capture intricate fingerprint images, subsequently processing, storing, and retrieving them for matching purposes. By eliminating the need for physical contact, the system effectively tackles issues related to inconsistent pressure and prolonged collection times. The touchless fingerprint technology showcased in this system holds great promise for diverse applications that demand secure and hygienic fingerprint recognition. The proposed method overcomes the limitations inherent in touch-based systems, making it well-suited for environments where health and safety considerations are paramount. The integration of this touchless technology not only enhances security but also contributes significantly to public health by reducing the risk of cross-contamination in shared touchpoints. As the world navigates the challenges posed by the pandemic, the adoption of touchless fingerprint recognition systems represents a crucial step toward creating safer and more hygienic environments.

Key words: Touchless fingerprint technology, Touch-based systems, Hygiene, Disease Transmission, Security, Accuracy.

Introduction

Biometrics, a field that harnesses unique biological or physical attributes to authenticate individuals, encompasses various technologies, such as fingerprint mapping, facial recognition, and retina scans. Biometrics can be categorized into three primary types: biological, morphological, and behavioral [1].

Among the morphological biometrics, fingerprint recognition stands out as a highly reliable, cost-effective, rapid, secure, and efficient method for authentication. It involves comparing captured fingerprint patterns with stored samples, exploiting the distinct ridges and grooves that characterize individual fingerprints. The minutiae points, which represent specific features like the endpoints of ridges or the locations of scars, play a pivotal role in creating a minutiae template for matching purposes [2]. Fingerprint recognition finds applications in a myriad of domains, including border control, banking, attendance management, elections, identification, law enforcement, and criminal investigation [3].

While fingerprint recognition systems have achieved widespread use, they often rely on touch-based interactions, which introduce certain limitations, such as elastic deformation, extended data collection times, and hygiene concerns. The COVID-19 pandemic has underscored the need for secure and hygienic fingerprint identification systems. To address these shortcomings, a touchless fingerprint identification system has been proposed.

The touchless system seeks to circumvent the drawbacks associated with touch-based systems by employing intelligent sensors capable of capturing fingerprint images without physical contact. This comprehensive system encompasses the entire fingerprint recognition process, from fingerprint acquisition to storage, retrieval, and matching.

The touchless approach offers a multitude of advantages, including enhanced safety, accuracy, speed, and efficiency. By eliminating the need for physical contact, it reduces the risk of disease transmission and ensures a hygienic method of fingerprint recognition. This system holds promise for various applications that demand dependable and secure fingerprint identification.

The development of a touchless fingerprint identification system is instrumental in enhancing both user experience and public health, offering a trustworthy and safe solution for fingerprint recognition across diverse domains.

Literature Review

Touch-based fingerprint recognition has been a subject of extensive research for several decades, initially finding applications in law enforcement and forensics and later expanding into the mobile market and nationwide systems [1-3]. Despite their prevalence, touch-based systems face challenges such as low-contrast signals, latent fingerprints, and distortions caused by finger pressure, along with concerns related to the acquisition process and hygiene [4]. Particularly, the COVID-19 pandemic has accentuated the need for secure and hygienic fingerprint identification systems. To overcome these limitations, touchless fingerprint identification systems have been proposed.

The pioneering touchless fingerprint recognition scheme by Song et al. in 2004 marked the inception of a growing body of research aimed at improving the reliability and user-friendliness of these systems [5]. Contributions by Parziale and Chen [6] and Khalil and Wan [7] distinguished between 2D and 3D acquisition technologies, processing strategies, and quality considerations, with additional insights into presentation attack detection (PAD) schemes. However, existing reviews lack a comprehensive discussion of current approaches. Notably, Malhotra et al. [8], Mil'shtein and Pillai [9], and Labati et al. [10] have explored various facets of touchless fingerprint recognition, providing valuable insights into mobile touchless recognition, comparative reviews, and a comprehensive overview of the entire recognition pipeline.

The touchless system aims to address the drawbacks of touch-based systems by employing intelligent sensors capable of capturing fingerprint images without physical contact. This approach offers advantages such as enhanced safety, accuracy, speed, and efficiency, eliminating the risk of disease transmission and ensuring a hygienic method of fingerprint recognition. Its potential applications span diverse domains, promising a trustworthy and safe solution for fingerprint identification.

The increasing popularity of mobile biometric technology, displacing more expensive scanners, is evident in law enforcement's preference for biometric traits such as fingerprints, face, and iris [11–14]. Leading players like Samsung, TBS, TrueID, and Diamond Fortress are incorporating touchless fingerprint recognition features into their products, advancing the integration of cutting-edge biometric technologies.

Studies [15–23] investigating finger image capture with smartphone cameras and various segmentation techniques have demonstrated progress. For instance, researchers [16] successfully captured finger images using smartphone cameras under uncontrolled conditions, emphasizing different techniques for feature extraction and minutiae analysis. Another study [17] utilized non-conventional scale-invariant texture features (SURF) for matching finger images, evaluating a dataset captured under uncontrolled conditions. However, smartphone-captured touchless finger photo databases face challenges such as preprocessing requirements, increased processing time, storage costs, and vulnerability to cyberattacks [21].

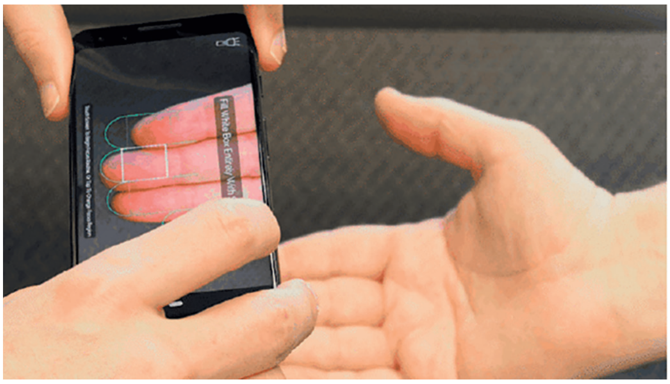

Figure 1 – An illustration of unrestricted fingerprint scanning

In the realm of touchless biometric systems, our research paper presents an innovative touchless fingerprint recognition system that marks a significant advancement in security compared to conventional touchless alternatives. Our approach integrates state-of-the-art touchless sensors, facilitating the capture of intricate fingerprint images. This system ensures rapid processing, efficient storage, and seamless retrieval for matching purposes. Noteworthy is our unique standalone device capturing and storage methodology, setting our approach apart as a secure alternative in contrast to touchless fingerprint recognition systems reliant on smartphones. This distinctive feature enhances the overall security and reliability of our proposed method.

Key Provisions
Materials and Methodology

In the conventional fingerprint recognition paradigm, the process typically involves three sequential stages: image preprocessing, feature extraction, and matching. Image preprocessing techniques enhance fingerprint image quality, while feature extraction identifies unique traits like minutiae points, ridge patterns, and texture. The matching stage compares extracted features with a stored fingerprint database to determine a match [2, 8].

Our proposed touchless fingerprint recognition system comprises three fundamental components: fingerprint scanning, storing, and retrieving. For touchless fingerprint capture, we employ optical devices, which may be modified general-purpose devices or specialized prototype hardware designs. These devices incorporate features such as LED illumination for optimal contrast and reduced external disturbances, with the additional use of colored lights to enhance fingerprint trait visibility.

Figure 2 – Hamster Air – SecuGen's New Contactless USB Fingerprint Reader

In instances where the capture system lacks on-screen guidance or dedicated hardware-based finger guiding, a finger detection algorithm is imperative. This algorithm serves as the foundation for an automatic capture system by detecting the location and direction of the finger. The fingerprint-containing area is then clipped and segmented, utilizing techniques like sharpness, shape, contrast, color, and image depth information [1]. Figure 1 illustrates an unrestricted fingerprint scanning.

Fingerprint recognition poses two main challenges: verification and identification. While verification involves a 1:1 comparison, identification requires a database search and a 1:N comparison, which is the focus of this paper. Identification outcomes include positive matches, false positives, rejections, or false rejections. Achieving accuracy in identification is challenging due to the need for multiple correct verifications and the risk of a single failure leading to a wrong identification.

Our touchless fingerprint system employs a structured methodology for accuracy and reliability. We utilize SecuGen fingerprint readers (Figure 2) known for consistent performance and security across various applications. These readers have a strong reputation backed by industry-leading warranty, extensive field use, and proven reliability in extreme conditions.

The process begins with the sensor detecting the fingerprint upon insertion. Once identified, the system captures its image, utilizing sophisticated image processing techniques to assess clarity and integrity. If the image meets quality standards, the system proceeds to extract unique fingerprint features using advanced algorithms and pattern recognition techniques. If the fingerprint is not registered, the system securely stores the captured image and associated information.

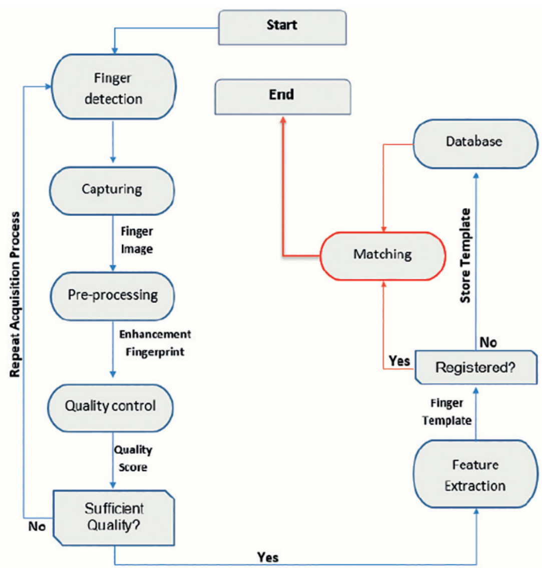

Figure 3 – Flow chart illustrating the methodology
for a smart sensor-based touchless fingerprint system

In cases where the fingerprint is already registered, the system performs a matching process by comparing the extracted features with the registered template, determining similarity or dissimilarity. Throughout the process, strict adherence to quality standards is maintained. If image quality falls below criteria, the system initiates a new attempt, returning to the detection stage for an improved image capture. For a visual representation of the process, refer to Figure 3, displaying a comprehensive flow chart of the touchless fingerprint system's step-by-step execution.

The Proposed System: Sensor-Computer Interface, Desktop Application Design, and Database Construction.

Sensor-Computer Interface: The initial step involved finding a suitable driver to establish compatibility between the sensor and the computer. Subsequently, we obtained the software development kit (SDK) to facilitate sensor integration and enable programming of the desktop application.

Sensor Testing on Demo Website: After successfully connecting the sensor to the computer, we conducted tests on a demo website to verify the sensor's functionality, assess image resolution, and determine if image processing was required.

Designing the Desktop Application: The desktop application was developed using the Java programming language, incorporating essential features to enable seamless interaction with the sensor. The user interface components of the application are illustrated in Figure 4.

Capturing Function: The «Capture R2» button initiates the process of capturing the user's fingerprint image using the SecuGen fingerprint device and extracting a template for subsequent processing. The steps involved in this function include retrieving the current image buffer, obtaining the fingerprint image, evaluating image quality, extracting relevant finger information, performing image quality checks, creating a template, and assessing template quality.

Matching Function: The «Button Register Action Performed» function within the biometric system facilitates the registration of fingerprints by comparing two captured fingerprint images. The steps encompass image comparison, determination of image matching, displaying registration success or failure, and adding the fingerprint to the database.

Sensor-Application Connection: The Main() function, acting as a constructor for an unspecified class, initializes and configures various user interface elements. Key actions performed by this function include initializing components, enabling or disabling buttons, connecting the SecuGen sensor device, retrieving device information, and updating the device's connection status.

Database Construction: Upon successful verification, this process updates fingerprint details for specified user(s) in the database. It involves retrieving user ID(s), modifying relevant fields in the employee table, executing SQL queries, displaying success or failure messages, and creating a new instance of the Biometric class.

Connecting the Database to the Application: The getUser() method retrieves user information from the employee table in a MySQL database. This process includes loading the MySQL driver, establishing a database connection, executing an SQL query, extracting column values, adding them to a table model, terminating the connection, and handling any exceptions that may arise. For a visual representation of the desktop application and its user interfaces, please refer to Figure 4 (p. 15), which showcases the front page, user information registration, biometric verification, and identity matching interfaces.

Results and Discussion

Having successfully integrated all the essential functions, the touchless fingerprint system is now fully operational, with seamless integration of both hardware and software components. This integration empowers the system to proficiently capture, match, and store fingerprint images in the database.

The integration of capturing functions involves a series of crucial steps. It commences by detecting whether the object inserted into the sensor is indeed a fingerprint. The LED is judiciously controlled to ensure optimal illumination for precise image capture. The system captures the fingerprint image with correct dimensions and conducts a quality test to ensure alignment with the required standards.

The database functionality has been successfully integrated and subjected to rigorous testing. This ensures the accurate storage of individuals' information, associating the captured fingerprint image with the corresponding data. As an additional security measure, the information is encrypted and securely stored locally.

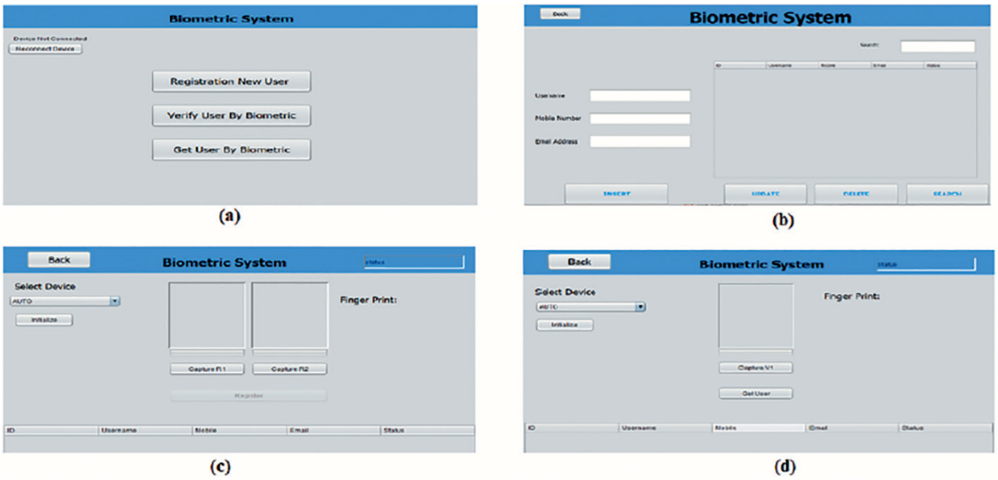

Figure 4 – (a) Front page of the application displaying the initial interface. (b) User-interface for registering the personal information of the user, allowing input of necessary details. (c) User interface for biometric verification, utilizing the biometric data registered in (a) to authenticate the user. (d) User-interface for identity matching, prompting the user to place their finger for identity verification

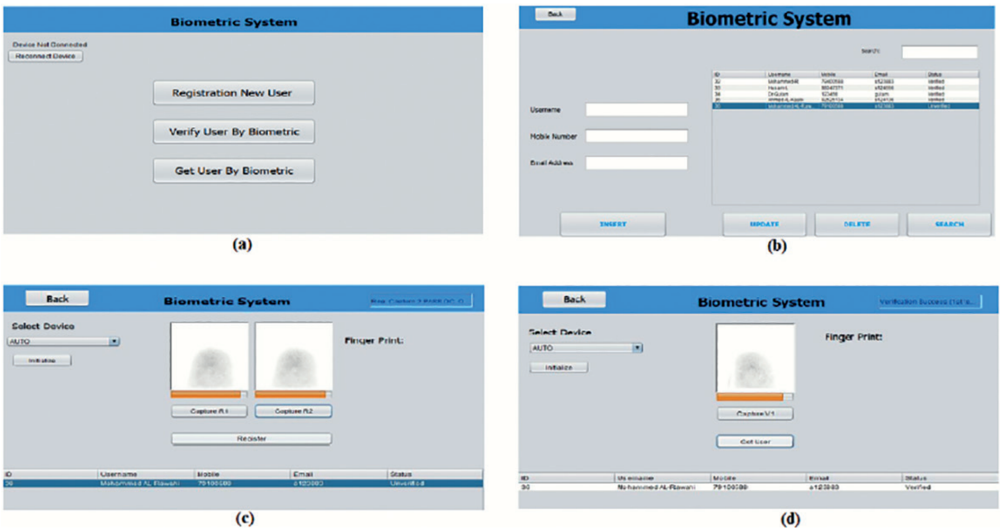

Figure 5 – (a) Front page of the application displaying the initial interface. (b) User-interface for registering the personal information of the user, allowing input of necessary details. (c) User-interface for biometric verification, utilizing the biometric data registered in (a) to authenticate the user. (d) User-interface for identity matching, prompting the user to place their finger for identity verification

For matching purposes, the capturing process is iterated and thoroughly tested. The system performs a comparison between the captured fingerprint image and the stored image in the database, subsequently verifying and retrieving the user's previously saved information. At this stage, the application undergoes comprehensive final testing, confirming the correct functioning of all application functions. The provided figures visually demonstrate the successful execution of these functions.

During the verification stage, users select an unverified ID, capturing their fingerprint image twice to enhance image quality, and proceed to register their personal information along with their fingerprint in the database.

In the retrieval stage, the system prompts users to insert their fingerprint for image capture. Upon capturing the image, users press the «Get User» button to retrieve their personal information from the database. Figure 5 provides a visual representation of the successful functioning of these integrated functions.

Conclusion and Future Work

In conclusion, the successful culmination of our touchless fingerprint system represents a significant milestone, addressing critical aspects and adhering to specified standards, all while considering the heightened importance of hygiene, particularly in the context of the ongoing COVID-19 pandemic. The system stands out for its precise and dependable fingerprint capturing, matching, and storage capabilities, all of which align with the current emphasis on touchless technologies for public health and safety.

We envision extending the reach of the developed system to cater to the requirements of both government services and private enterprises, acknowledging the demand for touchless solutions that align with hygiene standards. This expansion aims to provide a diverse user base with access to advanced capabilities, thereby contributing to heightened security and streamlined identification processes.

In our continuous pursuit of innovation, our future endeavors involve advancing the touchless fingerprint system even further. This includes exploring additional features and potential applications across various domains such as law enforcement, access control, and identity verification. Through ongoing research and development efforts, we strive to remain at the forefront of technological evolution, offering solutions that not only meet but redefine the standards of fingerprint recognition technology in the ever-evolving landscape, with a heightened awareness of hygiene concerns.

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БЕСКОНТАКТНАЯ СИСТЕМА ОТПЕЧАТКОВ ПАЛЬЦЕВ НА БАЗЕ ИНТЕЛЛЕКТУАЛЬНОГО ДАТЧИКА

Аннотация

В статье представлена бесконтактная система распознавания отпечатков пальцев, предлагающая гигиеничную альтернативу традиционным сенсорным системам. Основной целью является разработка и оценка комплексного решения, которое позволит устранить проблемы, связанные с гигиеной, и снизить риски передачи заболеваний, особенно в связи с продолжающейся пандемией Covid-19. Предлагаемая система использует современный бесконтактный датчик для захвата сложных изображений отпечатков пальцев, их последующей обработки, хранения и извлечения данных для дальнейшего сопоставления. Устраняя необходимость физического контакта, система эффективно решает проблемы, связанные с непостоянным давлением и длительным временем сбора данных. Бесконтактная технология отпечатков пальцев, представленная в этой системе, имеет большие перспективы для различных приложений, требующих безопасного и гигиеничного распознавания отпечатков пальцев. Предлагаемый метод преодолевает ограничения, присущие сенсорным системам, что делает его хорошо подходящим для сред, где вопросы здоровья и безопасности имеют первостепенное значение. Интеграция этой бесконтактной технологии не только повышает безопасность, но и вносит значительный вклад в здравоохранение за счет снижения риска перекрестного заражения в общих точках соприкосновения. В то время как мир преодолевает проблемы, связанные с пандемией, внедрение бесконтактных систем распознавания отпечатков пальцев представляет собой решающий шаг на пути к созданию более безопасной и гигиеничной среды.

Ключевые слова: бесконтактная технология отпечатков пальцев, сенсорные системы, гигиена, передача заболеваний, безопасность, точность.

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ЗИЯТКЕРЛІК ДАТЧИККЕ НЕГІЗДЕЛГЕН САУСАҚ ІЗІНІҢ БАЙЛАНЫССЫЗ ЖҮЙЕСІ

Аңдатпа

Мақалада дәстүрлі сенсорлық жүйелерге гигиеналық балама ұсынатын байланыссыз саусақ ізін тану жүйесі ұсынылған. Басты мақсат – гигиенаға байланысты мәселелерді жоятын және аурудың, әсіресе жалғасып жатқан Covid-19 пандемиясына байланысты вирустардың таралу қаупін азайтатын кешенді шешімді әзірлеу және бағалау. Ұсынылған жүйе күрделі саусақ ізі кескіндерін түсіру, оларды өңдеу, әрі қарай сәйкестендіру үшін деректерді сақтау мен алуда жетілдірілген байланыссыз сенсорды пайдаланады. Физикалық байланыс қажеттілігін жою арқылы жүйе тұрақсыз қысыммен және деректерді жинаудың ұзақтығымен байланысты мәселелерді тиімді шешеді. Бұл жүйеде ұсынылған байланыссыз саусақ ізі технологиясы саусақ ізін қауіпсіз және гигиеналық тануды қажет ететін әртүрлі бағдарламалар үшін үлкен перспективаға ие. Ұсынылған әдіс сенсорлық жүйелерге тән шектеулерді жеңе отырып, денсаулық пен қауіпсіздік мәселелері бірінші кезектегі ортада қолайлы құралға айналу мүмкіндігіне ие. Бұл байланыссыз технологияны біріктіру қауіпсіздікті арттырып қана қоймайды, сонымен қатар ортақ байланыс нүктелерінде айқаспалы инфекция қаупін азайту арқылы денсаулық сақтау саласына айтарлықтай үлес қосады. Әлем пандемиямен байланысты қиындықтарды жеңген уақытта, байланыссыз саусақ ізін тану жүйелерін енгізу қауіпсіз және гигиеналық ортаны құру жолындағы шешуші қадам болады.

Тірек сөздер: байланыссыз саусақ ізі технологиясы, сенсорлық жүйелер, гигиена, аурудың таралуы, қауіпсіздік, дәлдік.