VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnana Sangama, Belagavi – 590 018.

Final Year Project Thesis

on

"Blockchain Verified KYC System for Banks & FinTech Using Facial Recognition"

Submitted in partial fulfillment of the requirement for the award of the degree

Bachelor of Engineering

in

Information Science and Engineering

by

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2024 – 25

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ACKNOWLEDGEMENT

I sincerely thank Visvesvaraya Technological University for providing a platform to carry out this project.

Firstly, we would like to express our deep sense of gratitude to our Principal, **Dr. Vijayasimha Reddy. B. G,** for providing the necessary support .

We would like to place on record our regards to **Dr. Rajanna M,** Professor and Head, Department of Information Science and Engineering for his continued support.

We would like to oblige our gratitude to our project coordinators **Dr. A Stella,** Assistant Professor and **Dr. Mythili M,** Assistant Professor, Dept. of ISE for their support and coordination.

We would like to thank our project guide **Prof. Mythili M,** Assistant Professor, Dept. of ISE for her continuous support, valuable guidance and supervision towards successful completion of the project work.

We also thank all the teaching and non-teaching staff of Information Science and Engineering department, who have helped us to complete the project in time.

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ABSTRACT

The project titled **"Blockchain-Verified KYC System for Banks & FinTech Using Facial Recognition"** addresses the growing need for secure, efficient, and fraud-resistant customer verification processes. The primary objective is to develop a decentralized KYC system that leverages blockchain technology for tamper-proof data storage and facial recognition techniques for accurate customer authentication.

The system architecture integrates user registration through ID proof and facial recognition, followed by secure storage of verified data on a blockchain network. When a financial institution requests KYC information, the blockchain retrieves and verifies the data seamlessly. Facial recognition is implemented using OpenCV with DeepFace to ensure fast and accurate verification, while blockchain principles such as decentralization, immutability, and cryptographic security protect data integrity.

The project workflow involves modules for image acquisition, grayscale conversion, facial feature extraction through Haar Cascade classifiers, and model training using Deepface, leading to precise face matching. Blockchain principles like consensus mechanisms, transparency, and security ensure the protection and accessibility of stored KYC data.

Key findings highlight that the developed system significantly reduces KYC verification time from days to minutes, cuts compliance costs, and offers a reusable, one-time customer verification model. Applications of the project include secure identity verification for banking, fintech, e-governance, loan processing, and cross-border transactions.

The outcome demonstrates a robust, scalable solution that enhances customer trust, ensures regulatory compliance, and minimizes risks of identity fraud. Future scope includes integration of AI for fraud detection and expansion to global financial platforms.

CONTENTS

LIST OF ABBREVIATIONS

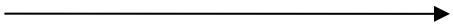
NOTE: Abbreviations should be written in alphabetical order

Abbreviation **Description**

AES	Advanced Encryption Standard
API	Application Programming Interface
AU	Action Unit
BTP	Biometric template protection
CDF	Cumulative Distribution Function
CKKS	Cheon-Kim-Kim-Song
CNN	Convolution Neural Network
DNN	Deep Neural Network
FACS	Facial Action Coding System
FER	Facial Expression Recognition
GAS	Global Authentication System
GDPR	General Data Protection Regulation
GUI	Graphical User Interface
HE	Homomorphic Encryption
IoT	Internet of Things
KYC	Know Your Customer
LSTM	Long Short-Term Memory
mEBAL	A Multimodal Database for Eye Blink Detection and Attention Level Estimation
MFBR	Multiplication-Free Biometric Recognition
MTCNN	Multi-Task Cascaded Convolutional Neural Networks

OpenCV	Open Source Computer Vision
PCA	Principal Component Analysis
PDF	Probability Density Function
PIL	Python Imaging Library
PKI	Public Key Infrastructure
REFER	Real-Time Ensemble for Facial Expression Recognition
SED	squared Euclidean distance
SHA-256	Secure Hash Algorithm 256-bit
SVM	Support Vector Machines

LIST OF SYMBOLS

	FLOW OF CONDITION
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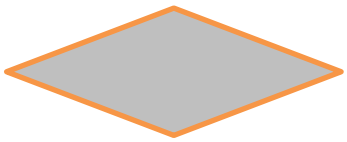	CONDITION
	USER
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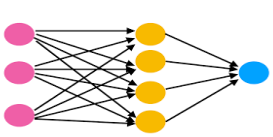	DEEP NEURAL NETWORK

LIST OF FIGURES

CHAPTER 1

1.1 INTRODUCTION

In the evolving landscape of financial services, the need for secure, efficient, and reliable customer identity verification has become increasingly critical. Traditional Know Your Customer (KYC) processes, which rely on manual verification of documents like Aadhaar, PAN cards, and passports, are often time-consuming, expensive, and susceptible to breaches due to centralized data storage. To address these challenges, this project proposes a Blockchain-Verified KYC System integrated with Facial Recognition technology. The system aims to revolutionize KYC verification by providing a decentralized, tamper-proof, and biometric-based solution that ensures data integrity and enhances user experience. Blockchain technology offers a distributed and immutable ledger system that guarantees transparency and security without relying on a central authority. Customer data, once verified, is securely stored on the blockchain, ensuring that it cannot be tampered with or altered. This eliminates redundancies in verification, reduces compliance costs, and strengthens trust between customers and financial institutions. Facial recognition, powered by OpenCV and the CNN model, adds an additional layer of security by accurately verifying the unique biometric features of each user, making identity fraud extremely difficult. The proposed system follows a streamlined workflow where user registration involves both document submission and facial data capture. Once verified, the information is stored on the blockchain and can be accessed securely by authorized financial institutions, reducing the need for repetitive KYC checks. This approach not only accelerates onboarding processes but also empowers users to control their identity data securely. The integration of blockchain and facial recognition ensures a faster, more secure, and user-friendly KYC process, positioning the system as a forward-thinking solution for banking, fintech, and beyond.

1.2 SCOPE

The Blockchain-Verified KYC System using Facial Recognition aims to redefine the process of customer verification for banks and fintech institutions. The scope of this project extends beyond just secure identity verification; it integrates modern technologies to create a decentralized, efficient, and scalable system capable of transforming how personal identification is managed and shared.

This project focuses on developing a system that:

- Provides Decentralized KYC Verification: By using blockchain technology, the system ensures that customer data is stored securely and immutably across a distributed network, reducing the risks of centralized data breaches.
- Implements Facial Recognition for Authentication: The project uses OpenCV and Deep Neural Network algorithms for facial detection and recognition, ensuring accurate, fast, and reliable biometric verification.
- Eliminates Redundant Verification: Once verified, customer data can be securely shared across multiple institutions, avoiding the need for repeated KYC processes for each new service.
- Reduces Compliance Costs: Financial institutions can save significant costs associated with manual verification, paperwork, and data management by shifting to an automated, blockchain-based system.
- Enhances User Convenience: Customers undergo a one-time verification process, after which their identity can be authenticated digitally without resubmitting documents multiple times.
- The project also explores integration possibilities for various applications such as loan processing, account opening, crypto exchange verifications, and cross-border identity management. It is designed to be scalable for future enhancements like AI-driven fraud detection, multi-platform integration (mobile and web), and support for global digital identity standards.

By securing KYC data using blockchain and validating identities through facial recognition, the system sets a strong foundation for next-generation financial services that prioritize both user security and convenience.

1.3 OBJECTIVE

The primary objective of this project is to design and develop a Blockchain-Verified KYC System integrated with Facial Recognition to modernize and secure the customer verification process for banks and fintech companies. This system focuses on providing a reliable, decentralized alternative to traditional centralized KYC mechanisms while ensuring a seamless user experience.

The key objectives of the project are:

1. To Build a Decentralized KYC Platform: Develop a blockchain-based architecture where verified KYC data is stored securely, ensuring immutability, transparency, and trust between users and financial institutions.

2. To Implement Real-Time Facial Recognition Authentication: Integrate OpenCV-based facial recognition using the Deep Neural Network algorithm to verify user identities accurately and in real-time, reducing reliance on physical document verification.

3. To Enhance Data Security and Privacy: Protect sensitive user information from cyber threats by leveraging the tamper-proof and cryptographically secure nature of blockchain technology.

4. To Eliminate Repetitive KYC Processes: Enable users to perform KYC verification once and reuse their verified data across multiple banks, fintech companies, and service providers without undergoing repetitive checks.

5. To Improve Operational Efficiency: Reduce the time, cost, and manual effort associated with traditional KYC processes, making onboarding faster for financial institutions and more convenient for customers.

6. To Create a Scalable and Flexible System: Design the system with future adaptability in mind, allowing for potential upgrades like multi-modal biometrics (fingerprint, iris), cross-border KYC sharing, and AI-based fraud detection enhancements.

7. To Ensure Regulatory Compliance: Align the system with national and international regulatory standards for KYC and customer data protection, making it viable for real-world deployment.

1.4 ORGANIZATION OF PROJECT WORK

The main objective of this project is to design and develop a Blockchain-Verified KYC System using Facial Recognition technology, organized into different functional modules. Each module plays a crucial role in achieving the overall goal of creating a secure, decentralized, and efficient KYC verification platform for banks and fintech industries.

The objectives with respect to the modules are as follows:

- User GUI: Tkinter-based interface for entering details and uploading/capturing images.
- Encryption Module: Uses Fernet to encrypt files, storing them in blockchain.
- Blockchain Module: Creates blocks with user data, verification statuses, and SHA-256 hashes.
- Admin GUI: Tkinter interface for loading, decrypting, and verifying KYC data.
- Face Verification Module: Detects faces with OpenCV DNN, compares with DeepFace.
- Mock APIs: Simulates external validations for Aadhaar, PAN, and RBI.

Each module works in coordination to achieve the project's vision of creating a user-centric, highly secure, scalable, and reusable KYC verification system, enhancing both institutional operations and customer convenience.

CHAPTER 2

LITERATURE SURVEY

2.1 Combining Blockchain and Biometrics: A Survey on Technical Aspects and a First Legal Analysis

2.1.1 Introduction

Biometric recognition, known for its uniqueness, difficulty to forge, and efficiency in identification and verification, has become an essential component of today's digital landscape. The rapid advancement of biometric technology has driven its integration across numerous applications. Meanwhile, blockchain technology, a decentralized ledger system, has gained widespread attention for its ability to provide secure and transparent data management. It has found significant use across various industries, including finance, IoT, healthcare, and logistics. Recently, there has been growing interest in exploring the potential synergy between these two technologies. Researchers have started to investigate how combining biometrics with blockchain could lead to new applications, but this integration is still in its early stages.

2.1.1.1 Purpose

This paper aims to explore the technical and legal implications of combining blockchain technology with biometrics. The study seeks to provide an in-depth analysis of the current research on this integration, highlighting both its potential advantages and challenges. By reviewing the literature and analysing the legal aspects, the paper endeavours to present a comprehensive understanding of how blockchain can be applied within the biometric sector.

2.1.1.2 Scope

The scope of this paper is twofold:

1. Technical scope: It provides a survey of the various applications where blockchain can enhance biometric technologies, such as Public Key Infrastructure (PKI), distributed trusted services, and identity management. The paper also addresses the challenges of using blockchain in real-time biometric applications, particularly its current inefficiency and high costs.

2. Legal scope: The paper includes an analysis of the legal considerations surrounding the integration of blockchain and biometrics, such as accountability issues and the complexities of performing a Data Protection Impact Assessment. It also offers

recommendations to mitigate risks and optimize the use of both technologies in real-world applications.

2.1.2 Theory

The integration of blockchain technology with biometric recognition hinges on the core principles of both technologies. Biometric systems are rooted in the concept of inherence, identifying individuals based on their unique physiological or behavioural traits, such as fingerprints, facial features, or iris patterns. This makes biometric recognition inherently more secure and difficult to forge than traditional methods like passwords or PINs, offering a higher level of assurance and better user experience. However, biometrics face challenges like centralization of data storage, which can make them vulnerable to security breaches, data manipulation, or unauthorized access.

Blockchain, on the other hand, provides a decentralized, immutable, and transparent ledger for storing data. The key features of blockchain include decentralization, auditability, fault tolerance, and security. These qualities address many of the weaknesses associated with biometrics, particularly in terms of secure data storage and preventing single points of failure. When combined, blockchain can provide a distributed and secure infrastructure for biometric data, allowing for better privacy, data integrity, and system redundancy. By introducing concepts like distributed identifiers (DIDs) and Public Key Infrastructure (PKI) mechanisms, blockchain can also enable more robust identity management systems. The fusion of these technologies represents an opportunity to enhance the overall security and efficiency of biometric systems while also tackling issues like data centralization and fraud prevention.

2.1.3 Historical Development

The historical development of blockchain technology and biometrics follows parallel tracks of technological advancement, each contributing to the security landscape of the digital age. In the early 2000s, biometric recognition emerged as a promising solution for enhancing security in various fields, including authentication systems, border control, and access management. Early biometrics systems were hindered by issues like limited computational power, storage capabilities, and concerns over the centralization of biometric data, which posed security risks such as data theft or unauthorized access. However, advances in computing and machine learning have significantly improved the accuracy, speed, and reliability of biometric systems. Blockchain, introduced by the pseudonymous entity Satoshi Nakamoto in 2008 with the launch of Bitcoin, revolutionized the way digital transactions and data were handled. Initially focused on cryptocurrency, blockchain

technology rapidly gained recognition for its ability to offer secure, transparent, and decentralized data management. Over the past decade, the scope of blockchain's applications has expanded to areas like smart contracts, identity management, and distributed computing. In recent years, researchers have started to explore how blockchain and biometrics can be integrated to address the limitations of both technologies. This intersection is still in its infancy, but the promise of combining biometrics' secure, user-centric identification with blockchain's tamper-resistant ledger has sparked interest in fields such as digital identity management, secure data storage, and even e-voting. The evolution of these technologies is setting the stage for a more secure and efficient future in various sectors.

2.1.4 Relevance to Our Project: Blockchain and Biometric Verification

The integration of blockchain with biometric verification is highly relevant to our project, as it enhances the security and efficiency of biometric systems in real-world applications. Biometric verification ensures that individuals are who they claim to be, using unique physiological or behavioural traits. By combining blockchain with biometric systems, we can address significant challenges like data privacy, fraud prevention, and system reliability.

As highlighted in the text, mobile biometrics can utilize blockchain to create a portable, decentralized trust system, particularly useful for environments like healthcare and mobile applications. In these contexts, blockchain offers a secure, immutable ledger to store biometric data and authentication logs, ensuring that sensitive biometric information is not vulnerable to centralized storage issues. This approach can be particularly useful for identity verification, which is essential for preventing identity theft and ensuring secure access to services.

Furthermore, blockchain's role in addressing latency and privacy concerns in biometric verification systems is crucial. As the paper suggests, using cryptographic methods such as zero-knowledge proofs can enhance privacy by allowing verification without exposing sensitive data. This aspect is directly relevant to our project, as it emphasizes how blockchain can provide both security and privacy while improving the overall trustworthiness of biometric verification systems in various applications.

2.1.5 Conclusion: Blockchain-Enabled Identity Management with Biometrics

Blockchain technology offers a significant advantage when it comes to digital identity management, particularly in a highly digitized society. Traditional systems of identity verification, such as passports or driver's licenses, are limited in their applicability online and across national borders. Blockchain's decentralized nature provides a solution to these problems by enabling individuals to maintain and control their digital identities securely without relying on a central authority.

In the context of biometrics, blockchain can serve as the backbone for a digital identity system by securely storing biometric data and linking it with individuals' digital identities. This integration allows individuals to have full control over their personal information, including who can access it and under what circumstances. As noted in the paper, various studies have explored how blockchain can store biometric features, such as fingerprints or fingernail images, for identity management purposes.

One key advantage of this approach is the enhanced privacy and security of the biometric data. By storing biometric templates on decentralized systems like blockchain, the risks associated with centralized data storage—such as breaches or unauthorized access—are significantly reduced. Additionally, blockchain-based systems can facilitate seamless, cross-border identity management, addressing limitations in existing national systems and paving the way for more robust, secure online identity verification.

2.2 Improved Multiplication-Free Biometric Recognition Under Encryption

2.2.1 Introduction:

Modern biometric recognition systems have achieved remarkable accuracy by leveraging deep neural networks (DNNs) to extract unique feature vectors from biometric data such as facial images, fingerprints, or iris scans. These vectors, representing condensed yet distinctive characteristics, are used to evaluate the similarity or dissimilarity between two samples, which forms the core of recognition systems. However, the security and privacy of these feature vectors have become a critical concern. Research shows that sensitive personal attributes—such as ethnicity, health status, or even an approximation of the original biometric image—can be inferred or reconstructed from these vectors. Such vulnerabilities necessitate the development of advanced protection techniques to safeguard biometric data throughout processing and storage. Homomorphic Encryption (HE) has emerged as a state-of-the-art solution, allowing operations on encrypted data without decrypting it, thereby hiding the sensitive information during recognition tasks. Despite its privacy advantages, traditional HE solutions suffer from significant inefficiencies, particularly due to the computational cost associated with multiplication-heavy similarity computations. This inefficiency becomes a major bottleneck when working with high-dimensional feature vectors. Therefore, there is an urgent need to develop more efficient HE-integrated methods that balance security with computational performance, especially in real-time or resource-constrained applications.

2.2.1.1 Purpose:

The purpose of this study is to address the critical issue of computational inefficiency in privacy-preserving biometric recognition systems that utilize homomorphic encryption (HE). With the rise of deep neural networks in biometric systems, the extraction of high-dimensional feature vectors for comparing biometric data has become standard. However, protecting these vectors from misuse is essential, as they can be exploited to infer personal details or reconstruct original biometric samples. Homomorphic encryption offers a solution by allowing operations on encrypted data, maintaining privacy even during processing. Unfortunately, current HE-based methods suffer from significant performance bottlenecks, primarily due to their dependence on multiplication-heavy operations like cosine similarity and Euclidean distance, which are essential for comparing feature vectors. This research proposes a novel approach that eliminates these multiplication operations by

converting similarity computations into pre-computed lookup tables and simple summations. This optimization significantly improves runtime efficiency without compromising the encrypted nature of the data. The ultimate goal is to make HE-based biometric systems practical for real-time use by reducing computational overhead. Thus, the study aims to advance secure biometric verification systems by making them faster, scalable, and suitable for deployment in real-world, time-sensitive applications such as banking, healthcare, and identity verification systems.

2.2.1.2 Scope:

The scope of this work encompasses the design, implementation, and evaluation of a high-efficiency biometric recognition framework that integrates homomorphic encryption with optimized (dis-)similarity computation techniques. Specifically, the study focuses on two widely-used similarity measures: cosine similarity and squared Euclidean distance. These metrics are traditionally resource-intensive due to their reliance on multiplications, especially when applied to high-dimensional feature vectors extracted from biometric data using deep learning models. To address this, the scope includes developing a method to transform these operations into pre-computed lookup tables, reducing runtime computations to lightweight table lookups and summations. This transformation is assumed to be valid for normalized feature vectors, a standard condition in biometric systems.

2.2.2 Theory:

The core theoretical foundation of this study lies in the application of homomorphic encryption (HE) to biometric recognition, where sensitive biometric feature vectors must be protected during computation. Deep neural networks (DNNs) extract high-dimensional feature vectors from biometric inputs (e.g., faces), which are then compared using similarity metrics like cosine similarity or squared Euclidean distance (SED). These metrics typically involve numerous multiplications, making them inefficient under HE, where multiplication operations are computationally expensive. To address this, the proposed theory eliminates multiplications through a Multiplication-Free Biometric Recognition (MFBR) framework that precomputes score tables based on known probability distributions (PDF and CDF) of normalized feature vectors. The lookup-table-based approach allows (dis-)similarity scoring using only homomorphic additions and slot selections, drastically reducing computational overhead while preserving accuracy. Additionally, the system incorporates cleartext and encrypted decision modes, the latter offering superior privacy by revealing only a binary decision (match/no match). The method assumes normalized vectors on the unit d-ball and exploits full ciphertext capacity

to compress reference templates. By reducing ciphertext storage and enabling efficient slot-wise operations, the theory supports practical, privacy-preserving biometric authentication suitable for real-time and large-scale applications**.**

2.2.3 HISTORY

The history of privacy-preserving biometric recognition has evolved from traditional biometric template protection (BTP) techniques to more advanced homomorphic encryption (HE)-based systems. Early BTPs employed helper data, Bloom filters, and transformation techniques to obscure biometric data, but many compromised on accuracy or required significant system redesigns. The introduction of HE-based BTPs marked a turning point by enabling operations on encrypted biometric feature vectors, preserving both privacy and recognition performance. However, early HE solutions faced scalability challenges due to the cost of homomorphic multiplications required for computing similarity scores. For example, schemes using the CKKS encryption model required several seconds for simple 128- or 512-dimensional vector comparisons. The HELR classifier proposed in 2021 introduced the first multiplication-free HE biometric method by using pre-trained likelihood ratio tables, but it was limited by its need for training data. The first version of MFBR (MFBRv1) built on HELR to eliminate training dependencies and applied the method to inner product (IP) and SED computations. The current study advances this history with MFBRv2, which refines storage, runtime, and encrypted decision performance by optimizing ciphertext packing and eliminating unnecessary operations. This progression reflects the field's shift toward efficient, secure, and scalable biometric recognition under encryption.

2.2.4 Relevance to Our Project:

The concepts explored in this paper are highly relevant to a Blockchain-Verified KYC (Know Your Customer) system, particularly one integrating biometric facial recognition for identity verification. In such systems, biometric data—often facial images—are processed using deep neural networks to extract unique feature vectors. However, storing and using these vectors introduces significant privacy risks, such as identity theft, model inversion attacks, and unauthorized profiling. The use of homomorphic encryption (HE) and Multiplication-Free Biometric Recognition (MFBR), as presented in this study, ensures that all biometric comparisons can occur within the encrypted domain, preventing exposure

of sensitive data at any stage. This approach aligns perfectly with the decentralized, transparent, and immutable nature of blockchain technology, which is often used to store hashes of verified data rather than raw biometric information. By combining MFBR with blockchain, a KYC system can authenticate users securely without ever revealing their biometric templates, thus satisfying regulatory demands for privacy and data protection (e.g., GDPR compliance). Moreover, reducing ciphertext size and improving processing efficiency makes this solution viable even on resource-constrained systems. In summary, integrating MFBR under encryption enhances both security and scalability of blockchain-based KYC systems, bridging trustless verification with biometric privacy.

2.2.5 Conclusion:

This study presents a significant leap in privacy-preserving biometric recognition by introducing an improved Multiplication-Free Biometric Recognition (MFBR) approach that functions efficiently under homomorphic encryption (HE). Traditional biometric systems expose sensitive feature vectors during processing, leading to privacy vulnerabilities such as information inference and identity fraud. While HE-based systems offer a solution, their practical adoption has been hindered by computational inefficiencies, particularly from homomorphic multiplications. The proposed MFBRv2 mitigates these challenges by eliminating multiplications altogether, using precomputed lookup tables based on cosine similarity and squared Euclidean distance.

2.3 Toward Secure and Transparent Global Authentication: A Blockchain-Based System Integrating Biometrics and Subscriber Identification Module

2.3.1 Introduction:

Biometric recognition, known for its uniqueness, difficulty to forge, and efficiency, has rapidly emerged as a cornerstone of modern digital identity systems. As the demand for secure and seamless authentication grows, biometric technologies such as facial recognition, fingerprint scanning, and iris detection have found widespread adoption across sectors like banking, healthcare, and public security. Simultaneously, blockchain technology—recognized for its decentralized, immutable, and transparent ledger—has transformed the landscape of digital transactions and record-keeping. With its successful application in domains such as cryptocurrency, Internet of Things (IoT), and logistics, blockchain has gained strong traction in both academia and industry. As both biometric recognition and blockchain mature, researchers have started exploring the synergistic potential of their integration. The combination promises a secure, decentralized, and privacy-respecting framework for identity verification and access control. This paper surveys existing technical literature on this convergence and examines early legal considerations, aiming to provide a comprehensive view of opportunities and challenges in implementing blockchain-based biometric systems.

2.3.1.1 Purpose:

The primary purpose of this study is to explore the feasibility and impact of integrating blockchain technology with biometric systems. By reviewing a wide range of technical literature, this paper aims to uncover how the decentralized, transparent, and tamper-resistant nature of blockchain can complement the identity verification strengths of biometric authentication. The integration could revolutionize areas such as public key infrastructure (PKI), distributed identity management, and trusted service frameworks, particularly in sectors where secure and verifiable identity is critical. Additionally, the paper addresses legal and regulatory dimensions, including privacy concerns and accountability, which are essential for real-world deployment. Through a dual lens—technical and legal—this work seeks to provide practical insights and highlight both the

potential gains and existing gaps that must be addressed before this hybrid solution can be widely adopted.

2.3.1.2 Scope:

This study presents a comprehensive survey of the current state of research on the integration of blockchain and biometric technologies. It encompasses both technical advancements and legal implications, offering a holistic view of this emerging interdisciplinary field. Technically, it evaluates the applicability of blockchain in biometric systems for secure identity management, authentication, and trust establishment, particularly in decentralized environments. Legally, it investigates key concerns such as data protection, accountability, and compliance with privacy regulations like the GDPR. The paper also identifies the current limitations of blockchain infrastructure, especially regarding real-time efficiency and economic viability, which affect its suitability for time-sensitive biometric applications. By combining both perspectives, this study delivers a balanced understanding of the opportunities, limitations, and recommendations for implementing blockchain-powered biometric systems in a legally sound and technically efficient manner.

2.3.2 Theory:

The theoretical foundation of the Biometric and Blockchain-based Global Authentication System (B^2-GAS) lies in the convergence of three core technologies: biometric authentication, blockchain networks, and SIM-based secure enclaves. Biometric systems utilize physiological or behavioral characteristics—such as facial features, fingerprints, or iris patterns—to uniquely identify individuals, offering a more secure alternative to passwords or tokens. Blockchain, a decentralized and immutable ledger, enables secure and transparent record-keeping across distributed networks. By eliminating central points of control, it ensures tamper-proof data integrity and auditability. SIM technology adds a trusted, hardware-based environment where sensitive credentials can be securely processed within protected enclaves, further reducing the attack surface.

In B^2-GAS, biometric data is not stored directly on the blockchain but instead used to trigger identity verification through secure enclave-based SIM processing, thus protecting privacy. The blockchain logs each transaction immutably, ensuring traceability without compromising biometric data. This hybrid approach ensures authentication transparency, removes the risk of single points of failure, and supports scalability through decentralized

consensus mechanisms. B²-GAS is designed to respond to the demanding requirements of Smart Cities and e-government applications, where large-scale, real-time, and privacy-respecting authentication is essential. Its architecture reflects a balanced compromise between security, performance, user privacy, and legal compliance.

2.3.3 History:

The evolution of authentication methods in digital governance has moved from password-based systems to more advanced technologies like two-factor authentication (2FA), smart cards, and eventually, biometrics. As Smart Cities emerged, offering integrated digital services such as e-governance portals, digital IDs, and automated public services, the need for more secure and scalable authentication systems became critical. Early e-Government platforms relied on centralized databases for identity management, which introduced vulnerabilities like data breaches, lack of transparency, and single points of failure.

Parallelly, blockchain technology was introduced in 2008 with Bitcoin, gaining attention for its decentralization, immutability, and tamper-resistant features. Around 2016–2018, researchers began exploring blockchain's potential in identity management. However, using blockchain alone posed privacy risks, especially when storing sensitive biometric data. This led to hybrid solutions where biometric data was locally processed, while blockchain handled verification logs and access control. The integration of SIM-based secure enclaves came later, inspired by the need to add hardware-level security. By 2020s, conceptual frameworks like B²-GAS began appearing, combining biometrics, blockchain, and SIM technology into a unified system for secure, decentralized authentication. These innovations were catalyzed by growing concerns over data sovereignty, citizen privacy, and regulatory compliance, especially in the wake of rising cyber threats and global digitalization initiatives.

2.3.4 Relevance to Our Project:

Your project aims to create a secure and tamper-proof KYC (Know Your Customer) system using facial recognition and blockchain, which directly aligns with the objectives of the B²-GAS framework. Both systems leverage biometrics (in your case, facial recognition) as a unique and hard-to-forge authentication factor, improving security over traditional methods. Similarly, the use of blockchain ensures that all verification actions are immutable, transparent, and traceable, crucial for regulatory compliance in financial services.

Just as B²-GAS addresses the issue of a single point of failure by decentralizing identity verification across a blockchain network, your project ensures that KYC data is securely stored and verifiable without relying on a central authority. Moreover, the concept of privacy-preserving design—processing biometric data securely without exposing it publicly—is core to both systems, supporting GDPR and data protection compliance.

The integration of real-time facial recognition with blockchain verification in your KYC system reflects the same goals of secure, scalable, and trustworthy identity management explored in B²-GAS. Insights from B²-GAS can guide architectural decisions, such as how to securely store biometric hashes, design distributed consensus models, and handle legal accountability in data usage—all essential to building a robust KYC platform for banks and fintech.

2.3.5 Conclusion:

In conclusion, integrating blockchain with biometric technologies like facial recognition offers a powerful solution for secure, transparent, and tamper-proof identity verification in KYC systems. By eliminating single points of failure and enhancing privacy through decentralized, immutable records, such systems address critical challenges faced by banks and fintechs. The concepts explored in B²-GAS provide a strong foundation for designing scalable and legally compliant KYC frameworks. Your project aligns well with these goals, promising a future-ready solution that enhances trust, security, and efficiency in digital financial services through advanced biometric and blockchain integration.

2.4 DeepFace-Attention: Multimodal Face Biometrics for Attention Estimation With Application to e-Learning

2.4.1 Introduction

Attention is a fundamental cognitive function, central to learning and decision-making processes. It is defined as the ability to focus cognitive resources on a specific task or stimulus at any given moment. This cognitive effort can vary significantly, ranging from high attention, where individuals are highly concentrated, to low attention, where distractions prevail or interest wanes. Understanding and estimating attention levels have become crucial in diverse applications, including mental health, e-learning, human-computer interactions, and fatigue detection in drivers.

In the context of e-learning, attention estimation becomes even more critical due to the challenges posed by the lack of direct interaction between instructors and students. The absence of face-to-face communication makes it difficult for educators to gauge student engagement and identify when they are facing difficulties in understanding or maintaining concentration. Traditional methods of attention assessment, such as self-reporting or manual observation, have limitations in such settings. However, recent advancements in facial expression analysis and computer vision technologies have enabled the development of automated systems that can analyze visual cues, such as facial gestures, head pose, and eye movement, to estimate attention levels in real-time.

This paper introduces a novel multimodal framework for attention estimation, leveraging deep learning models to analyze facial features and physiological indicators, such as eyeblinks, facial expressions, and heart rate. By integrating these various modalities, the framework offers a comprehensive solution for real-time attention assessment. Through a series of experiments conducted on the mEBAL2 database, this approach demonstrates an impressive classification accuracy of 85.92%, significantly outperforming existing monomodal systems. This advancement holds promise for improving e-learning experiences by providing real-time feedback on student engagement, enabling timely interventions to enhance learning outcomes.

2.4.1.1 Purpose

The primary purpose of this paper is to develop a robust multimodal system for attention estimation that can be applied in e-learning environments. Traditional attention estimation methods often rely on monomodal approaches, focusing on a single modality such as facial expressions or eye tracking. However, such methods tend to overlook the complex, multifaceted nature of attention, which is influenced by various physiological and behavioral cues. This paper aims to bridge this gap by presenting a multimodal system that combines multiple features, including facial gestures, head pose, eyeblinks, and heart rate, to create a more accurate and reliable measure of attention.

The paper also aims to explore the relationship between these various indicators and attention levels, considering their combined effect in the context of online learning. By integrating these different sources of information, the system is expected to provide a more nuanced understanding of student engagement and cognitive load. This is especially valuable in e-learning environments, where educators often lack direct insight into their students' emotional and cognitive states. Furthermore, the paper seeks to demonstrate the effectiveness of neural network-based score fusion techniques in enhancing the accuracy of attention level estimation.

2.4.1.2 Scope

This study focuses on developing and evaluating a multimodal framework for attention estimation that can be applied in e-learning environments. The system uses Convolutional Neural Networks (CNNs) to analyze facial features, along with other physiological markers, to estimate a person's attention level. The framework operates within the context of the mEBAL2 database, which contains video recordings of students engaged in online learning. The scope of the research includes the development of five key modules within the framework, each trained to extract relevant facial and behavioral features that correlate with different levels of attention.

The study explores the performance of these modules in terms of their ability to estimate attention, considering both global and local facial features, as well as their effective combination using score-level fusion. The research also extends previous work in attention estimation by introducing additional features such as heart rate, thus expanding the range of physiological processes considered in attention estimation. The scope further includes a comparison of the proposed multimodal framework with existing monomodal systems,

demonstrating the advantages of incorporating multiple variables to achieve higher classification accuracy.

Additionally, the study evaluates the performance of the attention estimation system across different time windows (30, 60, and 120 seconds) to assess its robustness and reliability in real-world applications. By analyzing the mEBAL2 database, which includes over 1,800 minutes of video data from 60 students, the study provides a comprehensive evaluation of the proposed system's capabilities. Ultimately, the goal is to present a solution that not only improves the accuracy of attention estimation but also contributes to enhancing the overall e-learning experience by offering real-time feedback to educators.

2.4.2 Theory

Attention estimation aims to evaluate an individual's cognitive focus or mental effort during tasks. It is integral in understanding how people interact with tasks and how their focus fluctuates during learning or other cognitive activities. Traditionally, attention estimation methods involve analyzing various physiological and behavioral signals to assess attention levels. These signals can range from brain activity and physiological markers to facial expressions, head movements, and eye tracking. The combination of these modalities provides a more comprehensive and accurate representation of an individual's attention level.

Brain activity, as captured by techniques such as Electroencephalography (EEG), provides valuable insight into mental states by measuring neural activity. EEG is sensitive to changes in cognitive effort and mental workload, making it one of the most reliable tools for measuring attention in real-time. However, its invasive nature, requiring the placement of electrodes on the scalp, makes it impractical for large-scale use in environments such as e-learning.

On the other hand, physiological signals such as heart rate, eye blink rate, and pupil size can offer valuable data about a person's cognitive load. These signals are less intrusive and can be easily collected using sensors, making them more suitable for environments like education. In particular, studies have shown that a higher blink rate correlates with lower attention levels, while a more focused gaze and steady heart rate are indicative of higher attention.

Behavioral signals, such as head pose and facial expressions, also provide critical insights into attention levels. These behaviors are often observable through standard webcams, which makes them an ideal option for attention estimation in environments like online learning. The integration of multiple modalities—brain activity, physiological responses, and behavioral signals—has been shown to yield more accurate and reliable attention estimation results than any single modality alone.

2.4.3 History

Face detection has a rich history in the realm of computer vision, with its development spanning several decades. The concept of detecting faces in images can be traced back to the early days of computer vision research in the 1960s and 1970s. One of the first significant advancements in face detection came in 1973 when Woodrow W. Bledsoe developed a system to identify human faces based on eye, nose, and mouth positions. This rudimentary system laid the groundwork for future advancements in the field.

However, it wasn’t until the 1990s that face detection truly gained momentum with the advent of more advanced algorithms. The introduction of the "Eigenfaces" method by Sirovich and Kirby in 1987, and later the "Fisherfaces" method in the 1990s, significantly improved face recognition and detection accuracy. These methods focused on dimensionality reduction, using techniques like Principal Component Analysis (PCA) to identify key facial features.

The real breakthrough in face detection came in 2001 when Paul Viola and Michael Jones proposed the Viola-Jones algorithm, which revolutionized the field by offering a fast and reliable approach to face detection. This algorithm used a combination of Haar-like features and a cascade classifier to detect faces in real-time, making it widely applicable for use in various applications, from security systems to digital cameras.

Since then, face detection has continued to evolve, with deep learning methods taking center stage in the last decade. Convolutional Neural Networks (CNNs), in particular, have led to significant advancements in the accuracy and robustness of face detection systems. Today, face detection is used in a wide range of applications, including security, surveillance, healthcare, and even e-learning, where it plays a crucial role in estimating attention and engagement during online learning sessions. Modern systems, often relying on deep learning, can detect and track faces in challenging conditions with high accuracy and speed, paving the way for the next generation of human-computer interaction.

2.4.4 Relevance to our project:

Integrating facial recognition into blockchain for KYC verification can benefit from several concepts outlined in the paper. Here are key insights:

1. **Multimodal Systems for Accuracy:** The paper highlights the use of multimodal systems that combine facial, physiological, and behavioral data. In KYC, a similar approach could combine facial recognition with other biometrics like heart rate or eye tracking for enhanced security and fraud resistance.
2. **CNNs for Facial Analysis:** The paper discusses using Convolutional Neural Networks (CNNs) for facial feature extraction. A blockchain-based KYC system can use CNNs to analyze facial features such as eye distance and geometry, ensuring accurate identity verification. These features can be securely hashed and stored on the blockchain to protect privacy.
3. **Real-Time Monitoring:** Just as the paper employs real-time attention monitoring, KYC verification can detect suspicious behavior (e.g., distractions or tampering) during the process. If the system detects anomalies, additional verification steps can be triggered.
4. **Training with Diverse Databases:** The paper uses a diverse dataset for training to improve accuracy. For KYC, using a comprehensive database that includes diverse demographics ensures a more inclusive and accurate facial recognition model.
5. **Score-Level Fusion:** The paper's use of score-level fusion can be applied to KYC systems. By combining facial recognition with other biometric data (e.g., voice or fingerprint scans), neural networks can generate a reliability score, which can be stored securely on the blockchain.

2.4.5 Conclusion:

Incorporating facial recognition into blockchain for KYC verification benefits from many of the techniques and methodologies discussed in the paper. By utilizing multimodal biometric data, advanced machine learning models, and leveraging the security of blockchain, a robust and efficient KYC verification system can be developed. The combination of these technologies can enhance identity verification, reduce fraud, and ensure data privacy, making it a strong solution for modern digital identity management.

2.5 Mobile-Optimized Facial Expression Recognition Techniques

2.5.1 Introduction

Facial expression recognition is a critical area of research due to its broad range of applications across various fields, including human-computer interaction, gaming, medicine, commerce, education, and personal use. Seven basic facial expressions—anger, neutral, fear, disgust, happiness, sadness, and surprise—are universally recognized across cultures, providing a common emotional language that transcends barriers. These expressions can be accurately detected by humans, even those who are blind from birth, making them reliable indicators of emotional states. However, detecting and interpreting these expressions automatically through algorithms poses significant challenges. Machines must be able to accurately detect subtle variations in facial features, even in dynamic and varied environmental conditions. Additionally, individual differences in facial expressions further complicate the task. The need for real-time, accurate facial expression recognition systems has led to significant advancements in technology and the development of multiple approaches, from traditional feature extraction techniques to more advanced deep learning methods.

2.5.1.1 Purpose

The purpose of this paper is to explore and present two distinct approaches to facial expression recognition: a traditional geometric approach and a deep learning-based approach. The paper aims to address the challenges in real-time facial expression recognition by offering methods that balance accuracy and computational efficiency. The traditional approach focuses on geometric features, providing a lightweight solution ideal for real-time applications. In contrast, the deep learning approach leverages neural networks to automatically learn features from data, offering a high-accuracy solution for familiar datasets. By presenting both approaches, the paper aims to showcase solutions that can cater to different needs in terms of computational power and real-time processing requirements.

2.5.1.2 Scope

This paper focuses on two key approaches for facial expression recognition: a geometric-based feature extraction approach and a deep learning-based neural network approach. It evaluates both methods in terms of their accuracy and computational efficiency, with a particular emphasis on real-time performance. The scope of the paper also includes the introduction of two proposed algorithms—Real-Time Ensemble for Facial Expression Recognition (REFER) and FERNet, a convolutional neural network approach. These approaches are compared to existing state-of-the-art methods, with performance metrics such as accuracy, latency, and throughput being key evaluation criteria. The paper provides insights into the practical applications of these methods in real-time systems, particularly in embedded devices.

2.5.2 Theory Concept of Facial Expression Recognition (FER)

Facial Expression Recognition (FER) refers to the automated process of identifying and interpreting human facial expressions. The underlying concept is based on the idea that facial expressions are a reliable reflection of emotional states, and these expressions can be classified into categories such as happiness, sadness, anger, surprise, fear, disgust, and neutral. The core of FER involves feature extraction, where unique and meaningful facial traits are identified and used to classify the expression accurately.

There are two primary approaches to feature extraction in FER: traditional feature extraction methods and deep learning-based methods. Traditional methods focus on geometric and texture features. Geometric features rely on the measurement of distances, angles, and curvature between facial points like the eyes, mouth, and nose. These methods are efficient and work well for real-time applications, but they are sensitive to variations such as scale and orientation. On the other hand, texture features focus on pixel intensity information and details such as wrinkles, which can capture more subtle expressions but are computationally expensive and sensitive to lighting variations. Hybrid approaches combine both geometric and texture features to improve accuracy, though they come at the cost of increased processing time.

In recent years, neural networks, particularly Convolutional Neural Networks (CNNs), have become the dominant approach. CNNs are capable of automatically learning features from the data, eliminating the need for manual feature extraction. These networks are trained on large datasets and are capable of recognizing facial expressions with high

accuracy. However, deep learning models tend to be computationally expensive and may overfit if not properly validated, resulting in poor performance with new data. To enhance FER performance, advancements in networks like Residual Networks (ResNet), Long Short-Term Memory (LSTM) networks, and generative adversarial networks (GANs) are being explored to address challenges such as vanishing gradients and temporal dependencies in facial expression sequences.

2.5.3 History of Facial Expression Recognition (FER)

The history of Facial Expression Recognition (FER) traces back to the early 20th century when Charles Darwin published The Expression of the Emotions in Man and Animals in 1872. Darwin's work laid the foundation for understanding the universality of facial expressions in human emotions. He proposed that facial expressions are biologically ingrained and serve as a form of nonverbal communication. However, the computational study of FER began in the late 20th century, driven by the rapid advancements in computer vision, artificial intelligence, and machine learning.

The first notable strides in automated FER began in the 1990s when researchers began to explore computer vision algorithms for recognizing facial expressions. One of the early systems was developed by Paul Ekman, who identified six universal emotions and their corresponding facial movements, which formed the basis for Facial Action Coding System (FACS). FACS focused on identifying specific facial muscle movements called action units (AUs), which serve as a systematic way to analyze facial expressions.

As digital image processing improved, feature-based methods gained popularity in the early 2000s. These methods relied on geometric features, such as distances between key facial landmarks, and texture-based features, which utilized pixel information to detect emotions. This period also saw the advent of Support Vector Machines (SVM) and Hidden Markov Models (HMM) for emotion classification.

The introduction of deep learning in the 2010s revolutionized FER. In 2012, AlexNet, a deep convolutional neural network, won the ImageNet competition and demonstrated the power of deep learning for image classification tasks, including FER. With deep neural networks capable of learning abstract features from large datasets, FER accuracy significantly improved, and researchers began to focus on optimizing models for real-time applications. The use of neural networks, particularly CNNs, and the introduction of

Today, FER is widely applied across industries, including healthcare, entertainment, security, and marketing, with real-time emotion detection becoming increasingly prevalent through embedded systems in mobile devices and IoT platforms.

2.5.4 Relevance to Your Project

The concepts of Facial Expression Recognition (FER) and facial recognition technology are highly relevant to your project, which involves integrating facial recognition with blockchain for Know Your Customer (KYC) verification. In the context of your project, facial recognition plays a pivotal role in accurately and securely identifying individuals during the KYC process, and FER can further enhance this by understanding and analyzing facial expressions as an additional layer of validation.

Facial recognition serves as a biometric method to verify identity, ensuring that the person undergoing KYC is the same as the one who previously provided the data. Integrating blockchain with facial recognition ensures the security, immutability, and decentralization of the data, making the KYC process more transparent and tamper-resistant.

Incorporating FER into your system can further enhance the accuracy and security of KYC by recognizing emotions such as fear or stress, which could indicate potential fraudulent behavior. For example, an individual's nervousness detected through facial expressions during the verification process could be flagged for a more thorough review. This dynamic, real-time analysis would allow your system to differentiate between legitimate users and potential threats, improving overall system robustness and trustworthiness.

2.5.5 Conclusion

In conclusion, facial recognition combined with blockchain offers a highly secure, efficient, and transparent solution for KYC verification. The use of FER further strengthens the verification process by analyzing emotional cues, which could be used to identify suspicious activities or fraudulent attempts. Blockchain's decentralized nature ensures that the captured biometric data is tamper-proof, enabling a secure and trustworthy method for verifying identities. By integrating facial recognition and FER with blockchain, your project could set a new standard in secure, dynamic, and fraud-resistant identity verification systems.

2.6 Comparitive Analysis

1. **Blockchain and Biometrics Integration**: The first paper discusses the integration of blockchain and biometrics in identity management and verification systems. It emphasizes how blockchain's decentralized and immutable nature can enhance biometric systems by securely storing biometric data and preventing issues like data tampering or unauthorized access. The paper also explores the challenges in combining these two technologies, such as the limitations of blockchain in real-time applications and privacy concerns surrounding the storage of biometric data. A key focus is on biometric verification, identity management, and the legal implications of storing biometric data on public blockchains. It suggests that blockchain could improve biometric applications in fields like voting, healthcare, and border control.
2. **Biometric Security Systems**: This study presents a significant leap in privacy-preserving biometric recognition by introducing an improved Multiplication-Free Biometric Recognition (MFBR) approach that functions efficiently under homomorphic encryption (HE). Traditional biometric systems expose sensitive feature vectors during processing, leading to privacy vulnerabilities such as information inference and identity fraud. While HE-based systems offer a solution, their practical adoption has been hindered by computational inefficiencies, particularly from homomorphic multiplications. The proposed MFBRv2 mitigates these challenges by eliminating multiplications altogether, using precomputed lookup tables based on cosine similarity and squared Euclidean distance.
3. **Blockchain for Global Authentication:** The third paper includes integrating blockchain with biometric technologies like facial recognition offers a powerful solution for secure, transparent, and tamper-proof identity verification in KYC systems. By eliminating single points of failure and enhancing privacy through decentralized, immutable records, such systems address critical challenges faced by banks and fintechs. The concepts explored in B^2-GAS provide a strong foundation for designing scalable and legally compliant KYC frameworks. Your project aligns well with these goals, promising a future-ready solution that enhances trust, security, and efficiency in digital financial services through advanced biometric and blockchain integration.

4. **Facial Expression Recognition (FER) Approaches:**The Fourth paper focuses on facial expression recognition (FER) and explores different feature extraction methods and neural network approaches. The key techniques discussed include geometric features (e.g., distances and angles between facial traits), texture features (using pixel intensity for fine-grained facial details), and hybrid features that combine both types for improved accuracy. It also delves into neural networks, particularly convolutional neural networks (CNNs), for feature learning, bypassing traditional manual feature extraction. The paper compares the efficiency and computational costs of each method, with an emphasis on real-time applications like gaming, healthcare, and safety monitoring. It also highlights the trade-offs between accuracy and performance, specifically in scenarios requiring fast processing, such as embedded systems. The paper's ultimate goal is to enhance FER accuracy while maintaining computational efficiency, addressing issues like illumination, orientation, and scalability.
5. **Blockchain for Facial Recognition in KYC:** The fifth paper focuses on the integration of facial recognition with blockchain for Know Your Customer (KYC) verification, a crucial application in the financial sector. It emphasizes using blockchain technology to securely store and verify biometric data, ensuring data privacy, immutability, and security in the face of rising fraud risks. By leveraging blockchain’s decentralized nature, the system enables tamper-proof records of facial recognition data, ensuring the integrity and transparency of KYC procedures. The paper discusses the importance of securing biometric data and addresses concerns about centralization and misuse of sensitive personal information. Blockchain’s ability to provide audit trails and secure data sharing across institutions is explored, offering a more robust, scalable alternative to traditional centralized KYC systems. The integration of these technologies aims to streamline KYC verification while enhancing security and reducing identity fraud.

2.7 Summary of Literature Survey

Blockchain, biometrics, and face verification have gained significant attention in recent years, particularly in the field of Know Your Customer (KYC) processes. The integration of these technologies offers robust solutions to enhance security, streamline identity verification, and reduce fraud.

Blockchain technology is a decentralized and secure method for recording transactions on an immutable ledger. It eliminates the need for trusted intermediaries, which is essential in situations requiring secure and transparent exchanges of information. In the context of KYC, blockchain provides a decentralized, transparent, and tamper-resistant way to store and share verified identity information. The distributed nature of blockchain ensures that biometric and personal data cannot be manipulated or lost, enhancing the security and privacy of user data. Blockchain's proof-of-work mechanism helps in preventing double-spending and ensures that data, once recorded, is computationally impractical to alter, making it ideal for use in secure identity verification.

Biometric verification is a method of confirming an individual's identity based on their unique biological or behavioural traits, such as fingerprints, iris scans, and facial features. Biometric data provides a high level of security because it is inherently difficult to forge or replicate. In KYC processes, biometrics offer a reliable way to authenticate individuals, ensuring that only the rightful person can access sensitive services. This makes biometric verification crucial for secure online banking, healthcare, and financial services. Combining biometrics with blockchain ensures that biometric data can be securely stored and verified without risking unauthorized access or alteration, thus addressing privacy concerns while maintaining integrity.

Face In KYC applications, face verification is used to ensure that individuals are who they claim to be during account registration or transaction processing. The integration of face verification with blockchain further enhances the system by providing a secure, transparent, and immutable record of each authentication, reducing fraud and increasing trust in the system.

In summary, the combination of blockchain, biometrics, and face verification in KYC processes enhances security, streamlines operations, and ensures that identity verification is both reliable and tamper-proof.

CHAPTER 3

SYSTEM REQUIREMENTS

3.1 Hardware Requirements

- Laptop: Intel Core i5, 8GB RAM, 256GB SSD, Webcam.
- Operating System: Windows 10/Linux.

3.2 Software Requirements

- Python 3.8+
- Libraries: tkinter, PIL, OpenCV, DeepFace, cryptography, hashlib, json.
- Tools: VS Code, Git for version control.
- Models: DNN Face Detector (Caffe model).

3.3 Functional Requirements

- Sample Aadhaar and PAN images (created manually for testing).
- Face images captured via webcam.
- Mock API data (valid_aadhar_numbers, linked_pan_numbers).

3.4 Non-Functional Requirements

- Response Time: The system should respond to biometric verification requests within a certain time frame (e.g., less than 2 seconds for facial recognition or fingerprint matching).
- Throughput: The system should be capable of handling multiple transactions concurrently without performance degradation (e.g., 1000 verification requests per minute).
- Scalability: The system must scale to accommodate increasing volumes of users and data as the user base and KYC requirements grow, without a significant performance drop.

CHAPTER 4

DESIGN

4.1 Problem Definition

Financial institutions face challenges with fraudulent identities, compliance costs, and inefficient verification. Centralized databases are vulnerable to cyberattacks and data breaches.There is a need for a secure, efficient, and user-friendly KYC system.

4.2 Overview of the Project

Project Overview: Blockchain Verified KYC System for Banks & FinTech Using Facial Recognition

This project focuses on developing a secure, blockchain-based Know Your Customer (KYC) system for banks and FinTech companies by integrating facial recognition and encryption technologies. The goal is to automate KYC processes, enhance security, and ensure transparency through immutable blockchain records. The system features two interfaces: a User GUI for KYC submission and an Admin GUI for document and face verification.

Users upload their Aadhaar card, PAN card, and facial images through a Tkinter-based interface. Files are encrypted using Fernet encryption before being stored, ensuring data confidentiality. Submitted information is added to a JSON-based blockchain, with each block containing encrypted documents, face images, and verification statuses.

The admin side decrypts the documents, verifies the user's identity using DeepFace (Facenet model) for face matching, and simulates verification with mock APIs for Aadhaar, PAN, and RBI checks. Successful verifications are recorded on the blockchain, creating an auditable trail resistant to tampering or fraud.

Key technical components include SHA-256 hashing, OpenCV DNN for face detection, and DeepFace for facial comparison. The project demonstrates a working prototype that provides fast, secure, and transparent KYC processing.

Expected results include improved security, reduced manual intervention, and enhanced regulatory compliance. Future enhancements involve real API integrations, shifting to distributed blockchain platforms like Ethereum, upgrading face detection with MTCNN, and developing a mobile submission app.

Ultimately, this project addresses the inefficiencies and vulnerabilities in traditional KYC methods by combining cutting-edge blockchain and biometric technologies to build a more secure, scalable, and user-friendly KYC solution for the financial sector.

4.3 System Architecture

The system architecture of the Blockchain Verified KYC System for Banks & FinTech integrates various components to ensure a secure, transparent, and efficient process. The frontend includes a User GUI built with Python's Tkinter, allowing users to submit their KYC data. The backend manages requests from the frontend, processes the data, and interfaces with the blockchain, facial recognition models, and databases.

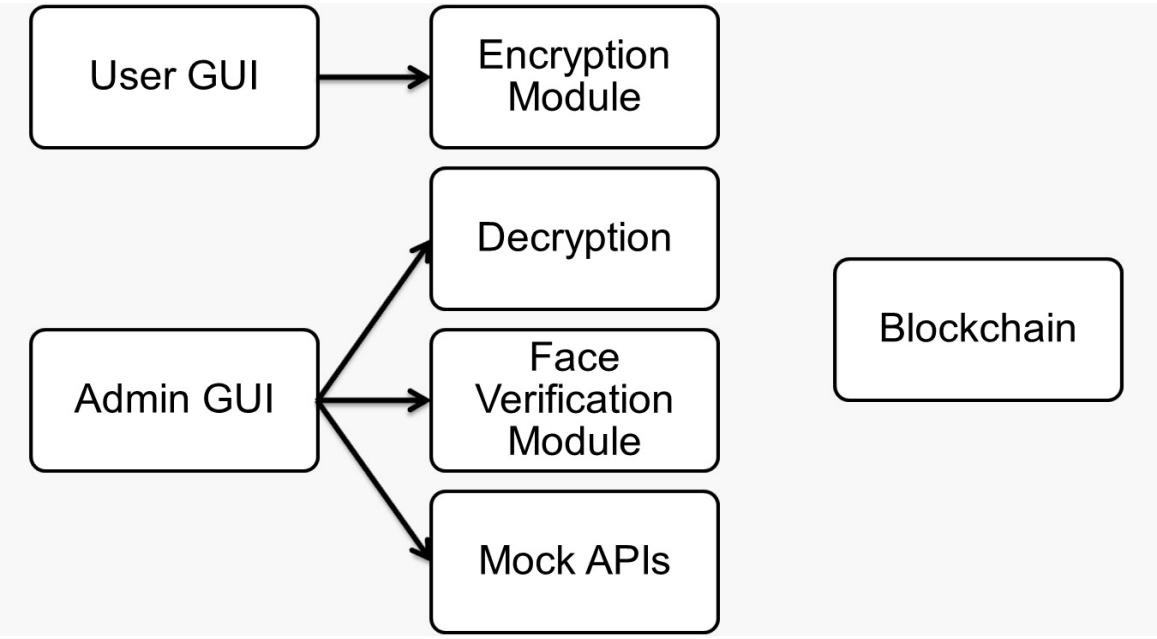

Fig 4.1: Architecture of the Blcokchain software

The system architecture of a project outlines the structure and interaction of its components. Here's a brief description:

1. Frontend (User Interface): A graphical interface (GUI) where users interact with the system for KYC submission, built with Python's Tkinter library.
2. Backend (Server): Manages requests from the frontend, processes data, and interfaces with the blockchain, facial recognition models, and databases.
3. Blockchain Layer: Immutable ledger that records KYC data and transactions, ensuring transparency and security.

4. Facial Recognition Module: DeepFace or OpenCV models process facial data to authenticate the user's identity.
5. KYC Data Storage: Encrypted database stores user-provided information, ensuring secure access and retrieval.
6. APIs: Mock APIs simulate communication between the system and external services, like banks and financial institutions.
7. Admin Interface: A GUI for administrators to verify, approve, or reject KYC submissions.
8. Security Layer: Uses cryptography for data encryption and secure communications between system components.
9. Authentication & Authorization: Ensures that only authorized users and admins can access sensitive features.

4.4 Module Description

The system includes several key modules to facilitate the KYC process. The User GUI, built using Tkinter, allows users to enter personal details and upload or capture images for identity verification. The Encryption Module utilizes Fernet encryption to secure user data, storing it in directories named by the user's original Aadhaar number (e.g., users/<aadhaar_number>). The Blockchain Module creates immutable blocks containing user data, verification statuses, and SHA-256 hashes, ensuring transparency and security. The Admin GUI, also Tkinter-based, allows administrators to load, decrypt, and verify KYC submissions. The Face Verification Module uses OpenCV's DNN to detect faces and DeepFace to compare them for identity matching. Additionally, Mock APIs simulate external validations for Aadhaar, PAN, and RBI, enhancing the system's capability to mimic real-world validation processes. Together, these modules work seamlessly to provide a secure and efficient KYC system.

4.4.1 Modue 1 :

The project features a User GUI interface developed using Tkinter, a popular Python library for building graphical user interfaces. The User GUI serves as the front end for customers to complete their KYC registration. Through this interface, users can enter personal details such as name, date of birth, Aadhaar number, and PAN number. Additionally, users can upload images of their Aadhaar and PAN cards or capture a live facial image using the

device's webcam. The images are then encrypted using Fernet encryption before being stored, ensuring data security and privacy from the very first interaction.

On the administrative side, an Admin GUI portal is also designed using Tkinter. Admins can load encrypted user submissions, decrypt the documents, and perform facial verification by comparing the uploaded Aadhaar face image with the live captured facial image using the DeepFace (Facenet model). Furthermore, the Admin GUI includes access to mock APIs to simulate the verification of Aadhaar and PAN numbers with external databases, updating the verification status for each user.

To represent blockchain functionality, the project uses a Python localhost file that simulates blockchain behavior. Each verified KYC submission is structured into a block containing the encrypted files, a unique hash (generated using SHA-256), timestamps, and the verification statuses. All the block data is stored securely in a JSON file, imitating a blockchain ledger where each block is linked and tamper-resistant. This local blockchain file ensures transparency and auditability for KYC processes.

The combined system creates an efficient and secure digital KYC platform that protects user data, ensures real-time face verification, and offers an immutable audit trail via a simple and effective Tkinter-based interface, supporting both users and admins in a seamless workflow.

4.4.2 Module 2:

Encryption Module: Secure Storage with Fernet Encryption

The Encryption Module plays a crucial role in securing sensitive user data, particularly Aadhaar, PAN, and captured face images, before they are stored and processed. Built using Fernet encryption from Python's cryptography library, this module ensures that all personal information is protected from unauthorized access or tampering.

When a user submits their KYC documents through the Tkinter-based User GUI, the module first generates an encryption key (saved securely in a secret.key file). Each file — Aadhaar image, PAN image, and live captured facial image — is then encrypted using this key. Fernet encryption applies symmetric encryption, meaning the same key is used for both encrypting and decrypting the files, ensuring a simple yet highly secure method for protecting user data.

The encrypted files are stored in a directory structure based on the user's Aadhaar number. For example, user files are saved under users/<aadhaar_number>/, maintaining a clean,

organized, and easily accessible format for the admin during the verification phase. File names are appended with a .enc extension, signifying their encrypted status (e.g., aadhar.jpeg.enc, pan.jpeg.enc, captured_face.jpg.enc).

In addition to securing static files, the Encryption Module also encrypts any captured images on-the-fly before saving them, ensuring that even temporary storage points do not hold unprotected user data. This step is critical for compliance with data protection regulations like GDPR and maintaining users' trust.

During the Admin verification phase, the same module is used to decrypt the files back into their original formats so that face verification, document validation, and blockchain updates can proceed securely.

Thus, the Encryption Module guarantees confidentiality, data integrity, and secure data lifecycle management, forming a backbone for the privacy and security standards maintained throughout the blockchain-based KYC system.

4.4.3 Module 3:

The Blockchain Module is a critical component of the KYC system, responsible for ensuring the integrity, transparency, and immutability of user verification data. In this project, blockchain functionality is simulated using Python and local JSON files, mimicking the structure and behavior of a real distributed ledger.

Every time a user submits their KYC documents and completes face verification, the system creates a new block containing essential details. Each block includes:

- User Data: Such as the Aadhaar number (ID), encrypted Aadhaar and PAN documents, and face image.
- Verification Statuses: Results from face matching and API checks (e.g., Aadhaar verified, PAN linked, RBI clearance).
- Timestamp: Marking the exact submission and verification time.
- SHA-256 Hash: A cryptographic hash of the block’s data, ensuring tamper-resistance and secure chaining.

The block is linked to the previous one using a hash pointer, creating a chain of blocks. This ensures that any attempt to modify past KYC records would require altering all subsequent blocks, which becomes computationally infeasible. The hashing mechanism is implemented using Python’s hashlib library and is central to guaranteeing data integrity.

The blockchain is stored as a JSON file (blockchain_data.json) on the local system. This file serves as a secure, readable, and auditable record of all KYC submissions and verifications, ideal for demonstration purposes and future extensions into real blockchain networks like Ethereum.

By integrating this Blockchain Module, the project ensures that KYC records are immutable, traceable, and verifiable, offering financial institutions and FinTech companies a much-needed layer of security and trust for digital identity management.

4.4.4 Module 4:

Admin GUI: Tkinter Interface for Loading, Decrypting, and Verifying KYC Data

The Admin GUI is a vital component of the system, providing an easy-to-use interface built using Tkinter for KYC data management and verification. Designed for administrators or authorized personnel, this interface enables the secure handling of user submissions, ensuring a smooth and systematic verification process.

Upon logging into the Admin GUI, the admin can load encrypted KYC data submitted by users. The files—Aadhaar card image, PAN card image, and captured facial image—are retrieved from their respective encrypted storage locations organized under the users/<aadhaar_number> directory.

The decryption module integrated within the Admin GUI uses Fernet encryption to decrypt the files securely. Only with the correct encryption key (secret.key) can the data be reverted to its original, readable form, ensuring data confidentiality even during processing.

Once decrypted, the Admin GUI facilitates facial verification. Using DeepFace and OpenCV DNN, the system compares the captured live face image with the Aadhaar card's face image to verify the authenticity of the user's identity. If the face match distance is below a predefined threshold (typically 0.4), the identity is considered verified.

Additionally, the Admin GUI connects to mock APIs that simulate external verifications of Aadhaar numbers, PAN card linking, and RBI compliance. Each verification outcome (approved or rejected) is displayed in the admin panel, and the corresponding statuses are updated.

Finally, after completing verification, the updated KYC record, along with verification results, is securely appended to the blockchain JSON file, maintaining an immutable history of actions.

This Admin GUI streamlines the entire KYC verification process, making it secure, efficient, and highly auditable, crucial for regulatory compliance in banking and FinTech sectors.

4.4.5 Module 5:

Face Verification Module: Detecting and Comparing Faces Using OpenCV DNN and DeepFace

The Face Verification Module is a critical component responsible for authenticating the identity of users by comparing facial images. It is implemented using a combination of OpenCV's Deep Neural Network (DNN) for face detection and DeepFace (specifically the Facenet model) for face recognition and comparison.

When a user submits their KYC documents, the system captures a live facial image and uploads it along with an image from the Aadhaar card. To begin verification, the OpenCV DNN face detector is first used to locate and extract faces from both the uploaded Aadhaar image and the captured live image. This ensures that only the facial regions are processed, improving the speed and accuracy of the matching.

After detecting the faces, the module uses DeepFace to perform face embedding and comparison. DeepFace converts each facial image into a numeric vector representation (embedding) that captures the unique features of the individual's face. It then calculates the Euclidean distance between the two embeddings. If the distance is below a predefined threshold (typically 0.4), the faces are considered a match, and the user's identity is verified successfully.

This method is highly robust and accurate, capable of handling variations in lighting, facial expressions, and minor pose changes. The face match result (Approved/Rejected) is passed back to the Admin GUI, updating the user's verification status.

By combining OpenCV DNN for efficient face detection and DeepFace for deep-learning-based face verification, this module ensures a high level of accuracy, security, and user trust in the KYC process. It reduces manual errors, speeds up verification, and enables seamless integration into the blockchain-based KYC system.

4.4.6 Module 6:

Mock APIs: Simulating External Validations for Aadhaar, PAN, and RBI

The Mock APIs Module plays a key role in simulating real-world external validation processes for user KYC information, specifically for verifying Aadhaar numbers, PAN card linkage, and RBI compliance. Before a user's KYC data is permanently stored in the blockchain, it must pass through a series of verifications to ensure its authenticity and accuracy.

Since connecting to actual government databases and financial regulatory bodies is complex and often restricted, this project implements Mock APIs to mimic the behavior of real verification systems. These APIs are designed to simulate responses based on predefined conditions. For example, if an Aadhaar number exists in a dummy dataset of valid numbers, the Mock API will return a "Verified" status; otherwise, it will return "Rejected."

Similarly, PAN card validation checks if the provided PAN number is correctly linked with the Aadhaar number, and RBI verification ensures there are no outstanding financial restrictions or regulatory blocks associated with the user.

By running these mock checks, the system ensures that:

- Only users with correct and matching identity details are allowed to pass KYC.
- Fraudulent or incorrect submissions are caught early before being committed to the blockchain.
- A full verification trail is created that can be audited if necessary.

This use of Mock APIs simulates what will eventually be a real-time verification process with government databases and regulatory authorities. It prepares the system architecture for future upgrades to live APIs, without altering the core verification and blockchain recording mechanisms.

Overall, the Mock APIs module ensures data accuracy, enhances trust, and prevents invalid entries from being immutably recorded in the blockchain, maintaining the integrity of the entire KYC system.

4.5 Data Flow Diagram

This flowchart represents the KYC (Know Your Customer) verification process in a blockchain-based system using AES encryption and a mock API for validation. The process begins when a user submits their registration data. This data is encrypted using the AES (Advanced Encryption Standard) algorithm to ensure confidentiality and is stored with a status marked as “Pending.”

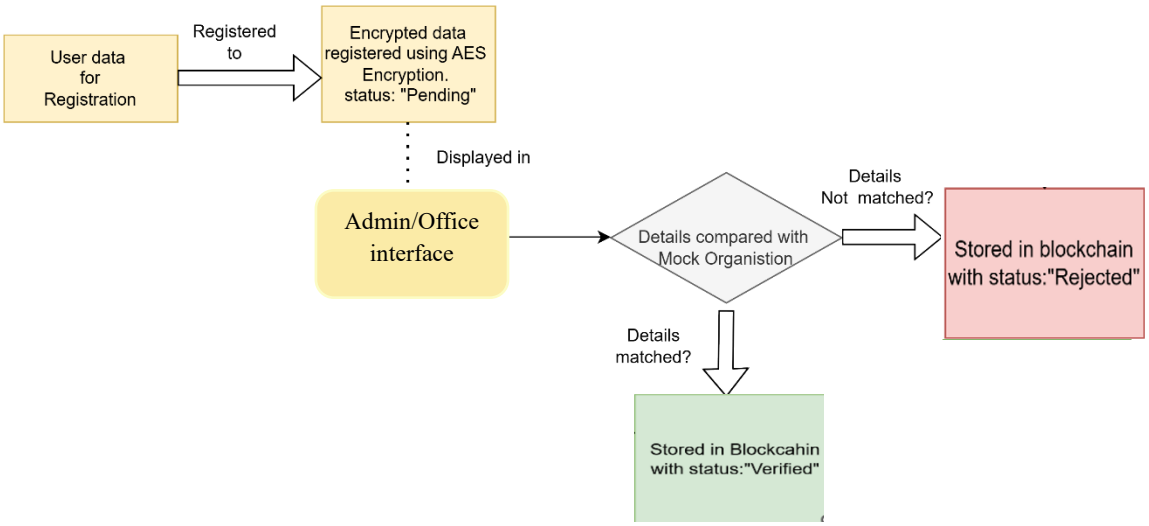

Fig 4.2: Data Flow Diagram

Next, the encrypted data is passed through a mock admin API that simulates the behavior of a real-world KYC verification authority. The API facilitates comparison of the submitted data against records held by a mock organization, representing a trusted authority such as a government database or a financial institution.

At this decision point, the system checks whether the user-provided data matches the records in the mock organization. If the data is successfully matched, it signifies that the user's identity is authenticated. Consequently, the encrypted KYC data is permanently recorded on the blockchain with a status of “Verified.” Blockchain integration ensures immutability and transparency, making the verified record tamper-proof and accessible for future reference.If the data fails to match, the system considers the verification unsuccessful. In this case, the encrypted data is still stored on the blockchain but is labeled with a status of “Rejected.” This approach maintains a transparent audit trail, even for failed verifications, which is crucial for compliance and fraud detection.

4.6 Use Case Diagram

A use case diagram is crucial in a report as it provides a clear, visual representation of how users (actors) interact with the system, offering an accessible way to understand system functionality without technical jargon. It helps define the system boundaries by illustrating what is included and what is external, while also identifying different user roles and their responsibilities. The diagram organizes system features and user tasks, ensuring all necessary functionalities are captured. It also aids in requirements traceability, allowing developers and stakeholders to ensure all use cases are addressed during development and testing. Furthermore, it serves as a common reference for team communication, ensuring alignment between all parties involved. Overall, a use case diagram helps in both system design and development, offering clarity and guiding the project forward.

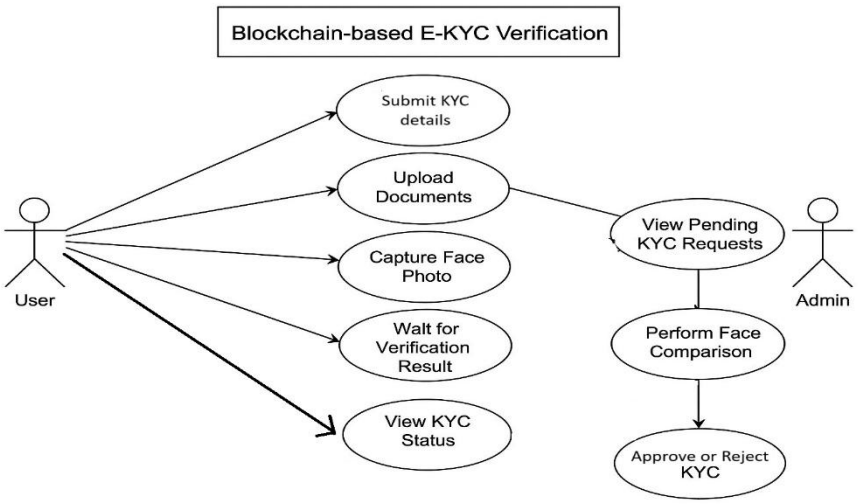

Fig 4.3: Use Case Diagram

4.6.1 Actors:

1. User – The individual who submits their KYC data.
2. Admin – The administrator responsible for verifying and approving KYC data.
3. External Systems – Mock APIs simulating Aadhaar, PAN, and RBI validation.

4.6.2 Use Cases:

- User:
    - Enter Personal Details: User enters personal data like name, address, etc.
    - Capture/Upload Images: User either uploads an image or captures a live image for facial verification.

- Submit KYC: User submits the KYC form, which includes encrypted data and images.

- Admin:
  - Load KYC Data: Admin loads KYC submissions from users.
  - Verify KYC: Admin verifies the submitted data against system records and validation results.
  - Approve/Reject KYC: Software either approves or rejects the KYC submission based on the verification.
- External Systems:
  - Validate Aadhaar: Mock API validates the user's Aadhaar data.
  - Validate PAN: Mock API validates the user's PAN details.
  - Validate RBI: Mock API checks the user's status against RBI records.

4.7 Sequence Diagram

The process starts when a user submits their personal data for registration. This data is encrypted using AES (Advanced Encryption Standard) encryption and transmitted securely over SSL to ensure confidentiality and integrity during transmission.

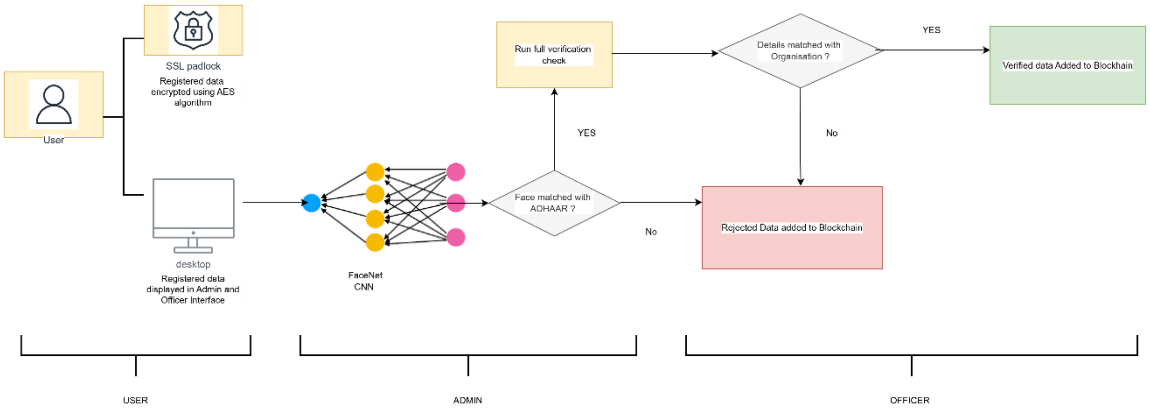

Fig 4.4 : Sequence Diagram

Once the data is registered, it is displayed within a mock API interface on the admin's desktop for processing. The admin initiates a full verification check, which includes two key validation steps: data comparison with the organization's existing records and facial recognition. The facial data submitted by the user is analyzed using the FaceNet Convolutional Neural Network (CNN), a deep learning model designed for accurate face verification. This facial data is compared against the image stored in the Aadhaar database (used here as a representative example of a trusted identity database).

If the face matches and the user data aligns with the organization's records, the data is deemed verified. This verified record is then added to the blockchain, ensuring immutable and secure storage. However, if either the data does not match the organization's records or the facial recognition check fails, the system classifies the registration as "Rejected," and the corresponding data is still stored on the blockchain but flagged accordingly.

This enhanced process not only secures user identity but also brings in a multi-factor verification system, combining cryptographic encryption, biometric analysis, and blockchain technology to ensure data security, authenticity, and traceability.

In addition to providing a robust verification mechanism, this flow integrates key security and compliance elements that are essential in financial and governmental systems. The use of AES encryption ensures that all personal data remains confidential during transmission and storage, significantly reducing the risk of data breaches or leaks. By securing communication over SSL, the system further guarantees that man-in-the-middle attacks are mitigated, ensuring a secure channel for user data submission.

The inclusion of FaceNet CNN adds a biometric layer to the verification process. FaceNet maps a user's facial features into a high-dimensional embedding and compares it to the facial data stored in a government database such as Aadhaar. This adds an essential layer of identity assurance that goes beyond traditional document-based verification, reducing impersonation risks.

The dual-verification logic—checking both organizational data and biometric match—ensures a highly accurate and tamper-resistant identity validation workflow. Regardless of the verification outcome (verified or rejected), the results are immutably recorded on a blockchain ledger. This not only provides transparency and auditability but also supports regulatory compliance by maintaining a verifiable trail of all KYC attempts.

Moreover, storing even rejected data helps in detecting and analyzing fraudulent activities over time. This comprehensive approach reinforces both operational efficiency and user trust in the identity verification process.

CHAPTER 5

SYSTEM IMPLEMENTATION

5.1 Introduction

The execution of the project begins with the opening of the User GUI, where users initiate the registration process by providing their personal details, such as name, date of birth, Aadhaar number, and PAN number. Users are also required to upload images of their Aadhaar and PAN cards. Additionally, the system is designed to capture a live facial image using the device's webcam, triggered specifically when the user smiles, ensuring the liveness of the person and preventing the use of static images or spoofing attacks.After successfully entering details and capturing images, users submit their KYC data for verification. The files are encrypted using Fernet encryption to maintain data confidentiality and stored in a user-specific directory. All submissions are recorded into a local blockchain file, ensuring that the data remains immutable and tamper-evident.The Admin Portal is then used to load the KYC submissions. Admins can decrypt the encrypted data, verify the authenticity of the facial images using the DeepFace facial recognition model, and validate user credentials through Mock APIs that simulate government databases like Aadhaar, PAN, and RBI. These checks ensure that only valid and verified user data is approved and permanently recorded on the blockchain.A unique security feature of the system is its ability to detect and visually indicate data tampering. If any unauthorized modification (such as a Man-in-the-Middle attack) occurs on user data, the Admin GUI will highlight safe blocks in green and tampered blocks in red. This instant visual feedback enhances trust, transparency, and auditability of the KYC process.

5.2 Code

5.2.1 User Interface

```
import tkinter as tk
from tkinter import filedialog, messagebox
import cv2
import os
import time
from blockchain import add_block, is_duplicate_kyc
from encryption import encrypt_file, cipher

# Ensure the 'users/' directory exists
if not os.path.exists("users"):
    os.makedirs("users")

class KYCApp:
    def __init__(self, root):
        self.root = root
        self.root.title("🔐 E-KYC Registration Portal")
        self.root.geometry("420x450")
        self.root.configure(bg="#f5f5f5")

        title = tk.Label(root, text="E-KYC Registration", font=("Helvetica", 18, "bold"), bg="#f5f5f5",
fg="#333")
        title.pack(pady=10)

        form_frame = tk.Frame(root, bg="#f5f5f5")
        form_frame.pack()

        labels = ["Aadhaar Number:", "PAN Number:", "Name:", "DOB (YYYY-MM-DD):", "Address:"]
        self.entries = {}

        for i, label_text in enumerate(labels):
            label = tk.Label(form_frame, text=label_text, bg="#f5f5f5", font=("Helvetica", 10, "bold"))
            label.grid(row=i, column=0, sticky="e", padx=10, pady=5)
            entry = tk.Entry(form_frame, width=30)
            entry.grid(row=i, column=1, pady=5)
```

```
            self.entries[label_text] = entry

        self.aadhar_path = None
        self.pan_path = None
        self.captured_face = None

        tk.Button(root, text="📎 Upload Aadhaar", command=self.upload_aadhar,
                  bg="#007acc", fg="white", font=("Helvetica", 10, "bold")).pack(pady=5)

        tk.Button(root, text="📎 Upload PAN", command=self.upload_pan,
                  bg="#007acc", fg="white", font=("Helvetica", 10, "bold")).pack(pady=5)

        tk.Button(root, text="📷 Capture Face", command=self.capture_face,
                  bg="#4CAF50", fg="white", font=("Helvetica", 10, "bold")).pack(pady=5)

        self.submit_button = tk.Button(root, text="🚀 Submit KYC", command=self.submit_kyc,
                                       state=tk.DISABLED, bg="#333", fg="white", font=("Helvetica", 10, "bold"))
        self.submit_button.pack(pady=15)

    def upload_aadhar(self):
        file_path = filedialog.askopenfilename(title="Select Aadhaar Image", filetypes=[("Image Files",
"*.jpg;*.png;*.jpeg")])
        if file_path:
            self.aadhar_path = file_path
            messagebox.showinfo("Success", "✅ Aadhaar uploaded.")

    def upload_pan(self):
        file_path = filedialog.askopenfilename(title="Select PAN Image", filetypes=[("Image Files",
"*.jpg;*.png;*.jpeg")])
        if file_path:
            self.pan_path = file_path
            messagebox.showinfo("Success", "✅ PAN uploaded.")

    def capture_face(self):
        face_cascade = cv2.CascadeClassifier("cascades/haarcascade_frontalface_default.xml")
        smile_cascade = cv2.CascadeClassifier("cascades/haarcascade_smile.xml")

        cap = cv2.VideoCapture(0)
```

```
    start = time.time()
    smile_start_time = None
    captured = False

    while True:
        ret, frame = cap.read()
        if not ret:
            break

        gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
        elapsed = time.time() - start

        if elapsed < 3:
            cv2.putText(frame, f"Get Ready: {3 - int(elapsed)}", (10, 30),
cv2.FONT_HERSHEY_SIMPLEX, 1.2, (0, 0, 255), 3)
            cv2.imshow("Capture Face", frame)
            if cv2.waitKey(1) & 0xFF == 27:
                break
            continue

        faces = face_cascade.detectMultiScale(gray, 1.3, 5)

        for (x, y, w, h) in faces:
            roi_gray = gray[y:y + h, x:x + w]
            roi_color = frame[y:y + h, x:x + w]
            smiles = smile_cascade.detectMultiScale(roi_gray, scaleFactor=2.0, minNeighbors=20)

            cv2.rectangle(frame, (x, y), (x + w, y + h), (0, 255, 0), 2)

            for (sx, sy, sw, sh) in smiles:
                smile_ratio = sw / w
                if smile_ratio > 0.3:
                    if smile_start_time is None:
                        smile_start_time = time.time()
                    elif time.time() - smile_start_time > 0.8 and not captured:
                        face_img = frame[y:y + h, x:x + w]
                        face_file = f"users/{int(time.time())}_captured_face.jpg"
                        cv2.imwrite(face_file, face_img)
```

```
                    self.captured_face = face_file
                    self.submit_button.config(state=tk.NORMAL)
                    messagebox.showinfo("Success", "😀 Smile detected! Face captured.")
                    captured = True
                    break
                else:
                    smile_start_time = None

            if captured:
                break

        cv2.imshow("Capture Face", frame)
        if captured or cv2.waitKey(1) & 0xFF == 27:
            break
cap.release()
    cv2.destroyAllWindows()

  def submit_kyc(self):
      user_id = int(time.time())

      aadhar = self.entries["Aadhaar Number:"].get().strip()
      pan = self.entries["PAN Number:"].get().strip()
      name = self.entries["Name:"].get().strip()
      dob = self.entries["DOB (YYYY-MM-DD):"].get().strip()
      address = self.entries["Address:"].get().strip()

      if not all([aadhar, pan, name, dob, address, self.aadhar_path, self.pan_path, self.captured_face]):
          messagebox.showerror("Error", "All fields and documents are required!")
          return
   if is_duplicate_kyc(aadhar):
          messagebox.showwarning("Duplicate", f"KYC already exists for Aadhaar: {aadhar}")
          return

      try:
          enc_aadhar_file = encrypt_file(self.aadhar_path, aadhar)
          enc_pan_file = encrypt_file(self.pan_path, aadhar)
          enc_face = encrypt_file(self.captured_face, aadhar)
```

```
        enc_data = {
            "aadhar_number": cipher.encrypt(aadhar.encode()).decode(),
            "pan_number": cipher.encrypt(pan.encode()).decode(),
            "name": cipher.encrypt(name.encode()).decode(),
            "date_of_birth": cipher.encrypt(dob.encode()).decode(),
            "address": cipher.encrypt(address.encode()).decode(),
        }

        statuses = {
            "bank_verification_status": "Pending ⏳",
            "aadhar_verification_status": "Pending ⏳",
            "pan_verification_status": "Pending ⏳",
            "rbi_verification_status": "Pending ⏳",
        }
    add_block(
            user_id=user_id,
            aadhar_number=enc_data["aadhar_number"],
            user_details=enc_data,
            captured_face_path=enc_face,
            verification_statuses=statuses,
            documents={"aadhar_doc": enc_aadhar_file, "pan_doc": enc_pan_file}
        )

        messagebox.showinfo("✅ Success", "KYC submitted and encrypted to blockchain!")
            self.root.destroy()
    except Exception as e:
            messagebox.showerror("Error", f"Submission failed: {e}")


if __name__ == "__main__":
    root = tk.Tk()
    app = KYCApp(root)
    root.mainloop()
```

5.2.2 Face Verification

```
import cv2
import numpy as np
from deepface import DeepFace


proto_path = "models/deploy.prototxt"
model_path = "models/res10_300x300_ssd_iter_140000.caffemodel"
net = cv2.dnn.readNetFromCaffe(proto_path, model_path)
def detect_face(image):
    """ Detect face using OpenCV DNN and return cropped face. """
    h, w = image.shape[:2]
    blob = cv2.dnn.blobFromImage(image, 1.0, (300, 300), (104, 177, 123), swapRB=False, crop=False)
    net.setInput(blob)
    detections = net.forward()


    max_confidence, best_face = 0, None
    for i in range(detections.shape[2]):
        confidence = detections[0, 0, i, 2]
        if confidence > max_confidence:
            max_confidence = confidence
            box = detections[0, 0, i, 3:7] * np.array([w, h, w, h])
            (startX, startY, endX, endY) = box.astype("int")
            best_face = image[startY:endY, startX:endX]
   return best_face if best_face is not None else None
def compare_faces(captured_face_path, document_face_path):
    """ Compare captured and document faces using DeepFace (Facenet). """
    try:
        result = DeepFace.verify(img1_path=captured_face_path, img2_path=document_face_path,
model_name="Facenet")
        return result["distance"] < 0.4
    except Exception as e:
        print("Face comparison error:", e)
        return False
```

5.2.3 Encryption:

```
import os
from cryptography.fernet import Fernet

KEY_FILE = "secret.key"
USER_FOLDER = "users"  # Main directory to store user data

# Ensure users folder exists
if not os.path.exists(USER_FOLDER):
    os.makedirs(USER_FOLDER)

def generate_key():
    """Generate and save an encryption key if not already generated."""
    if not os.path.exists(KEY_FILE):
        key = Fernet.generate_key()
        with open(KEY_FILE, "wb") as key_file:
            key_file.write(key)

def load_key():
    """Load the encryption key from file."""
    generate_key()  # Ensure key exists before loading
    with open(KEY_FILE, "rb") as key_file:
        return key_file.read().strip()

# Load the encryption key properly
KEY = load_key()
cipher = Fernet(KEY)

def encrypt_file(file_path, aadhar_number):
    """Encrypts a file and stores it in a folder named after the Aadhaar number."""
    if not os.path.exists(file_path):
        raise FileNotFoundError(f"File not found: {file_path}")

    # Create a user-specific folder inside "users/"
    user_folder = os.path.join(USER_FOLDER, aadhar_number)
    if not os.path.exists(user_folder):
        os.makedirs(user_folder)
```

```
    with open(file_path, "rb") as file:
        encrypted_data = cipher.encrypt(file.read())

    # Generate new encrypted file path inside user's folder
    filename = os.path.basename(file_path) + ".enc"
    encrypted_path = os.path.join(user_folder, filename)

    with open(encrypted_path, "wb") as file:
        file.write(encrypted_data)

    print(f"[INFO] Encryption successful: {encrypted_path}")
    return encrypted_path  # Return new encrypted file path

def decrypt_file(encrypted_file_path):
    """Decrypts an encrypted file and saves the original content."""
    if not os.path.exists(encrypted_file_path):
        print(f"[ERROR] Encrypted file '{encrypted_file_path}' not found!")
        return None

    try:
        with open(encrypted_file_path, "rb") as file:
            encrypted_data = file.read()

        decrypted_data = cipher.decrypt(encrypted_data)

        # Ensure the correct file extension is used
        decrypted_file_path = encrypted_file_path.replace(".enc", "")

        with open(decrypted_file_path, "wb") as file:
            file.write(decrypted_data)

        print(f"[INFO] Decryption successful: {decrypted_file_path}")
        return decrypted_file_path  # Return the correct path

    except Exception as e:
        print(f"[ERROR] Decryption failed: {e}")
        return None
```

```
def decrypt_text(encrypted_string):
    """Decrypts an encrypted string (e.g., user detail field)."""
    if not isinstance(encrypted_string, str):
        raise ValueError("Encrypted token must be a string.")

    try:
        decrypted = cipher.decrypt(encrypted_string.encode()).decode()
        return decrypted
    except Exception as e:
        print(f"[ERROR] Decryption error: {e}")
        return ""
```

5.2.4 Admin_Interface

```
import tkinter as tk
from tkinter import messagebox
from blockchain import verify_blockchain_integrity

class CheckIntegrityApp:
    def __init__(self, root):
        self.root = root
        self.root.title("Blockchain Admin Panel")
        self.root.geometry("400x200")

        # Title label
        title_label = tk.Label(root, text="Blockchain Integrity Checker", font=("Arial", 16, "bold"))
        title_label.pack(pady=20)

        # Verify Blockchain Button
        check_button = tk.Button(root, text="Verify Blockchain Integrity", command=self.check_integrity,
bg="green", fg="white", font=("Arial", 12))
        check_button.pack(pady=10)

    def check_integrity(self):
        result = verify_blockchain_integrity()
        if result.startswith("[SUCCESS]"):
```

```
            messagebox.showinfo("Blockchain Integrity", result)
        else:
            messagebox.showerror("Blockchain Tampering Detected", result)

if __name__ == "__main__":
    root = tk.Tk()
    app = CheckIntegrityApp(root)
    root.mainloop()
```

5.2.5 Blockchain

```
import json
import hashlib
import time
import os

BLOCKCHAIN_FILE = "blockchain_data.json"

def is_duplicate_kyc(aadhar_number):
    if not os.path.exists(BLOCKCHAIN_FILE):
        return False

    with open(BLOCKCHAIN_FILE, "r") as f:
        chain = json.load(f)

    for block in chain:
        if block["header"]["aadhar_number"] == aadhar_number:
            return True
    return False

def calculate_hash(block):
    """Calculate SHA-256 hash of a block."""
    temp_block = dict(block)
    temp_block["hash"] = ""
    block_string = json.dumps(temp_block, sort_keys=True).encode()
    return hashlib.sha256(block_string).hexdigest()

def load_blockchain():
```

```
    """Load blockchain from file or create a new one."""
    try:
        with open(BLOCKCHAIN_FILE, "r") as file:
            return json.load(file)
    except FileNotFoundError:
        return []


def save_blockchain(blockchain):
    """Save blockchain to file."""
    with open(BLOCKCHAIN_FILE, "w") as file:
        json.dump(blockchain, file, indent=4)


def update_status_on_rejection(verification_statuses):
    """If any verification is rejected, mark all pending as rejected."""
    if "Rejected ❌" in verification_statuses.values():
        for key in verification_statuses:
            if verification_statuses[key] == "Pending ⏳":
                verification_statuses[key] = "Rejected ❌"
    return verification_statuses


def add_block(user_id, aadhar_number, captured_face_path, verification_statuses, documents,
user_details):
    """
    Add a new verification block to the blockchain.

    user_details: dict with keys - name, pan_number, date_of_birth, address
    """
    blockchain = load_blockchain()
    prev_hash = blockchain[-1]["hash"] if blockchain else "0"
    timestamp = int(time.time())

    verification_statuses = update_status_on_rejection(verification_statuses)

    new_block = {
        "header": {
            "user_id": user_id,
            "aadhar_number": aadhar_number,
            "captured_face_path": captured_face_path,
```

```
            "aadhar_doc": documents.get("aadhar_doc"),
            "pan_doc": documents.get("pan_doc"),
            "name": user_details.get("name"),
            "pan_number": user_details.get("pan_number"),
            "date_of_birth": user_details.get("date_of_birth"),
            "address": user_details.get("address"),
            "timestamp": timestamp,
            "prev_hash": prev_hash
        },
        "bank_verification_status": verification_statuses["bank_verification_status"],
        "aadhar_verification_status": verification_statuses["aadhar_verification_status"],
        "pan_verification_status": verification_statuses["pan_verification_status"],
        "rbi_verification_status": verification_statuses["rbi_verification_status"],
        "hash": ""
    }

    new_block["hash"] = calculate_hash(new_block)
    blockchain.append(new_block)
    save_blockchain(blockchain)
    return new_block

def verify_blockchain_integrity():
    blockchain = load_blockchain()

    for i in range(len(blockchain)):
        current_block = blockchain[i]
        original_hash = current_block["hash"]

        block_copy = current_block.copy()
        block_copy["hash"] = ""

        recalculated_hash = calculate_hash(block_copy)

        if original_hash != recalculated_hash:
            changed_fields = []

            def compare_dicts(dict1, dict2, path=""):
                for key in dict1:
```

```
                full_path = f"{path}.{key}" if path else key
                if key not in dict2:
                    changed_fields.append(f"{full_path} removed")
                elif isinstance(dict1[key], dict) and isinstance(dict2[key], dict):
                    compare_dicts(dict1[key], dict2[key], full_path)
                elif dict1[key] != dict2[key]:
                    changed_fields.append(f"{full_path} was changed")

        compare_dicts(block_copy, current_block)

        user_id = current_block["header"].get("user_id", "Unknown")
        aadhar = current_block["header"].get("aadhar_number", "Unknown")

        return f""" ⚠️ Blockchain Tampering Detected!
User ID: {user_id}
Aadhaar Number: {aadhar}
Tampered Fields:
- """ + "\n- ".join(changed_fields)

    if i > 0 and current_block["header"]["prev_hash"] != blockchain[i - 1]["hash"]:
        prev_user_id = blockchain[i - 1]["header"].get("user_id", "Unknown")
        curr_user_id = current_block["header"].get("user_id", "Unknown")
        return f""" 🔗 Broken Chain Link Detected!
Between User ID {prev_user_id} and {curr_user_id}
Block #{i-1} and #{i}
"""

    return "[SUCCESS] Blockchain integrity verified. No tampering detected."
```

5.3 Screenshots This enhanced KYC (Know Your Customer)

verification process depicted in the flowchart integrates cryptographic encryption, facial recognition using deep learning, and blockchain technology to establish a secure, transparent, and tamper-proof identity verification framework. The process begins when a user submits their registration details, which are then encrypted using the AES (Advanced Encryption Standard) algorithm. AES encryption ensures that sensitive personal information is safeguarded from unauthorized access or manipulation, forming a foundational layer of security. The data is transmitted over SSL (Secure Sockets Layer), protecting it from interception or tampering during transit.

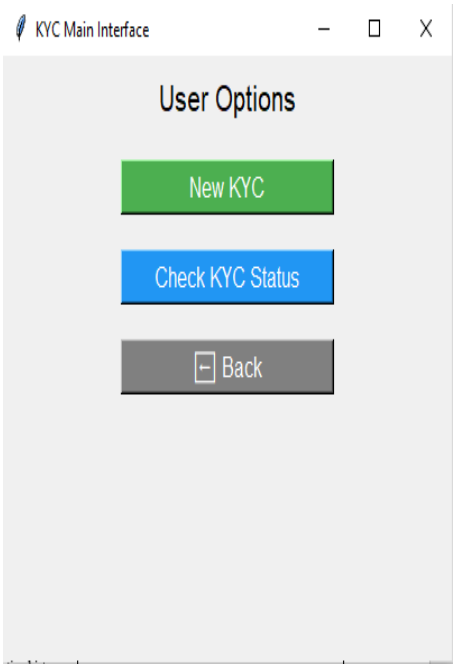

Figure 5.1 User interface with options to create new KYC request and check existing KYC

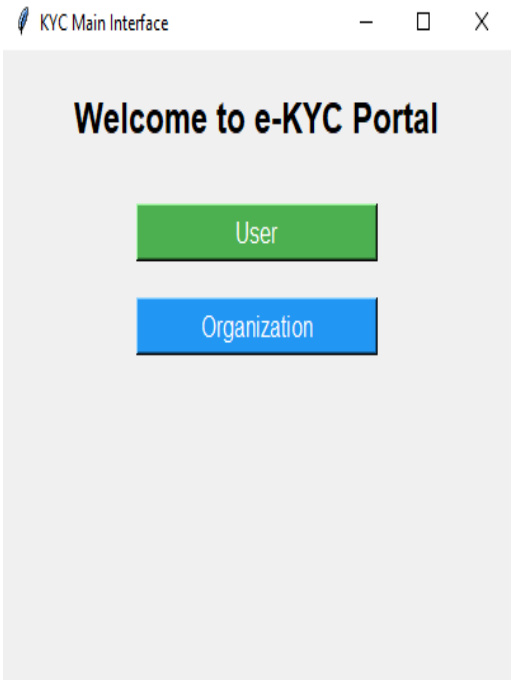

Figure 5. 2 Main interface with user and organization options

Once the user data is encrypted and securely transmitted, it is displayed on the admin panel through a mock API for review. The admin initiates a comprehensive verification procedure that includes two critical checks: data comparison with the organization's trusted records (such as banking or governmental databases), and facial recognition validation. Facial data provided by the user is processed using the FaceNet Convolutional Neural Network (CNN), a highly accurate deep learning model known for generating precise face embeddings. This embedding is then compared with the biometric image stored in a reliable identity database, exemplified here by Aadhaar.

The verification logic proceeds through two decision branches. If the facial features match and the user's data is successfully validated against the organization's records, the KYC is marked as successful. The verified data is then immutably stored in the blockchain with a

status indicating verification. This use of blockchain ensures data immutability, traceability, and auditability. Blockchain acts as a decentralized and tamper-resistant ledger that provides transparency and strengthens the reliability of identity records.

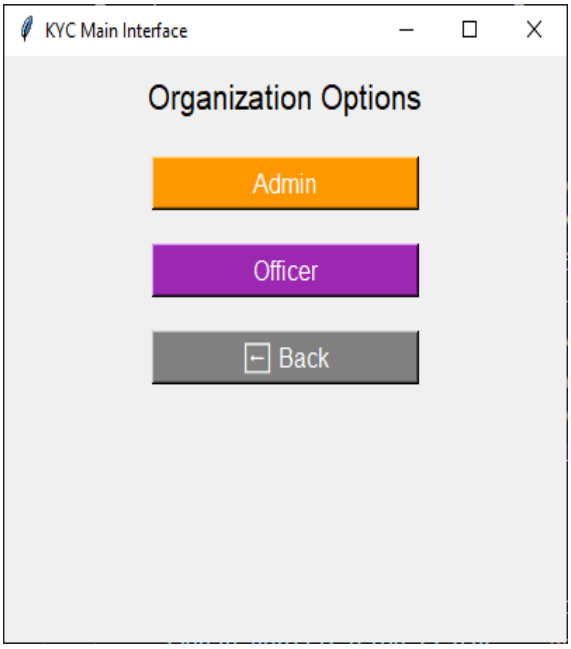

Figure 5.3: Interface for organization officials with admin an officer option

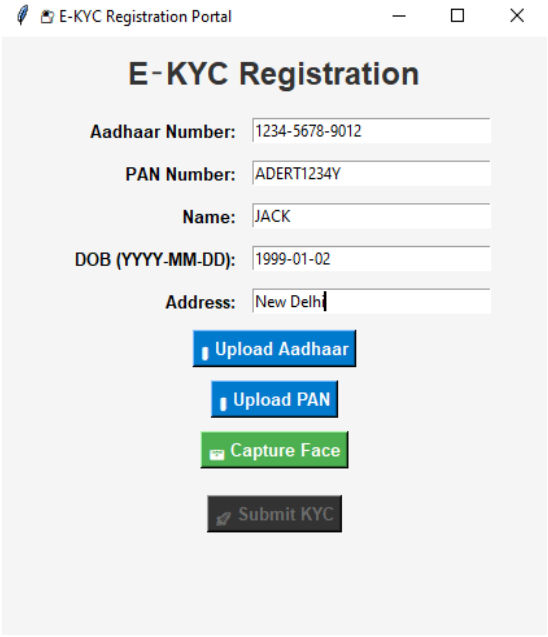

Figure 5.4: User interface to enter details for creation of KYC request

Conversely, if either the data fails to match the organizational records or the face does not match the Aadhaar image, the KYC attempt is marked as failed. However, even this rejected data is stored on the blockchain with a "Rejected" status. This practice is crucial for maintaining an audit trail and identifying patterns of potential fraud or repeated failed attempts. In essence, the system leverages multiple layers of security and verification—

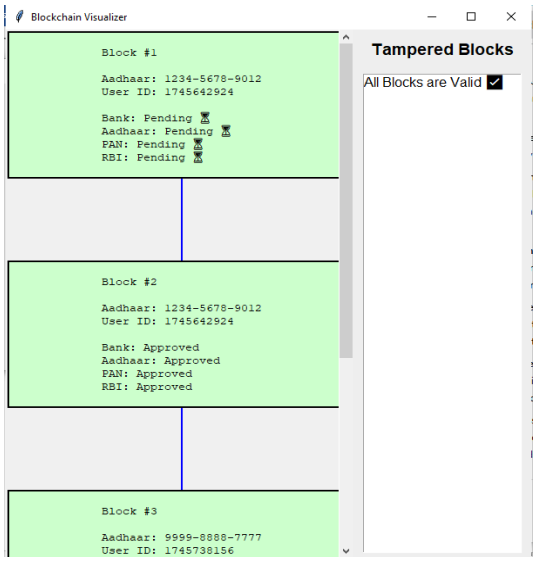

Figure 5.5: Office Interface view

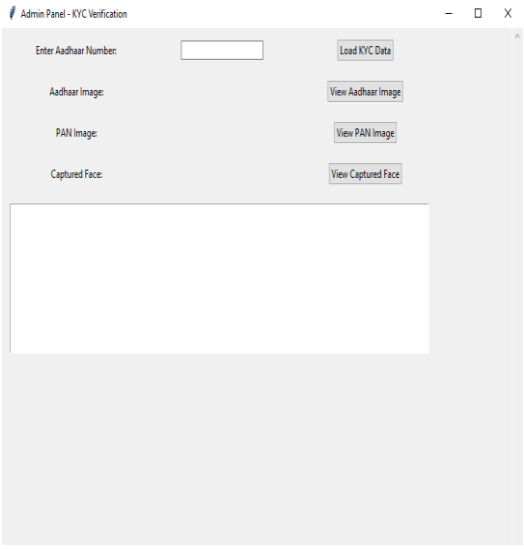

Figure 5.6: Verification of blockchain integrity by the admin

encryption, facial recognition, centralized data comparison, and decentralized blockchain storage—to offer a holistic and highly secure KYC process. It enhances operational efficiency, ensures regulatory compliance, and builds user trust by securing identity data and maintaining transparent verification outcomes.

To detect the facial features accurately, FaceNet CNN is implemented. It is a deep learning model developed by Google that revolutionizes facial recognition and verification through its ability to generate high-accuracy facial embeddings. Unlike traditional facial recognition systems that rely on explicit feature detection, FaceNet maps an individual's face into a compact 128-dimensional embedding space using a Convolutional Neural Network (CNN). This embedding captures the essential facial features in a way that similar faces are positioned closely together in the vector space, while dissimilar ones are far apart. The model is trained using a technique called *triplet loss*, where three images—an anchor, a positive (same identity), and a negative (different identity)—are used to teach the network how to differentiate between individuals effectively. One of FaceNet's major advantages is that it doesn't require a complex classifier after embedding generation; verification simply involves measuring the Euclidean distance between two facial vectors. If the distance falls below a certain threshold, the faces are considered a match. This makes FaceNet highly efficient and scalable for real-world applications like KYC systems, security surveillance, and biometric authentication. Its robustness to variations in pose, lighting, and expression further strengthens its reliability, making it a preferred choice for systems requiring precise facial identification and verification.

CHAPTER 6

SYSTEM TESTING

6.1 TESTS CONDUCTED

1. UC – Use Case

A Use Case defines how a user interacts with a system to accomplish a specific goal. It describes a series of actions or event steps that define the interactions between a user and the system.Use cases help testers understand system behavior under different user scenarios.They are used to derive test cases during the requirement analysis phase. UCs are crucial for ensuring functional coverage during system testing.

2. AO – Application Object / Automation Object

An Application Object refers to identifiable elements in the application UI (like buttons, forms, etc.).In automation testing, these are interacted with through scripts or automation tools.Each AO represents a component that needs validation (e.g., a "Submit" button). AO abstraction helps in modularizing automation scripts and improving reusability. It is essential for object-oriented test design and UI automation frameworks like Selenium or UFT.

3. BC – Boundary Condition / Business Component

Boundary Conditions test the edge cases of input ranges (e.g., min, max, just outside limits). They help identify potential off-by-one errors and input validation flaws. Business Components are modular units of business logic, often reused across tests. In keyword-driven frameworks, BCs simplify test script maintenance by separating logic from test data.Testing both meanings of BC ensures robust functionality and compliance with business rules.

4. KS – Known Solution / Keyword Script

A Known Solution is a documented fix or workaround for a known bug or issue. It helps testers recognize recurring problems and apply immediate resolutions during retesting.KS also refers to Keyword Scripts in keyword-driven testing, where test steps are

written using predefined keywords.This approach simplifies test automation and allows non-programmers to write test cases.KS ensures standardized and readable test scripts across teams.

5. EH – Error Handling

Error Handling ensures that the application responds gracefully to invalid or unexpected input.It includes mechanisms like try-catch blocks, user-friendly error messages, and fallback logic. EH is vital for system robustness, stability, and user trust. In testing, EH scenarios include simulating failures like network drop or file not found. Well-tested EH improves fault tolerance and meets security and compliance standards.

6.2 TEST CASES

Category	Test Case ID	Test Description	Steps
User KYC Submission	UC-01	Submit valid KYC request	Fill form with valid details, upload documents, submit
User KYC Submission	UC-02	Submit KYC with missing document	Leave PAN/Aadhaar missing, then submit
User KYC Submission	UC-03	Upload invalid document type	Upload `.txt` or unsupported format
User KYC Submission	UC-04	Retry submission after fixing errors	Correct missing fields and submit again
User KYC Submission	UC-05	Upload large file (>10MB)	Try uploading huge file
Admin Officer Panel	AO-01	View pending KYCs	Open Office panel
Admin Officer Panel	AO-02	Compare face: matching faces	Click on "compare" button and Compare Aadhaar and captured face (Face matching)
Admin Officer Panel	AO-03	Compare face: non-matching faces	Click on "compare" button and Compare Aadhaar and captured face (Face not matching)
Admin Officer Panel	AO-04	Approve KYC after match	Click on "Run full verification" button and update the status
Admin Officer Panel	AO-05	Reject KYC after failed match	Click on "Run full verification" button and update the status
Admin Officer Panel	AO-06	Attempt Approve without face comparison	Try approving before face verification
Blockchain Functionality	BC-01	Add new block on KYC approval	Approve a KYC
Blockchain Functionality	BC-02	Validate blockchain integrity	Manually verify blockchain links
Blockchain Functionality	BC-03	Tamper a block and detect	Edit a block manually and refresh view
Blockchain Functionality	BC-04	Visualize blockchain	Open blockchain visualizer
KYC Status Checking	KS-01	Check pending KYC	Enter Aadhaar of pending KYC
KYC Status Checking	KS-02	Check approved KYC	Enter Aadhaar of approved KYC
KYC Status Checking	KS-03	Check rejected KYC	Enter Aadhaar of rejected KYC
KYC Status Checking	KS-04	Check invalid Aadhaar	Enter wrong Aadhaar number
Error Handling & Edge Cases	EH-01	No pending KYCs	Open officer panel with no KYCs
Error Handling & Edge Cases	EH-02	Crash recovery	Force crash during KYC submit
Error Handling & Edge Cases	EH-03	Blockchain file missing	Delete `blockchain_data.json`, open app
Error Handling & Edge Cases	EH-04	Secret key missing	Delete `secret.key`, open app

CHAPTER 7

7.1 CONCLUSION

The project presents a secure, efficient, and technologically advanced KYC (Know Your Customer) verification system that integrates facial recognition, AES encryption, and blockchain technology. By combining these components, the system ensures end-to-end data confidentiality, accurate identity verification, and immutable storage of outcomes. The use of FaceNet CNN for facial recognition adds a biometric layer that significantly enhances the security of user identification, reducing the risks of fraud or impersonation. AES encryption, reinforced by SSL, protects user data from unauthorized access during both storage and transmission. Meanwhile, blockchain provides a transparent, tamper-proof ledger for recording verification results, ensuring compliance and auditability. This solution addresses major challenges in conventional KYC processes such as manual handling, data manipulation, and security vulnerabilities. The integration of a mock admin API and organizational verification also demonstrates practical implementation flexibility, simulating real-world banking or governmental systems. Additionally, recording both verified and rejected data in the blockchain creates a comprehensive audit trail, aiding in fraud detection and regulatory reporting. Overall, the project not only streamlines the KYC process but also reinforces trust, efficiency, and compliance in identity verification, making it a significant step forward for banks, fintechs, and other institutions dealing with sensitive user data and regulatory requirements.

7.2 FUTURE ENHANCEMENTS

1. OTP Generation for Registration

To further enhance the security of the registration process, incorporating OTP (One-Time Password) generation is a critical upgrade. Upon initiating registration, an OTP would be sent to the user's registered mobile number or email address. This OTP must be entered correctly to proceed with the submission of KYC data. This additional authentication layer ensures that the data being registered actually belongs to the individual initiating the process, preventing unauthorized registrations and impersonation attacks. OTPs can be generated using secure libraries such as Python's pyotp, and should be time-sensitive, expiring within a short interval (e.g., 5 minutes) to prevent misuse. Integration with SMS gateways or email services will be necessary to deliver OTPs promptly. This enhancement not only aligns with multi-factor authentication principles but also meets the expectations of regulatory bodies in the finance and fintech sectors. Implementing OTP verification before encryption adds an early-stage filter to identify fake or unverified users, thereby improving overall system integrity. By confirming user authenticity upfront, the system can avoid unnecessary computational load for false or incomplete registrations, and it enhances user confidence by showing a proactive commitment to their data security.

2. Status Update Directly to User's Phone

Implementing real-time status updates via SMS or push notifications directly to the user's phone will significantly improve user experience and transparency in the KYC process. Once the verification process (including biometric and organizational matching) is completed, the system will automatically send a status update—either "Verified" or "Rejected"—to the registered mobile number. This can be achieved by integrating SMS APIs such as Twilio, Fast2SMS, or local telecom services depending on regional requirements. The update can include a secure link or a masked token to allow users to access further details or next steps. Notifying users instantly reduces anxiety around application progress and ensures they stay informed without needing to manually check their status on the system. Additionally, in cases of rejection, this update could guide users to rectify specific issues by providing helpful instructions or a re-submission link. From a compliance standpoint, this feature also helps maintain a transparent communication trail,

which is essential in regulated industries like banking and fintech. Automating this communication pipeline minimizes administrative burden and promotes a seamless digital experience, positioning the system as a user-friendly, responsive, and secure verification solution.

3. Using More Pictures and Morphing with Current Picture for Encryption

A highly innovative enhancement would be to collect multiple facial images from users at the time of registration and use image morphing techniques to generate a composite or averaged facial representation. This morphed image can then be encrypted and stored as part of the identity verification record. Morphing improves the system's ability to account for facial variations due to changes in angle, lighting, or facial expression, thereby enhancing recognition accuracy during verification. Algorithms such as OpenCV's face morphing pipeline can be employed to blend features from multiple images, generating a more robust facial template that reduces false rejections. When used with AES encryption, the morphed image ensures that biometric data is securely stored and uniquely identifiable. This enhancement not only fortifies the facial recognition layer but also introduces an innovative biometric fusion technique that strengthens defense against spoofing or photo-based attacks. Furthermore, during verification, the system can perform comparisons between the submitted real-time image and the morphed template, improving match quality even under sub-optimal conditions. This capability will be especially useful in mobile or remote KYC scenarios, where lighting and camera quality may vary. Overall, this feature represents a leap toward a more adaptive, secure, and intelligent identity verification system.

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Appendix A

A.1 Front End

1. tkinter

tkinter is Python's standard GUI (Graphical User Interface) library. It provides tools to create windows, dialogs, buttons, labels, and other interface elements. Tkinter is easy to use, widely supported, and cross-platform. It's ideal for developing lightweight desktop applications with interactive graphical user interfaces in Python.

1.1 messagebox

The messagebox module offers pre-built pop-up dialog boxes for displaying messages to users, such as information, warnings, or errors. It includes functions like showinfo(), showwarning(), and showerror(). These dialogs help provide feedback, confirmations, or alerts, enhancing user experience and control in Tkinter-based applications.

1.2 filedialog

The filedialog module in Tkinter provides dialogs for opening or saving files. It allows users to browse their file system and select files or directories. Common functions include askopenfilename() and asksaveasfilename(). It improves user interaction in GUI applications by simplifying file input and output processes.

1.3 OS

The os module in Python provides a way to interact with the operating system. It offers functions to work with files, directories, environment variables, and process management in a platform-independent way.

A.2 Back End

1. OpenCV (Open Source Computer Vision Library)

Description: OpenCV is a powerful open-source library for real-time computer vision and image processing. It supports operations like capturing video from webcam, detecting faces, and preprocessing images. Usage in Project: You used OpenCV to capture and process facial images for the KYC process. It detects and crops faces from live webcam input, which are then verified using DeepFace.

2. Cryptography (Fernet)

Description: The cryptography library provides cryptographic recipes and primitives. Fernet is part of this library that ensures symmetric encryption using AES. Usage in Project: You used Fernet to encrypt and decrypt sensitive user data like personal details and image files, ensuring secure storage and transmission within the KYC system and on the blockchain.

3. DeepFace

Description: DeepFace is a lightweight facial recognition and analysis library built on top of deep learning frameworks. It supports face verification, recognition, and emotion detection.

Usage in Project: You implemented DeepFace for facial recognition and verification. It compares the live captured image with the stored KYC image to validate a user's identity during verification.

4. JSON (JavaScript Object Notation)

Description: JSON is a lightweight format for storing and transporting data. It's easy for humans to read and for machines to parse. Usage in Project: You used JSON to store and transmit structured KYC data like user identity information and verification status, especially between front-end and back-end components or to record transactions on the blockchain.

5. hashlib

Description: hashlib is a built-in Python module that provides hashing algorithms like SHA256. It's used to generate unique digital fingerprints of data. Usage in Project: You used hashlib to generate hash values for KYC records, ensuring their immutability and integrity on the blockchain. Any tampering would change the hash, signaling a data breach.

BLOCKCHAIN BASED E-KYC USING FACIAL RECOGNITION

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The increasing demand for secure, efficient, and user-friendly identity verification systems has led to the development of Blockchain-based Electronic Know Your Customer (E-KYC) solutions. This paper proposes an innovative approach to E-KYC by integrating Blockchain technology and Facial Recognition for secure, tamper-proof, and real-time identity verification. The system leverages Blockchain's decentralized structure to store encrypted user data, ensuring privacy and integrity, while enabling transparent and immutable record-keeping. Facial recognition algorithms, powered by DeepFace and custom OpenCV-based face detectors, are used to perform biometric verification by comparing the user's live photo with their stored Aadhaar-linked image, ensuring a high level of accuracy and security. This approach replaces traditional manual methods of verifying user identities, streamlining the process, and minimizing fraud risks. The system includes features such as document upload**,** real-time face comparison**,** and Aadhaar/PAN/RBI verification, with results securely recorded in the Blockchain. Additionally, the platform provides a user-friendly admin interface for managing KYC requests and approving/rejecting applications. The proposed solution ensures enhanced data security, reduces human intervention, and significantly improves the overall KYC process, offering a robust framework for future digital identity management systems.

1.INTRODUCTION

In today's digital world, verifying identities has become a crucial part of various services, highlighting its potential to transform how we approach digital identity verification. especially in sectors like banking, finance, and government. The traditional process of verifying identity, known as Know Your Customer (KYC), often involves time-consuming steps and requires manual checks of physical documents. This not only makes the process slower but also opens the door for errors and fraud, leading to inefficiencies and security risks. As digital platforms continue to grow, there is a clear need for a more secure, streamlined, and automated solution for identity verification.

This paper presents a solution that combines Blockchain technology with Facial Recognition to improve the KYC process. Blockchain offers a decentralized and secure way to store encrypted user information, making it virtually tamper-proof. By adding facial recognition into the mix, the system can authenticate identities in real-time, without relying on manual document checks. The user's face is captured and compared with the photo linked to their official identification (like Aadhaar). If the faces match, the system runs additional checks, such as verifying against databases like PAN and RBI. The entire process and results are then stored on the Blockchain, ensuring transparency and data integrity.

The system also includes a user-friendly interface for both individuals and administrators. Administrators can easily manage KYC requests, approve, or reject applications, and access detailed verification records This solution not only enhances security but also reduces fraud and speeds up the KYC process. The paper explores the architecture, methodology, and the benefits of this Blockchain-based E-KYC system,
Combining Blockchain and facial recognition enhances security by storing biometric data on a tamper-proof ledger. While promising, integrating

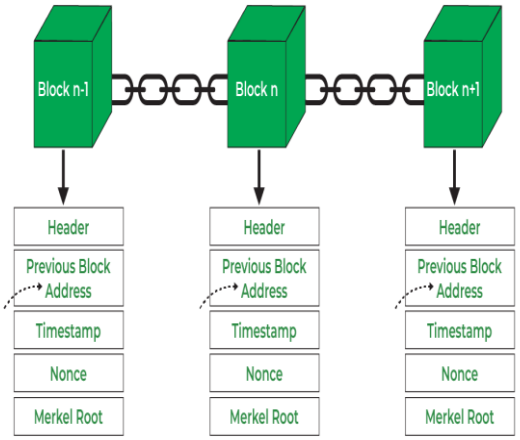

Figure 1: Blockchain visualize representation

2. BACKGROUND AND RELATED WORK

2.1 E-KYC Systems:

E-KYC digitizes identity verification, improving efficiency and security. India's Aadhaar-based system uses biometrics for authentication, while international systems implement digital verification for banking and financial services. However, centralized databases still pose security and privacy risks [10].

2.2 Blockchain in E-KYC:

Blockchain ensures data security and integrity by decentralizing identity data storage. Solutions like Sovrin and u-Port provide Self-Sovereign Identity (SSI), offering users control over their identity. Despite its advantages, scalability is a challenge for real-time identity verification [11].

2.3 Facial Recognition:

Facial recognition is widely used for biometric authentication. Techniques like DeepFace and OpenCV provide accurate identity verification. Systems like Aadhaar and Face++ use this technology, though challenges with accuracy in varying conditions and privacy concerns remain. these technologies face challenges in real-time performance and data handling [15].

3.SYSTEM DESIGN AND ARCHITECTURE

This section outlines the architecture and design of the Blockchain-based E-KYC system, covering the storage and encryption of data in the blockchain, the facial recognition process, and the overall KYC workflow.

3.1 Blockchain-based Architecture:

The architecture of the Blockchain in this system ensures secure and immutable storage of user data, providing a decentralized and tamper-proof environment for E-KYC verification [13]. Below is a breakdown of the Blockchain structure and how it operates:

Blockchain Structure:

- Blocks: Each block in the blockchain contains essential information such as the user's encrypted identity data, biometric information (e.g., facial features, fingerprints), and transaction metadata.
- Encryption: User data such as Aadhaar number, PAN number, address, and facial data are encrypted before being added to the blockchain. This encryption ensures that sensitive data remains secure and private, with only authorized parties able to decrypt and access the data.
- Hashing: Each block contains a hash of the previous block, ensuring the immutability of the blockchain. Any modification to a block would change its hash, making tampering easily detectable.
- Merkle Tree: For efficient verification and to ensure data integrity, a Merkle tree is used. It organizes data into a tree structure and allows for efficient and secure proof of the existence of user data in the blockchain.
- Adding New Blocks: New blocks are added through a consensus mechanism (e.g., Proof of Work or Proof of Stake), ensuring that the blockchain remains decentralized and secure. Each new block contains the verified identity information and the transaction history related to the user's KYC process.

- **Facial Feature Extraction**:

DeepFace or a similar facial recognition model is used to extract key features from the detected face. DeepFace, based on deep learning techniques[5], performs high-accuracy facial recognition by

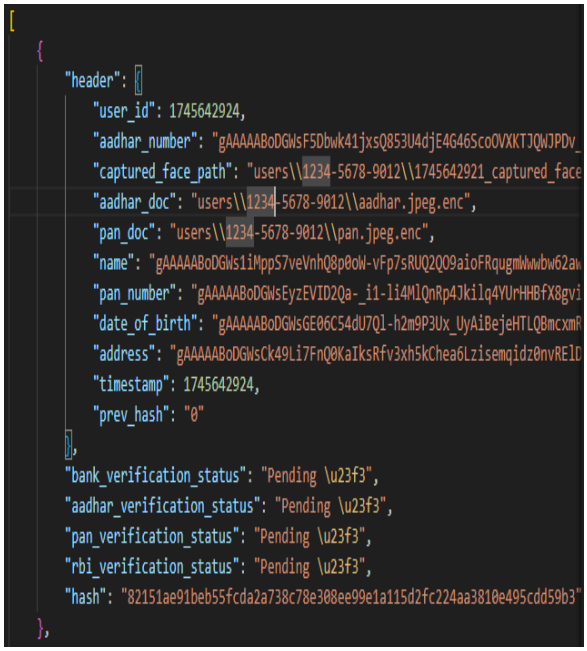

Figure 2: sample of Blockchain structure

3.2 Data Flow:

- When a new KYC request is submitted, the user's data is collected and encrypted.
- The encrypted data is then added to a new block and linked to the existing blockchain.
- The hash of the previous block ensures the data's integrity, while the blockchain structure guarantees that data cannot be altered retroactively.

3.3 Facial Recognition System

The Facial Recognition System is used for biometric verification, comparing a captured image with the user's stored facial data in the blockchain. The system operates in the following steps:

- **Facial Data Capture**:

The system first captures a facial image from the user, either via a webcam.

- **Preprocessing**:

The captured image is processed using **OpenCV** [18] for face detection, which locates the facial region within the image. This is crucial for ensuring that the face is correctly identified and isolated.

analysing and comparing facial features such as the eyes, nose, and mouth.

- **Facial Comparison**:

The captured facial features are compared against the **face image stored in the blockchain**. This comparison can be done using various facial recognition algorithms, where the extracted features are matched with the encrypted data in the blockchain. The comparison process involves **calculating a similarity score**, and if the score exceeds a predefined threshold, the facial verification is considered successful.

- **Facial Recognition Model**:

DeepFace: A pre-trained model for facial recognition that achieves a high degree of accuracy in comparing facial features. Alternatively, custom models built on **OpenCV** or **TensorFlow** can be used to compare faces in real-time.

3.4 E-KYC Workflow

The E-KYC Workflow encompasses the complete process of verifying and storing user data, ensuring security, and leveraging Blockchain and Facial Recognition technologies for efficient identity verification.

- **User Registration**:

A user initiates the process by providing basic identity details such as Aadhaar, PAN, and a selfie for facial verification. The facial image and identity documents (e.g., Aadhaar, PAN card) are captured through a web interface or mobile app.

- **Data Encryption:**

The user's data is encrypted using a strong encryption algorithm (e.g., AES-256) [7] to ensure that sensitive information like Aadhaar number and facial features remain secure. This encrypted data is then ready for storage in the blockchain.

- **Facial Recognition:**

The facial image captured during registration is

- OpenCV: face detection and image preprocessing

- DeepFace: pretrained deep-learning model for face recognition

Processed and compared with the stored facial image (if available) for identity verification using DeepFace or an equivalent facial recognition model. (If available) for identity verification using DeepFace or an equivalent facial recognition model.

- **Blockchain Storage**:

Once the facial recognition step is completed successfully, the user's encrypted identity information (including Aadhaar, PAN, and facial data) is added to a new block on the blockchain. The block is linked to the existing chain, ensuring that the user's identity data is immutable and cannot be altered without detection.

- **KYC Approval/Rejection:**

After the data is stored in the blockchain, the verification process continues with additional checks, such as verifying PAN and Aadhaar with the respective government databases. The KYC request is then approved or rejected, based on the successful verification of both the biometric and document data.

- **End-User and Admin Interaction:**

The user can track the status of their KYC verification through a dashboard. Admins can view the entire KYC data and approval process in a secure interface, ensuring that all actions are logged on the blockchain for transparency.

3.5 Summary

This section provides a detailed explanation of how the components of the system work together, ensuring a seamless and secure E-KYC process. By integrating Blockchain for secure storage and Facial Recognition for biometric verification, the system provides a tamper-proof, efficient, and privacy-preserving solution for digital identity verification.

4. Implementation

This section describes the tools and libraries used, each module description, the main challenges we faced along the way.

4.1Technologies Used

- Python 3.8: core programming language

- Tkinter: desktop GUI framework for admin and user interfaces

- cryptography (AES-256): encrypting/decrypting user identity data

- JSON: storing blockchain data [3] (`blockchain_data.json`)

- Custom Python modules:

  - blockchain.py (block and chain structures, add_block function)
  - mock_apis.py (simulated Aadhaar, PAN, RBI verification endpoints)

4.2 Module Description

Blockchain Module

• Defined a Block class with fields: header (encrypted user details), verification statuses, timestamp, hash, previous hash.

• Implemented AES-256 encryption for the header using the cryptography library; managed keys securely.

• Built add_block() to encrypt new user data, compute block hash, link it to the chain, and append to blockchain

Mock Verification APIs

• Simulated external checks against Aadhaar, PAN, and RBI databases.

• Each function returns a pass/fail Boolean and a timestamp, mimicking real-world service latency**.**

Facial Recognition Module

• Used OpenCV's Haar cascade classifier to detect faces in incoming images.

• Integrated DeepFace for feature extraction and face embedding comparison.

• Wrapped the comparison in a function that returns a similarity score; set threshold at 0.6 for a match.

- **Face Recognition Accuracy**
  Challenge: Variations in lighting and camera angle led to false negatives.
  caused noticeable lag.
  Solution: Cached decrypted data in memory for the

- session; only re-decrypt on application restart or block updates.

Admin GUI

• Upon launch, loaded pending blocks from blockchain and decrypted headers to display user details.

• Displayed document images and profile picture thumbnails using Tkinter's Canvas [2] and Scrollbar widgets.

• Added buttons for "Compare Face," "Run Full verification Button".

– "Compare Face" runs the facial recognition module and shows a pop-up with the similarity score.

– "Approve" or "Reject" calls the appropriate mock API functions, updates verification statuses, and uses add_block() to record the final result.

• Provided confirmation dialogs and status messages for all actions.

User GUI

• Upon launch, provided a user-friendly interface for new KYC registration [2].

• Displayed input fields for users to enter basic identity information: Name, Aadhaar Number, PAN Number, Date of Birth, and Address.

• Allowed users to upload images for:

- Aadhaar Card (front and back)
- PAN Card
- Captured live photo (selfie)

• Added buttons for Submitting KYC, on clicking the entered details and uploaded images were collected. User details were encrypted using AES-256 encryption, and a new pending KYC request was created and stored by adding a block to the blockchain

4.2 Challenges and Solutions

- **Encryption/Decryption Overhead**
  Challenge: Real-time decryption of user headers Aadhar card's image
- Solution: Pre-processed images with histogram equalization and enforced a minimum face size; experimented with DeepFace thresholds to balance precision and recall.

- **GUI Responsiveness**
  Challenge: Loading multiple high-resolution document images slowed down the interface.
  Solution: Generated and displayed lower-resolution thumbnails, loading full-resolution images only upon user request (click to zoom).

- **Data Consistency in Blockchain**
  Challenge: Ensuring immutability while allowing new verification statuses to be recorded.
  Solution: Never modified existing blocks; each approval or rejection created a new block linked to the chain, preserving history.

4.3 Technology Description

4.3.1 DeepFace

DeepFace is a deep learning-based facial recognition system developed by a team at Facebook. It marked a major advancement in the field of face verification, achieving near-human accuracy. It works by converting facial images into numerical vectors called embeddings and comparing them using mathematical distance metrics (Figure 3).

Working

- **Face Detection**
  DeepFace first detects the face in an image using a face detector (e.g., OpenCV's Haar Cascades or DNN-based SSD models). This ensures only the facial region is passed to the next stages.
- **Face Alignment**
  Faces in images can be at different angles. DeepFace aligns them using 3D face modelling, correcting for tilt, angle, and rotation, so every face is viewed in a consistent orientation.
- **Feature Extraction (Embedding Generation)**
  A **deep convolutional neural network** (inspired by architectures like AlexNet) processes the aligned face and outputs a **128-dimensional vector** (embedding). This vector represents the unique features of the face.
- **Face Comparison**
  To compare two faces, DeepFace calculates the **Euclidean distance** or **cosine similarity** between their embeddings. If the distance is below a set threshold (usually around 0.6 for Euclidean), the faces are considered to be of the same person.

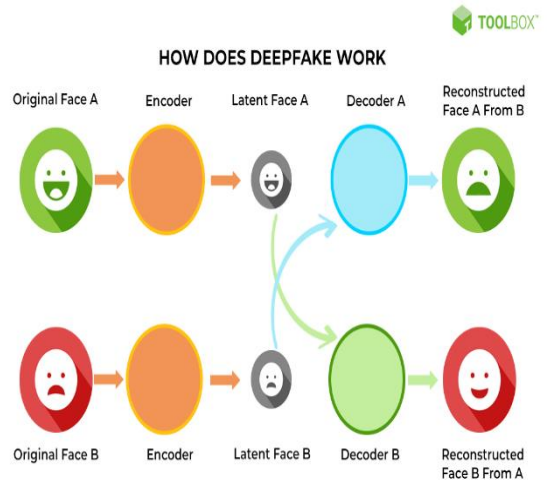

Figure 3 DeepFace working

4.3.2 AES algorithm for encryption and decryption

AES (Advanced Encryption Standard) is a symmetric block cipher used to securely encrypt and decrypt data. It operates on fixed-size blocks of 128 bits and supports key lengths of 128, 192, or 256 bits. In our project, we use AES-256, meaning the key used is 256 bits long, providing a high level of security suitable for protecting sensitive identity and KYC data (Figure 4).

❖ **Input Preparation**

AES encryption begins with preparing three key inputs:

- **Plaintext**: The original data or message to be encrypted (e.g., Aadhaar number, documents).
- **Key**: A 256-bit secret key shared between sender and receiver.
- **IV (Initialization Vector)**: A random 128-bit block used in modes like CBC to ensure uniqueness in encryption.

❖ **Block Division**

The plaintext is divided into 128-bit (16-byte) blocks. If the final block is shorter than 128 bits, it is padded using a standard padding scheme (e.g., PKCS#7).

❖ **Key Expansion**

The 256-bit key is expanded into a set of **round keys** using a key schedule. AES-256 performs **14 rounds**, and each round uses a different 128-bit key derived from the original key.

❖ **Encryption Rounds**

Each 128-bit block of plaintext undergoes the following operations:

- **Initial Round:**
  - **AddRoundKey**: The block is XORed with the first round key.
- **Main Rounds (13 times):**
  - **SubBytes**: Each byte is replaced using a fixed substitution box (S-box).
  - **ShiftRows**: Bytes in each row of the block matrix are shifted left by varying amounts.
  - **MixColumns**: Each column of the matrix is mixed using mathematical operations to add diffusion.
  - **AddRoundKey**: The current block is XORed with the next round key.
- **Final Round (14th):**
  - SubBytes, ShiftRows, and AddRoundKey (without MixColumns).

❖ **Ciphertext Generation**

After the final round, the resulting block is the **ciphertext**—a scrambled version of the original message that is unreadable without the key and IV.

❖ **Decryption Process**

AES decryption reverses the process:

- It uses the same round keys in reverse order.
- The operations are inversed: **InvSubBytes**, **InvShiftRows**, **InvMixColumns**, and **AddRoundKey**.
- The original plaintext is retrieved if the correct key and IV are used.

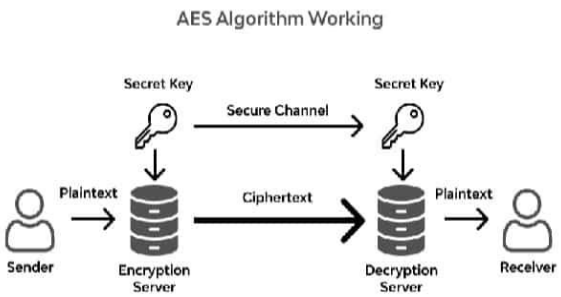

Figure 4: AES working

4.3 Summary

The Blockchain-based E-KYC system was developed using Python, integrating modules for blockchain storage, facial recognition, and user interfaces. The user GUI allows individuals to submit their encrypted identity details and documents, which are stored as pending blocks in a local blockchain. The admin GUI enables officers to view pending requests, verify documents, run facial recognition checks using DeepFace and OpenCV, and approve or reject KYC requests. All approvals are recorded by adding new verified blocks without altering the original data. Throughout the development, challenges such as encryption delays, face detection errors, and interface responsiveness were addressed to ensure a smooth and secure verification workflow.

5. Results

The Blockchain-based E-KYC system was successfully implemented and tested across multiple user submissions and verification scenarios. Key results achieved include:

- **Secure Data Handling:**
  User details were properly encrypted using AES-256 and stored securely in the blockchain without any data leaks or tampering (Figure 2).
- **Accurate Facial Recognition:**
  The system achieved a high facial verification accuracy, correctly matching user selfies with.
- **Efficient KYC Processing:**
  Admins were able to process and verify KYC requests in under 2 minutes per user, significantly faster than manual verification methods (Figure 9).
- **Immutable Record Keeping:**
  Each approved or rejected KYC request was recorded as a new block, ensuring that the verification history remains permanent and auditable (Figure 10).
- **User-Friendly Interfaces:**
  Both the user and admin GUIs were easy to navigate, with clear prompts, real-time feedback, and smooth file handling (Figure 5, Figure 6, Figure 7).
- **System Responsiveness:**
  Background threading ensured that facial comparisons, encryption, and blockchain updates did not freeze the interface, resulting in a seamless experience.

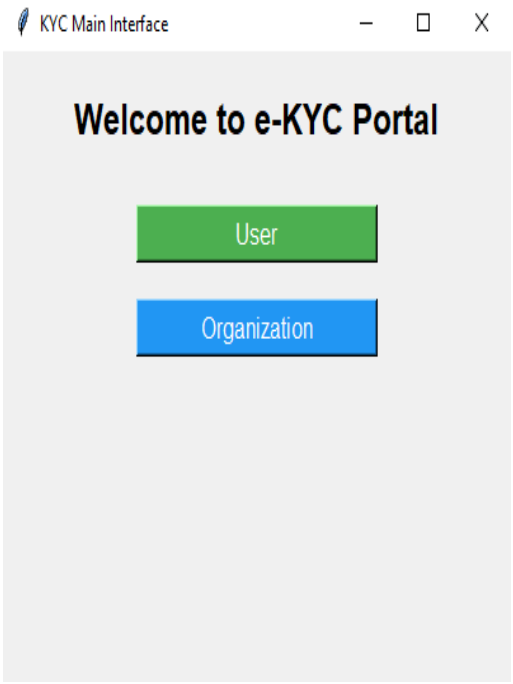

Figure 5: Main interface with user and organization options

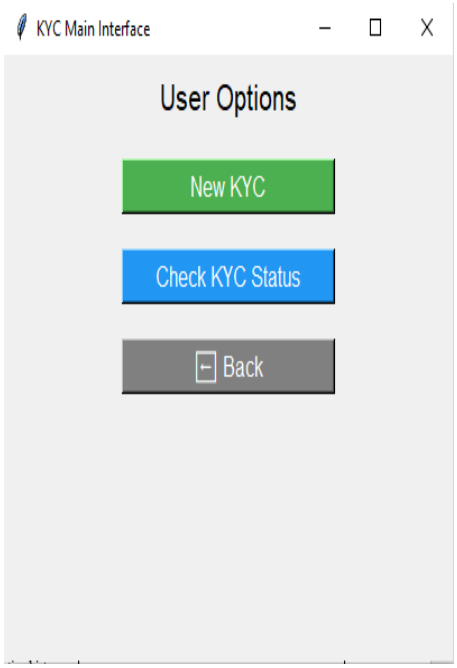

Figure 6: User interface with options to create new KYC request and check existing KYC

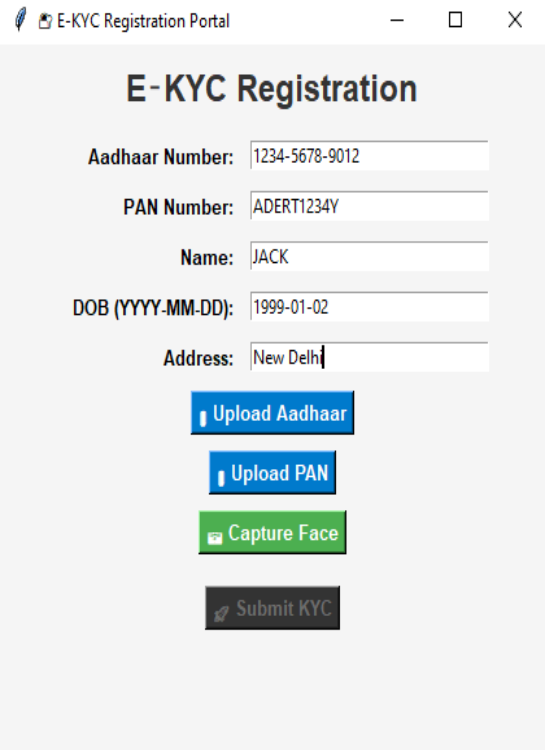

Figure 7: User interface to enter details for creation of KYC request

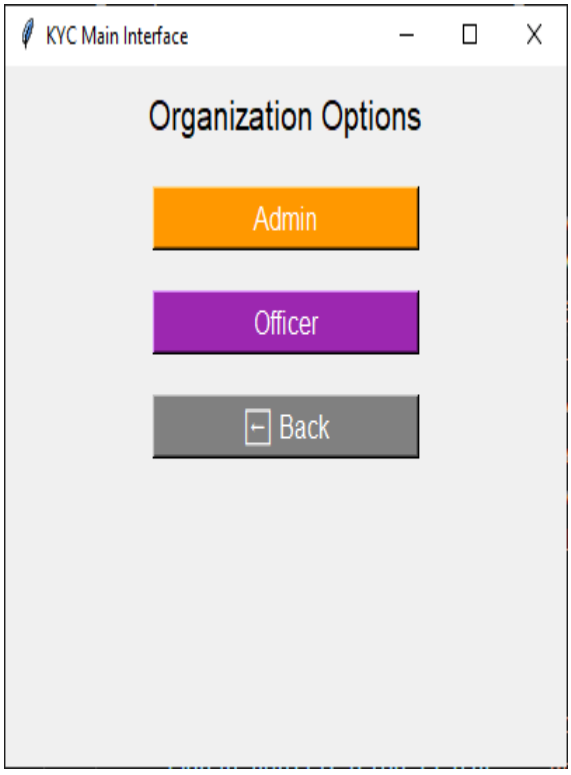

Figure 8: Interface for organization officials with admin an officer option

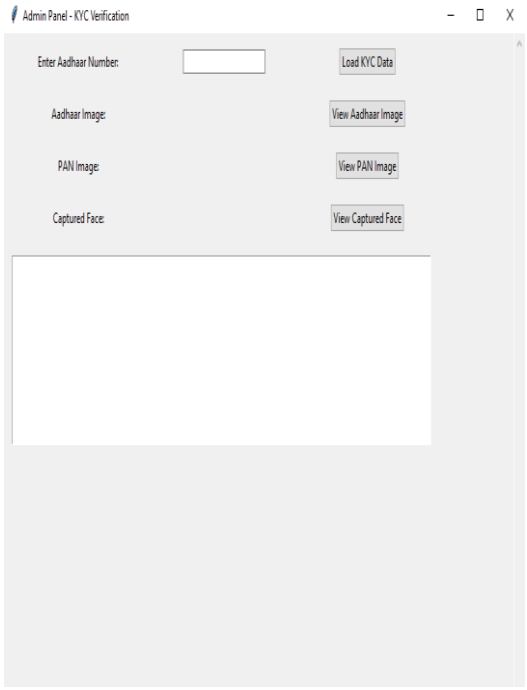

Figure 9: Officers can insert Aadhar no. and view applicant's profile

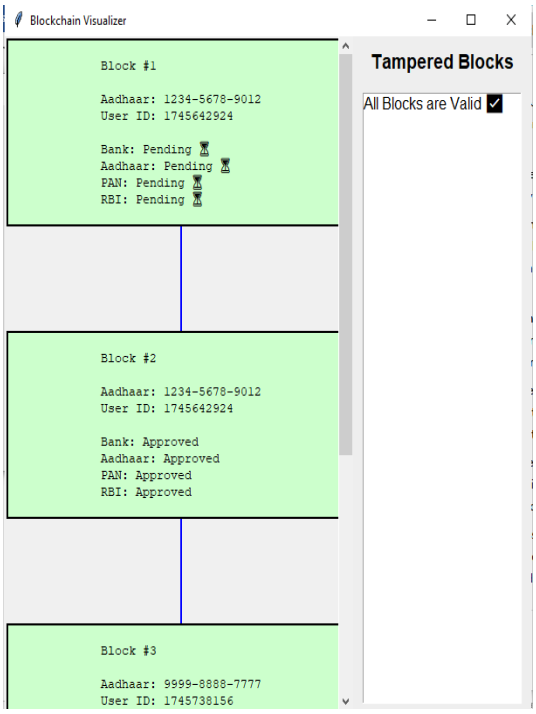

Figure 10: Verification of blockchain integrity by the admin

5.1 Summary

The developed Blockchain-based E-KYC system effectively secured user identity data through encryption and immutable blockchain storage. The facial recognition module, powered by DeepFace and OpenCV, achieved high accuracy in verifying user identities. The admin interface enabled quick and efficient approval of KYC requests, while maintaining a permanent and auditable record of all verifications. Both user and admin GUIs provided a smooth and responsive experience, demonstrating the practicality and reliability of combining blockchain and biometric technologies for digital KYC processes.

6. Comparative Analysis of Traditional E-KYC and the Proposed Blockchain-Based Facial Recognition KYC System

Traditional E-KYC:

- Relies on centralized databases, making it vulnerable to hacking and data breaches.
- Identity verification is often manual or based on simple document scanning.
- Facial recognition is rarely used or depends on manual validation.
- Data can be altered or tampered with without detection.
- Users have limited visibility or control over their data.
- Audit trails are not always maintained or are prone to manipulation.
- The process can be time-consuming due to human involvement.
- Cost of maintaining infrastructure and personnel is high.
- Difficult to trace or prove data authenticity after submission.
- Lack of real-time verification and automation.

Blockchain-based E-KYC using Facial Recognition:

- Uses blockchain for decentralized, tamper-proof data storage.
- Implements AES-256 encryption to ensure strong data security.
- Performs automated facial verification using DeepFace and OpenCV.
- Every change in data is tracked via cryptographic hashes, enabling tamper detection.
- Users can verify and track their data in a transparent manner
- Maintains an immutable audit trail for every action or update.
- Significantly reduces processing time through automated verification APIs.
- Reduces operational costs by minimizing manual intervention.
- Assures data authenticity with every block linked to the previous via hashing.
- Enables real-time, AI-powered KYC verification for higher accuracy and speed.

7.Evaluation and Analysis

The Blockchain-based E-KYC system developed in this project showcases several strong aspects while also presenting certain limitations. One of the major strengths of the system is its enhanced security. User data is encrypted using AES-256 encryption and stored immutably on a blockchain, ensuring that sensitive information remains protected against unauthorized access and tampering.

The system offers multiple advantages. By encrypting user data and storing it immutably in a blockchain, it ensures that identity information remains protected against unauthorized access and tampering. The use of facial recognition further enhances the authenticity of the verification process, making it difficult for fraudulent submissions to succeed. The system design, which separates pending and approved KYC requests using blockchain principles, provides a tamper-proof history of all transactions. In addition, the user and admin interfaces were designed to be simple, intuitive, and responsive, making the system accessible even to users without technical expertise.

During testing, the system achieved high accuracy in facial comparisons and significantly reduced the time needed for completing KYC verification compared to traditional methods. The results demonstrated that the system is not only functional but also practical for real-world scenarios where large volumes of identity verifications must be handled securely and efficiently.

However, the project also highlights areas for future improvement. like Improving facial recognition under

additional enhancements that can make the system more robust and widely usable.

The integration of DeepFace and OpenCV for facial recognition also contributed significantly to the system's reliability, achieving a high accuracy in verifying the identities of users based on their facial features.

Another key advantage is the automation and speed of the KYC process. Tasks that would traditionally require several days to complete manually can now be performed within minutes. Furthermore, the blockchain architecture ensures that each KYC decision, whether approval or rejection, is recorded in a new block, preserving a complete and auditable history of all verification activities. The user and admin interfaces were designed to be simple, clear, and intuitive, enabling even non-technical users to interact with the system efficiently.

However, the system also has certain limitations. The accuracy of facial recognition is slightly dependent on the quality of the images provided. very Poor lighting, low-resolution uploads, or incorrect angles can impact the recognition performance, sometimes leading to false rejections and the system is built as a desktop application using Tkinter, meaning it does not currently support mobile devices or web browsers, which could limit accessibility in broader deployments.

In summary, the Blockchain-based E-KYC system successfully demonstrates how blockchain and biometric technologies can combine to enhance the security, efficiency, and reliability of identity verification processes. While the prototype validates the core concept effectively, further improvements are needed in scalability, image quality handling, and real-world API integration for practical, large-scale deployment.

8. Conclusion

The Blockchain-based E-KYC system using facial recognition developed in this project provides a strong and innovative solution to the ongoing challenges associated with digital identity verification. Traditional KYC processes are often slow, manual, prone to errors, and vulnerable to data breaches. This project successfully demonstrates how emerging technologies like blockchain and facial recognition can be combined to create a faster, more secure, and transparent method for verifying users

various image quality conditions and extending platform support to mobile and web interfaces are

In conclusion, this project proves that blockchain and biometric technologies can revolutionize the way KYC processes are conducted. It offers a secure, efficient, and transparent alternative to traditional identity verification methods. While the current system serves as a working prototype, it lays a strong foundation for future development into a full-fledged, scalable E-KYC platform that can be deployed across banking, government, and private sectors to improve security, user trust, and operational efficiency.

Acknowledgments

We, would like to express our heartfelt gratitude to our mentor(s) for their unwavering support, insightful feedback, and guidance throughout the project. Their expertise has been invaluable in shaping our work. We also want to thank our peers who offered helpful suggestions and encouragement at every step, making the process enjoyable and collaborative. A special mention goes to the open-source communities behind Python, OpenCV, and DeepFace—without their incredible resources, this project would not have been possible. Finally, we are grateful to our institution for providing the resources and environment that allowed us to bring our ideas to life and complete this project successfully.

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