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Advanced Encryption Techniques in Biometric Payment Systems: A Big Data and AI Perspective

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ABSTRACT

In the rapidly evolving landscape of biometric payment systems, the integration of advanced encryption techniques is crucial for ensuring robust security and privacy. This paper explores cutting-edge encryption methodologies tailored for biometric data in the context of big data and artificial intelligence (AI) applications. We investigate how these advanced techniques address the unique challenges posed by the vast amounts of sensitive biometric information generated and processed in modern payment systems. The study provides an overview of various encryption strategies, including homomorphic encryption, secure multi-party computation, and quantum-resistant algorithms, evaluating their effectiveness in safeguarding biometric data against emerging threats. Additionally, the paper examines the role of AI in enhancing encryption mechanisms and optimizing performance, highlighting how machine learning models can predict and mitigate potential vulnerabilities. By analyzing real-world case studies and empirical data, we offer insights into the practical implementation of these technologies and their impact on the security landscape of biometric payments. This research contributes to a deeper understanding of how advanced encryption and AI can collaboratively fortify biometric payment systems, ultimately paving the way for more secure and privacy-preserving financial transactions.

Keywords: Advanced Encryption,Biometric Payment Systems,Big Data Security,Artificial Intelligence,Cryptographic Techniques,Data Privacy,Secure Authentication,Biometric Data Protection,Encryption Algorithms,AI in Cybersecurity,Data Encryption Standards,Biometric Security Protocols,AI-driven Encryption,Privacy-preserving Techniques,Big Data Encryption,Biometric Authentication Systems,Machine Learning Security,Data Integrity,Encryption in Financial Transactions,Advanced Cryptographic Methods,Secure Biometric Data,AI Security Applications,Biometric Encryption Algorithms,Threats and Vulnerabilities in Biometric Systems,Secure Payment Technologies..

INTRODUCTION

With the advent of Big Data and AI technologies, biometric characteristic matching is performed at a faster rate with high accuracy. Algorithms are built with specialized skills to learn their inputs. When advanced artificial intelligence techniques are used to fool or confuse biometric characteristic matching, it is called spoofing. Spoof fingerprint images can be synthesized in a variety of ways and features. A biometric payment system should be properly secured since biometric data is personal. An advanced encryption technique using the hidden hinged whale optimization-based backpropagation network and digital envelope is presented in this paper to secure biometric payment data from thieves and fake users. Further advanced processing would be made depending on the output of the ridge counting. The time complexity of this strategy is also calculated.

Biometric systems are gaining momentum in recent years due to their security, convenience, and fast performance in various domains. Among these biometric characteristics, fingerprints stand as a strong biometric modality. Minutiae matching (point-by-point matching) is the most commonly used method for fingerprint recognition. In point-by-point fingerprint verification/authentication systems, the points of the query fingerprint image correspond to the points in the reference fingerprint image. In other words, for a pair of corresponding points in fingerprint images, they should have corresponding locations to match these points. Minutiae angle (direction/orientation) and minutiae type are checked. Advanced encryption techniques are used to enhance the security of the BFS. These include public key cryptography, hidden Markov model, and cryptographic hash functions.

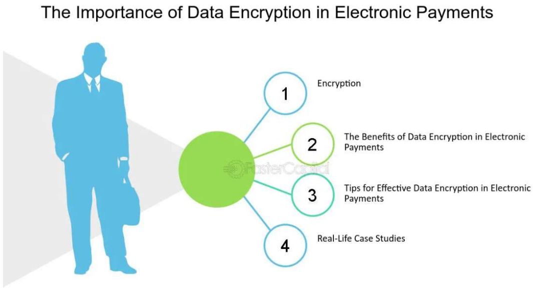
The Importance of Data Encryption in Electronic Payments
1
Encryption
2
The Benefits of Data Encryption in Electronic Payments
3
Tips for Effective Data Encryption in Electronic Payments
4
Real-Life Case Studies

Fig 1 : Data Encryption In Electronic Payments

1.1. Background of Biometric Payment Systems

To take advantage of these payment features, initially, biometrics generally began as a standalone access control system for point-of-sale (POS) terminals and ATMs that were expensive for merchants and vendors. According to a previous study, the use of biometrics as a complement to payment systems began in 1973 to facilitate state-run retail stores, and as of 1999, there were only 60 terminals available internationally that could perform a biometric transaction. Today, many banks, telecom providers, government departments, airlines, customs and immigration, and retail chains worldwide have started to use biometric technology solutions as an alternative payment system. There are still different specialized gadgets and systems worldwide that offer biometric technology as an added advantage for end-users. Biometric payment is known by many names in the financial and marketing sectors. The Biometric Institute estimates that, except for smartphones, customer recognition and electronics programs serve payment as Email, Palmsecure Hand Vein Reader, and Clear INSIDE ClearFastPass. Biometric technology is the process that relies on the inherent physical or behavioral path of the user and is mainly used for the identification and authentication process of the user in a financial card. Since 1930, the use of various biometric traits has been studied in depth as a replacement for cryptography-based financial cards. As per the review, it is clear that with the evolution of the biometric system and technology, end-user acceptance has changed gradually. Over time, certain concerns about the implementation of biometrics in payment systems, transactions, and financial markets have been overcome. The technology has improved considerably and has been proven to be highly advanced, user-friendly, accurate, and reliable in today's context. Biometric technology has solidified its place as a promising alternative in the global market. Despite various advantages, previous concerns about biometric technology, such as high costs for product deployment, end-users privacy and concerns, fraud, tampering, and criminal history, have yet to be addressed.

1.2. Significance of Advanced Encryption in Biometric Payments

Biometric authentication is becoming a very versatile form of digital payment mechanism at the consumer end. Defense mechanisms are required to properly address the frauds encountered in such human behavior-oriented digital payment system setups, such as counterfeit finger patterns or finger card integrity. The role of cartographic artificial intelligence, cognitive advanced encryption, and big data in biometric payment systems is to encrypt the extremely confidential information of a user, which is stored in their device in some form or another. This development includes a cloud version of the same cryptographic voice information in the nougat version by the IBM Watson cognitive solutions, and then the transactions are carried out.Biometric payments are a diversified subject that combines three pillars of knowledge: biometrics, big data, and artificial intelligence. A combination of these three topics makes up a biometric payment system. As the industrial revolution progresses, it brings its complexities. The main motive for such an advanced payment platform is to reduce forgery, and fake transactions, and encrypt biometric information so that the operational form of biometrics is no longer required. Advanced encryption techniques come with a cognitive system where the transaction is done, which not only encrypts biometric data but also maps them with the user's coherent voice, wherever their earlier encrypted versions are kept.

2. Biometric Payment Systems: Overview and Components

The proposed encryption requires the following credentials (also known as keys, used for encryption and decryption) to operate on the functional components of biometric payment systems, which include a Fraud Detection Engine, Payment Processor, Authentication with Biometrics, and Bank. The Master Public (MPK) Key and Master Private (MPrK) keys will be shared between the Fraud Detection Engine (FDE), Payment Processor (PP), and Banks. The communication channel between the above-mentioned entities will be a secure channel such as Transport Layer Security (TLS), secured with Master Public (MPK) and Master Private (MPrK) Keys. The second encryption credentials (keys) include a Customer Public (CPK) and a Customer Private (CPrK), used mainly for generating the Patient-Derived key and have to be kept in the user's mobile application. The Knowledge Component will be shared by the user and amongst the Entities and will be changed frequently, i.e., during each transaction; this is known as the shared secret between the user's mobile phone and the mentioned functional components above. The algorithm implementation will be performed on a payment gateway, financial institutions (FIs), behavioral biometric modality, and other entities, that is to say, non-bank companies or organizations.Biometric payment systems exist at the intersection of biometrics, which are used to recognize humans using their psychological or physiological characteristics, and payment systems, which facilitate the buying and selling of products and services in exchange for electronic money. While not a complete solution, the use of biometric authentication has made payments more secure, especially in a world where credit/debit cards can be duplicated and used. Additionally, biometric payment systems provide a convenient, quick, safe, private, and secure transaction process for consumers. Currently, systems have been deployed that are based on input of fingerprint, face (facial characteristics), iris, retina, palm, voice, and hand.Biometric payment systems represent an advanced integration of biometric authentication and electronic payment processes, enhancing both security and user convenience. These systems leverage unique physiological or behavioral traits, such as fingerprints, facial features, iris patterns, or voice, to authenticate users and authorize transactions. By employing encryption credentials—such as Master Public (MPK) and Master Private (MPrK) Keys for secure communications between Fraud Detection Engines, Payment Processors, and Banks, and Customer Public (CPK) and Customer Private (CPrK) Keys for individual user authentication—these systems ensure robust protection against fraud. The use of a frequently updated shared secret between the user’s mobile app and the payment components further strengthens security. This layered approach not only mitigates the risks associated with traditional credit or debit card fraud but also streamlines the payment experience, making transactions quicker and more reliable. By combining biometric verification with secure encryption protocols, these systems deliver a compelling blend of safety, privacy, and efficiency in financial transactions.

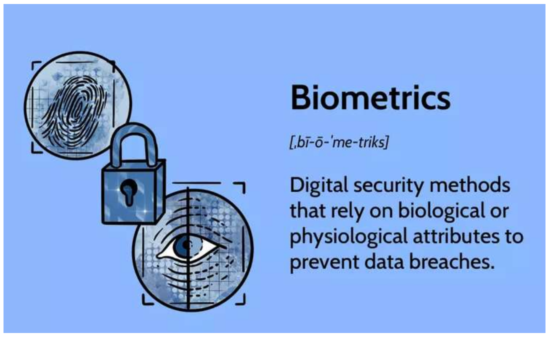
Biometrics
[ˌbī-ō-ˈme-triks]
Digital security methods that rely on biological or physiological attributes to prevent data breaches.

Fig 2 : Biometric Payment System

2.1. Definition and Functionality

In short, the biometric payment systems allow putting a biometric template of the customer in the payment device stored in a secure part of the payment device. As soon as a payment application is initiated, the biometric template can be verified to avoid any authorization refusal in case the user does not correctly put the biometry on the sensor. It is also possible to stop a transaction as soon as an invalid PIN is entered. This solution is now one of the most secure. In 2020, this will prevent 14.9 billion euros of fraud. In a constantly changing digital world, biometric payment systems should be able to offer more than a capacitor's experiments. The time when biometric template files occupied a few tens of kilobytes of data is over. Today, the databases of public security forces from several Western countries alone contain millions of GB of biometric data.

The digitization of the economy is giving rise to new ways of paying. Non-cash payments with credit cards, bank cards, or smartphones contribute to a certain growth in the value of global payment operations. However, these different solutions present some security or authentication problems: PIN codes are easily violated, and smartphones are easily stolen. The payment solution which ensures security can be the substitution of a plastic payment card with the biometric data of the user in a secure part of the device, without having to enter the PIN code.

2.2. Types of Biometric Data Used in Payments

In the case of deep learning, the features are automatically chosen by the learning process. The learning approach using deep neural networks, together with the increased "large-and-increasing" amount of data, has had a game-changing impact (deep learning's performance now lies within the domain of experts). Extracting biometric features from the acquired data to be used in a biometric payment system requires intelligent algorithms to process the biometric features of the data. Besides the amount of data, these algorithms are now relatively mature. The mathematical techniques (feature extraction and template generation) that depend on the usage of the collected biometric data are different based on the used biometric data. Thus, the detailed characteristics and specific ID and verification authentication technical considerations must be different as well. From the perspective of system diagnostics and treatment of data missteps, legal professionals must understand each case where the encrypted templates are located.

(i) Fingerprint Data and Hand Geometry: Fingerprint data is the most popular technique used in biometric payment systems. The finger geometry patterns and traits of the human hand are different for every individual. These can also be used for payment systems.

(ii) Iris recognition: The distinctiveness of the iris, and the fact that it is a protected, yet externally visible organ of the eye, makes the iris one of the strongest biometric characteristics.

(iii) Face recognition: Face recognition is the method of establishing a person's identity using the unique characteristics of a person's face. The human face plays an important role in personal identification.

(iv) Voice recognition: The human voice is also a unique identifier. The physical body part responsible for the human voice is termed. The voiceprint is a unique rough spectral outline of the voice. Different individuals have different voice prints, similar to fingerprints.

3. Advanced Encryption Techniques

Encryption techniques are the most important element to secure the biometric payment system against traditional threats but are not limited to cutting-edge threats such as big data attacks, AI, etc. In the context of biometric payments, the data is stored and transmitted in the secured format using traditional cryptographic techniques. The most popular cryptographic techniques involve asymmetric encryption and symmetric encryption. In symmetric key encryption, a single key is used for both encryption and decryption, while in asymmetric encryption, different keys are used for encryption and decryption. However, big data attacks, AI, etc. are evolving so fast, and it is a tremendous task to prevent any of the attacks using conventional cryptographic techniques. The scope of this paper focuses on homomorphic encryption for secure biometric payments by considering various encryption techniques such as symmetric, asymmetric, hybrid, etc., and comparing them for their performance in relevant practical scenarios.

Discrete approaches in biometric hashing and data summarization have serious limitations, and the computational and communication security of conventional cryptographic techniques for data hiding and digital signatures has been introduced with the development of big data processing tools based on AI. Based on the drawbacks of hash-based approaches, in this section, we introduce an in-depth study of the advanced cryptographic techniques present today. This mainly involves asymmetric encryption, symmetric encryption, lattice-based encryption, homomorphic encryption, and the comparative studies between various encryption techniques.

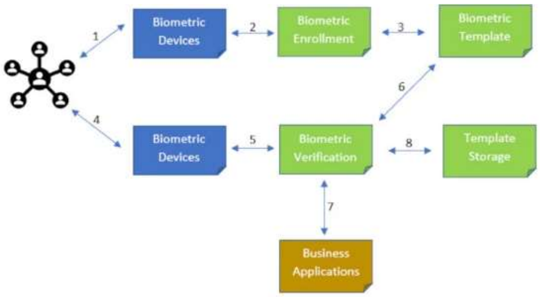

Fig 3 : Encryption Scheme with Biometric Authentication

3.1. Symmetric vs. Asymmetric Encryption

Asymmetrical encryption is also known as public-key cryptosystems, which deploys two closely related keys, one is private and the other is public key. The advantage of this technique is its compatibility with digital signatures. The primary application of the public key is to enhance secured e-commerce transactions. The main advantage is not with encryption but with public and private key usage. However, the mechanism also encounters the challenge of being computationally intensive, due to the intricacy of the algorithms that are used. Consequently, its applications are limited to secured connections. It is due to asymmetric encryption's belief of overall security superiority that it is applied to authenticate transactions when encrypting short data transfers with fewer dependencies, as in the case of chip and PIN systems, in biometric payment systems. The public key is used to encrypt the message (or transaction), and only the recipient (private key holder) can decrypt the encrypted message. In the reverse process, a signer will use a private key to encrypt a lumpy hash data, which can then be decrypted using a public key, thereby authenticating them as the sender of a digital message. The public key thus reveals the sender of the data (i.e., digital signature).

Symmetric encryption, also known as secret key encryption, utilizes a single focus for the encryption and then sends the message over the channel to the receiver (based on the assumption that no eavesdropper is present). This sender and the receiver then employ a single separate secret cryptographic key to decrypt the message. The underlying advantage of symmetric encryption is the simplicity of the algorithms that are applied. Therefore, cryptography can be implemented using less computational resources and therefore consumes less power for encryption functions. Symmetric encryption primarily deals with bulk or block data transfers and offers good security standards. Hopefully, it is due to the simplicity that it offers. On the flip side, the primary challenge of secret key cryptography is the concern of transferring the key to the other side, which involves the risk of exposure.

3.2. Homomorphic Encryption in Biometric Payments

CryptDB is a practical database with a secret schema. It uses an onion of encryption layers with different semantics, for instance, deterministic encryption enables search while order-preserving encryption maintains sorting. Homomorphic encryption uses a private-key encryption solution for an encrypted database. Its computational and size requirements are still large for most relational database evaluations, but data outside DB can be encrypted. Partial information leakage exists in queries and functions' operation as there are some searchable functions. Most of the database encryption available can be used here to apply in bank use-cases and are context-preserving, which means they can encrypt using initialization vectors (IVs) with a length equal to the possible range of the encrypted value, for example, geographic locations can be used.

Homomorphic encryption encrypts data in the encrypted form and accepts encrypted operands that enable decryption of the result (related to the clear data) of the operations and provide a truncated version of it. There are two main types of homomorphic encryption. The additive homomorphic encryption performs addition and multiplication over encrypted data, providing exact results in the decrypted format; for instance, the Paillier scheme is based on addition while the Brakerski-Fan-Vercauteren is based on multiplication. The FHE performs integer operations, supporting arbitrary operations over encrypted data, and it provides significant computational cost.

The aim of privacy-preserving in biometric payments is to protect the biometric data in the open environment during payments. Using public key encryption of biometrics requires high computational costs due to the size of most biometric data being bigger in comparison to traditional data. Another possibility is to use symmetric key encryption and secure elements located in cards; however, these pose security and user-friendly problems as well as the distribution of cards.

4. Big Data and AI in Biometric Payments

This section seeks to expound on the role of big data in biometric payments by discussing three sections: new system, products and loyalty, and payment processes. In addition, three sections related to the last topic are included: knowledge discovery; recommendation and prediction; and payment authentication. In addition, this section mentions advanced AI and machine learning algorithms to authenticate and classify buyers, as well as AI encryption techniques to secure biometric payment data.

In biometric payments, knowledge discovery and prediction in big data can help to design a unique marketing strategy tailored for individual customers. Big data or AI can be used for the following purposes:

(a) New system, products, and loyalty: Big data representing the volumes of signals of consumers can be exploited to analyze the possibility market due to a new biometric payment system. More precisely, analyzing brain waves collected from web actions on social networks will help large companies design new marketing campaigns as well as novel loyalty schemes optimized for different customers.

(b) Payment processes: Big data and AI can be used to recognize users who perform browsing and buy transactions via the acquisition of biometric data. AI and also the large volumes of biometric training data permit accurate bio-physiologic authentication of buyers to improve e-commerce and m-commerce business. Security in biometric payments can be attained by AI learning algorithms. To authenticate or classify buyers, AI, and machine learning algorithms are paradigms with better performance. Moreover, AI with encryption can formalize biometric data before using it as a payment tool. AI encryption in biometric research usually involves identifying patterns in data and discovering associations and a mathematical model. The measurements, attributes, or any data representation can be used to infer knowledge about you when encrypted. Using AI encryption, new signals, rules, or hidden themes about you can be inferred.In the realm of biometric payments, big data and advanced AI technologies play a crucial role in enhancing user experiences and security. Big data enables the creation of innovative systems, products, and loyalty programs by analyzing vast volumes of consumer signals, such as brain wave patterns from social media interactions, to tailor marketing strategies and loyalty schemes more precisely. In payment processes, AI and big data contribute to refining user authentication by leveraging extensive biometric training datasets to accurately recognize and authenticate buyers, thereby enhancing both e-commerce and m-commerce security. AI-driven algorithms improve performance in buyer classification and authentication, while AI encryption techniques secure biometric data by identifying patterns and associations in encrypted data. This approach not only protects sensitive information but also uncovers new insights and rules about users, facilitating a more personalized and secure payment experience.

Fig 4 : biometric security of digital payments

4.1. Role of Big Data in Biometric Payment Systems

The proliferation of IoT-based biometric payment applications started a long time ago, gathering a large number of fingerprint samples used for the development of better biometric payment databases. Currently, large portions of this research focus on analyzing and adjusting genuine/friendly and malicious transactions among the large dataset to improve payment accuracy. Hence big available data, when combined with the concept used in facial

BIGPIC and BEST, can be used to conduct verification of offering of UTD FP template protection system that has lower FRR and better security. In our biometric payment system, all this big data is utilized. Seriously, large-scale data, cooperation learning, and AI or data analysis and AI improve communication in push payments to a large extent.

One of the facilitators to harness the big data in BPSS of biometric payments is the contribution of large available data. A typical biometric system processes personal data to give a unique identification capability to conduct minimum-friction verifications with low FAR/FRR at <1%. Card details, user lists, and transactions are already available in electronic form and can be easily processed through push payments and associated security features. During push payments, enormous data is used to conduct the analysis that can minimize risk, ensuring payers making payments other than the payer, with which the data associated, are detected with high accuracy. Big data is analyzed through AoT (Analytics of Things) to conduct in-stream analysis. In our banking and its modern technology world, the IoT-based banking transaction is at the heart of the fourth industrial revolution based on the Industrial Internet of Things (IIoT).

4.2. Machine Learning and AI Applications

An attempt is made to detail how AI techniques can be integrated with biometric payment systems to make them secure. An in-depth analysis of different AET techniques is also explained in this category. Hence, the main focus of this section is to discuss the applications and integrations of AI techniques in BPS. These AI-based applications can be applied to a variety of biometric payment systems, allowing for easy integration of artificial intelligence. With a large amount of identity and transactional data being stored and processed by third-party companies or, in some cases, by the government, there should be a level of encryption in the system to secure the critical information used by these applications.

Machine learning and AI applications have a wide range of uses within biometric payment systems. Some of these prominent applications that are gaining increasing acceptance within the ML community are artificial neural networks, deep learning, gradient boosting, and more. These techniques are used in encryption techniques for spoofing detection and prevention. In the artificial neural network, machines help to model the 'brain' by gathering hormone and electrical signal information. The combination of AI, big data, and machine learning allows for large amounts of disparate data to be integrated to improve the performance of database predictions. The result is a more robust and secure system.

5. Challenges and Future Directions

Future directions: • Transaction-based solutions to process more business and maintain the degree of fraud. • The quest for zero-dwell defense strategies along with high safety prevention mechanisms. Due to the increase in the number of AI/ML-based identity solutions, the prospects of a proposal would be 1) as an analogy comparing our proposal with existing anti-pattern analysis software to measure its efficacy, typically assessed using a baseline. Our proposal could become a weapon to safely secure AI-based pharmaceutical products. • New phase multiphase bionic systems should be built, and unconventional study architectures introduced by the neurobiological biometry. • Respect for people: they are based on the old habits of proper identification (using biometry) and the assimilation of emerging technologies. Areas should be created to upgrade existing humans and software (especially older models) to replace their older unique biometric operation codes with advanced biometrics for better flexibility, stability, and noise resistance. Areas should be created to upgrade existing humans and software (especially older systems) to replace their older unique operation codes successfully with unique biometrics for better flexibility, stability, and noise resistance. • Blockchain, privacy, security, etc. Blockchains can be natively linked with personalized operations as well as personalized biometrics. Integrated blockchain cryptocurrency settlement will lead to improved security clarity in real-time pre-processing, allowing for personalized operations and leading to better KRAs underpinning any security model for relevant and better techno-economic operation. Some emerging fields (subject to on-the-fly pre-conditioning improvements) include: ○ Combining biometry with cryptography. ○ A biometric-based advanced encryption system using an intelligence-oriented big data forming climate approach.

• Organized Crimes: Criminal organizations may extort end-users with privately owned biometric templates. Criminal organizations may suspect airstaff and extort personal biometric data from each other. Lastly, syndicates may demand biometric information as a target identifier. In every case, biometric data protection is prioritized over data protection, and extensive personal damage to end users may emerge. • Privacy Preserving: Preserving the privacy of every individual (who pays) is an extreme challenge in itself. Although use-case tracking is an emerging research area, concerns about data mining and knowledge discovery persist. To this end, case-based research examining biometry from the standpoint of knowledge and privacy extraction should undergo additional scrutiny. • High-level security and zero-dwell defense: Hybrid AI methods should be included in the equipment to perform the cybersecurity processes. Reasonably well-archived Planck encryption methods deliver a zero-elapse safety credential for enabling systems with real-time encryption integrated cryptography.

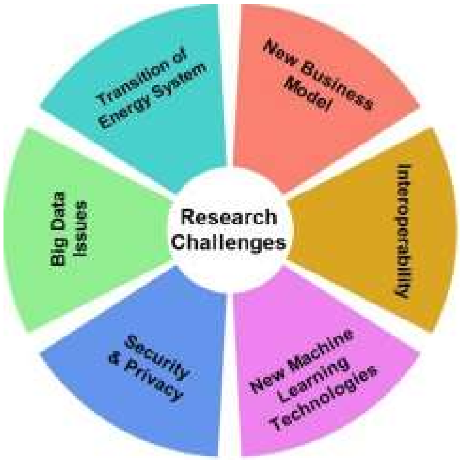

Fig 5 : Challenges of Biometric Authentication

5.1. Security and Privacy Concerns

State-of-the-art advances in AI have demonstrated the feasibility of creating highly convincing deepfakes. Likewise, fingerprint presentation attacks use gummy fake fingers or can be imitated by 2D or 3D images that are directly presented to the scanner. Since the majority of fingerprint sensors rely on the capacitive principle, they cannot distinguish between a live and a dummy finger. Thus, encrypting biometric data most securely becomes critical. Biometric security can be enhanced and the privacy impact lessened by encrypting the biometric before sending it to a payment processing center or storing it on cards. This, in addition to tokenizing and securing sensitive data, provides an invisible security layer during communication in both contact and contactless payments. Some of the techniques that have successfully demonstrated encrypted biometric payment systems with promising security and privacy impact include secure sketch, hashing, and cryptosystem.

Security and privacy are the major concerns in biometric payment systems. Fingerprint scans and face scans used in biometric payment systems must be secured. When a biometric is compromised, an attacker can impersonate a valid client and obtain services or transactions without being detected. An individual's face or fingerprint can be acquired and processed, and it can be used to fabricate a realistic spoof. Apart from these attacks, another inherent security risk is the privacy concern related to the storage and use of biometrics in the system. If the biometric is directly stored in the database, there is a high chance of someone hacking an account since personal characteristics are permanent and long-lasting, and these characteristics are common knowledge. If the biometric is stored in the device, there is no risk of leaking personal information, but the privacy of the user is not protected since the bank or merchants can potentially know the personal information of the biometric when there is a problem with the device. From the aforementioned, this could mean that there have been possibilities of attackers stealing the biometric information and using it for an illegal act. This shows there is a total threat to the data secrecy of clients and data mining attacks.

5.2. Integration with Emerging Technologies

In terms of data storage, the potential of quantum-resistant encryption approaches is included, reflecting future changes in the generation of encryption requirements. Telecommunication speeds and latency have also seen significant changes due to the advent of high-speed broadband and the inception of 5G networks. Smartphones commonly have an all-in-one processing unit that has a dedicated neural processing unit (NPU) to perform AI functions and techniques like adaptive AI that can change the features impressed into the model ('enrollment features') for every user's personalized security benefit ("adversarial AI"). The adoption of standardized cryptogram technologies is likely. AI can be employed to profile individual presentations to fine-tune feature extraction, which does not require encryption but involves morphing each presentation in unique ways. Adaptive encryption keys require not only the use of facial holograms but also a physically switched cryptographic key or token to be used on secondary devices.

The payment industry is in a state of flux, with technologies being continually developed and updated to facilitate transactions and to make the payment process more secure and efficient. As a consequence, encryption processes must be adaptive so that biometric payment systems can operate successfully with a variety of new technologies. The proliferation of innovations means that the use of big data to analyze the newest emerging technologies and AI to adapt encryption and biometric presentation by individual end users is equally important. In this context, an examination of the implications of the following key innovative features on the encryption processes of biometric templates and feature data is presented.

6. Conclusion

Biometric payment systems have an integrated cashless and cardless model that uses multiple advanced encryption techniques to secure the data of the Biometric Customer Account. This definitive paper showcases a unified model that includes several encryption algorithms ranging from symmetric to asymmetric and hash algorithms up to distributed Blockchain cryptography based on salient characteristics, strengths, limitations, and hash functions. Big data infrastructure, machine learning models, distributed storage systems, and both centralized and distributed cryptographic encryption techniques provide better operational services and identify the security loopholes that exist within a broader merger. Although the portion of this research strategy (i.e., Blockchain technology) is currently in the growth stage, the deployment of future research would be truly relevant in terms of allying with this biometric payment system. The encryption technique often makes biometric payment systems more robust and, consequently, turns them into a commodity.

Biometric data enhances the security of systems and improves the experiential factor associated with such systems. Nonetheless, associated with the concepts of fraud and breaches, security enthusiasts are always motivated to work on making the systems more secure. A system can be completely secure; however, logical measures such as encryption techniques can reduce the intensity and impact of the damages caused by breaches and attack problems. The evolution of the encryption process has reformed the traditional way of cryptographic mathematical data encryption. The convergence of advanced, discrete, and quantum computation-based cryptographic techniques has both centralized and big data perspectives to address the security requirements of biometric payment systems.

6.1. Future Trends

Future research should focus on not only whether these cur of advanced encryption should be incorporated into biometric payment flows but also on determining the best practices in terms of their harmonization and potential contribution to socio-economic aspects of this evolving field-driven innovations in finance and ubiquitous computing landscape. Thus, the vision is that in the next few decades, the innovative solutions would use biometric payment systems and devices embedded in cognitive radio-based systems, intelligent and context-aware algorithms, secure and ubiquitous artificial intelligence in autonomous environments, supercomputing, and very high-speed wireless and optical networks for fully automated business, finance, and service delivery.

Shortly, the volume, speed, and dynamics of data would make the biometric payment systems and other big data analytics systems quantum computing resistant. It is expected that the continuous and turbo transitions in big data science would result in fully automated and standalone intelligent and artificial intelligence (AI) based big data systems that are feasible, perform biometric payments negotiation, detect, estimate, and take actions on financial engineering security issues. The complexity and highly diverse rapidly changing payments ecosystem would encourage further research on a blending, adaptation, and hybrid of various advanced encryption methods such as quantum computing-resistant encryption, blockchain, and neo-form encryption technologies to biometric payments.

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