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IDENTITY VERIFICATION SYSTEM WITH OCR AND FACE MATCHING

A PROJECT REPORT

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PRESIDENCY SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

BONAFIDE CERTIFICATE

Certified that this report "IDENTITY VERIFICATION SYSTEM WITH OCR AND FACE MATCHING" is a bonafide work of "KUDUMULA PHANI KEERTHAN REDDY (20221CAI0040), KOTAPALLI LAKSHMI PRASANNA (20221CAI0034), ABHINAV K(20221CAI0050)", who have successfully carried out the project work and submitted the report for partial fulfilment of the requirements for the award of the degree of BACHELOR OF TECHNOLOGY in COMPUTER SCIENCE ENGINEERING, AI&ML during 2025-26.

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DECLARATION

We the students of final year B.Tech in COMPUTER SCIENCE ENGINEERING, AI&ML at Presidency University, Bengaluru, named KUDUMULA PHANI KEERTHAN REDDY, KOTTAPALLI LAKSHMI PRASANNA, ABHINAV K hereby declare that the project work titled **"IDENTITY VERIFICATION SYSTEM WITH OCR AND FACE MATCHING"** has been independently carried out by us and submitted in partial fulfillment for the award of the degree of B.Tech in COMPUTER SCIENCE ENGINEERING, AI&ML during the academic year of 2025-26. Further, the matter embodied in the project has not been submitted previously by anybody for the award of any Degree or Diploma to any other institution.

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ABSTRACT

Digital ecosystem security includes various components of which Biometric Authentication is among the most important ones, particularly in applications that require compliance with KYC regulations (Liu et al., 2023) [9]. While several commercial solutions have emerged, such as Onfido and Jumio, they each utilize a pipeline that is divided into modules: Optical Character Recognition (OCR); Face Recognition; and Liveness Detection. This causes fragmentation and makes integration difficult while also generating privacy issues by transferring collected data from users via the cloud (Thompson et al., 2023) [10].

In this paper we describe an Integrated End-To-End Document Verification System (IVVDS) that includes Deterministic Validation, Deep Learning-Based Image Analysis, and Liveness Detection all within a Secure Edge Computing Architecture. Therefore, our main contributions are:

1. A Hybrid Framework for Validation; utilizing Verhoeff Checksums for Aadhaar Documents; Regex for PAN/NREGA; Vision Model-Based Field Extraction utilizing Generative AI, supported by recent OCR research (Kumar et al., 2023; Chen & Li, 2023) [2][5].
2. Multi-Threshold Risk Scoring Engine utilizing Document Confidence (SDoc), OCR Accuracy (SOcr), Liveness Confidence (SLive); enabling Tiered Decision Making: Auto Approve, Manual Review, Reject—aligning with multi-modal authentication studies (Rahman et al., 2022) [4].
3. Serverless Privacy-Preserving Architecture utilizing Edge Functions for Deterministic Validation and In Situ Image Processing; with deletion of verified documents immediately upon verification and with no stored Persistent Biometric Data, consistent with privacy-preserving frameworks (Liu et al., 2023) [9].

We evaluate IVVDS using over 850 documents (Aadhaar, PAN, NREGA): achieving **92.3% Field Level OCR Accuracy** (similar to benchmarks in Kumar et al., 2023) [2]; **3.2% False Acceptance Rate (FAR)** and **2.1% False Rejection Rate (FRR)**, aligning with lightweight facial verification insights (Singh & Patel, 2023) [3]. Additionally, we demonstrate Liveness Detection achieves robustness: **96.1% vs Printed Photo Attacks; 92.3% vs Screen Replay Attacks; 87.5% vs 3D Mask Attacks**, consistent with anti-spoofing literature (Zhao & Wang, 2023) [7]. Finally, verification processing occurs in **8.7 seconds using only a CPU**, making the system suitable for deployment in resource-constrained environments and aligned with real-time optimization principles (Thompson et al., 2023) [10].

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ABBREVIATIONS

OCR	Optical Character Recognition
API	Application Programming Interface
PAN	Permanent Account Number
SSIM	Structural Similarity Index
ORB	Oriented FAST and Rotated BRIEF
HSV	Hue, Saturation, Value
JSON	JavaScript Object Notation
CORS	Cross-Origin Resource Sharing
UI	User Interface
SDK	Software Development Kit

CHAPTER 1
INTRODUCTION

1.1 Background

Digital Identity Verification (DIDV) has emerged to be a crucial requirement of various industries including Banking, Finance, Telecom, Government Services, and E-Commerce because of the need to employ secure digital verification of users in distant settings. As the internet fraud incidences continue to rise, businesses are willing to use remote digital identification as opposed to the traditional physical verification technique, which is characterized by slowness, inconsistency, and error-induced nature. Another issue that leads to difficulties in the process of verification is the variety of Indian identity papers, Aadhaar, PAN, Passport, and Driving License, which come in various forms and languages. Thus, the proposed project will address these concerns by developing an Automated Identity Verification System that incorporates OCR, Face Detection, One-to-One Face Matching and Liveness Detection. OCR facilitates the extraction of text in identity documents with high precision [2][5] and face-matching lightweight models provide the validation of the user identity [3]. Multi-modal liveness also helps in preventing spoofing attacks by measuring multiple biometric indicators [4][7]. All these technologies make the processes of identity verification accurate, strong, and secure.

1.2 Statistics of Project

The overall market in the digital identity verification sector is expected to grow to USD 24.4 billion in 2028 due to the growth of digital onboarding, cybersecurity, and remote KYC needs. Since 2020, India has experienced nearly 300 percent growth in the use of digital identity verification as a result of increased use of fintech and UPI services and increased development of digital public infrastructure. Despite the growth, identity fraud leads to loss of money in thousands of crores of money mostly through impersonation and forging of documents. Existing commercial verification systems can only identify with 85 percent to 95 percent to be accurate, and are extremely affected by the quality of the image, the light source and the face-matching algorithms [3][10]. In order to address these concerns, the new identity verification system should incorporate multi-language OCR [5], perfect face matching [3], and modern liveness detection [4][7] to counter the spoofing attacks.

The planned project will offer the lightweight, security and real time verification system applicable in various industries.

1.3 Prior Existing Technologies

The existing companies like Onfido, Jumio, and AWS Rekognition use modular architectures that combine OCR, face recognition, and liveness detection. Nevertheless, comparative analyses indicate that there are a number of problems:

A) The Pipeline Partitioning Problem.

Field extraction is done with the help of OCR engines (e.g., Tesseract or deep learning-based OCR) independently of face recognition and liveness modules. There are inconsistencies between face regions, misplaced liveness scores, and so on due to independent processing. The requirement to have integrated OCR and recognition pipelines has been highlighted in modern works since they are more reliable [2][5][7].

B) Privacy and Data Residency

Cloud-based verification systems provide the transfer of sensitive PII to out-of-company servers, which is inconsistent with the principles of privacy protection. Federated and edge-based learning models are proposed, and these approaches are aimed at maintaining the privacy of users and reducing the risk of data leakage [6][9].

C) One-metric Decision Making

Majority of commercial systems rely on basic face matching thresholds (e.g. similarity >0.70). Nonetheless, the proposed research suggests using multi-metric decision engines, which integrate OCR confidence, face embedding scores, and liveness markers to do a robust verification [3][10].

The commercial systems are weak concerning liveness detection as they are largely based on appearance-based systems. Research points to weaknesses against photo attacks, replay attacks, 3D masks and deepfakes [4][7]. It is suggested that strong anti-spoofing is required to be achieved with multi-modal physiological and temporal analyses.

D) Anti-Spoofing Weakness in Live Detection: Commercial systems are overtly optimized to Western documents. The identity documents of Indians must be verified on checksum (e.g., the Verhoeff algorithm of Aadhaar) and format verification, as reported in recent studies on OCR [2][5].

E) Limited Support for Document Types: Closure source commercial tools allow little interpretability. The architectures today focus on the use of transparent decision logs in order to be compliant and traceable [10].

F) Inadequate Audit Trails and Interpretability: Commercial closed-source systems provide little transparency. Compliance auditors, government organisations, and financial institutions require clear verification reasoning, such as: Why was this document rejected? Which areas caused concern? Did the system recognise signs of spoofing? Which confidence scores affected the choice? User support and compliance are made more difficult by proprietary systems that provide rejection codes but lack thorough verification justifications.In light of these challenges, we suggest an open, adaptable, integrated verification system that combines multi-threshold decision engines, complete system integration, hybrid model-based and deterministic validation, and privacy-focused edge-computing architecture to address all six issues.

1.4 Proposed Approach

The Integrated Document Verification System is a complete end-to-end solution proposed for verification of documents that includes OCR, face recognition, liveness detection and deterministic validation all in one decision engine. The Integrated Document Verification System will self-host on edge-computing infrastructure instead of depending solely on the cloud with all data being performed locally by each user. Users have full control of their own private data and retain all rights associated with that information. The core innovation is the combination of both a hybrid model-based and deterministic validation method of document verification. The solution does not rely on just model-based validation (such as deep learning) for document verification, which can often not provide explainability and can miss specific types of validation in a domain (especially think of things like Financial Services/Financial Crimes). Instead, the Integrated Document Verification System uses a combination of unstructured analysis using deep learning (like Generative AI) and structured deterministic validation. Examples of deep learning used in the integrated document verification platform include vision-based document field extraction (using a generative AI model such as OpenAI Vision API, LLaVA; or other similar generative AI models), Face-embedding extraction (i.e., InsightFace, ArcFace), Liveness Detection (i.e., combining detection types for best accuracy). For visual understanding, the model-based components will handle complex tasks of visual understanding whereas the deterministic validation component will enforce strict document-

specific validation rules. Examples of validation rules include the use of Verhoeff checksum algorithm for Aadhaar verification; pattern matching (matching alphanumeric values) of PAN cards; date ranges (specific to NREGA cards) and region codes (specific to NREGA cards); and matching the names and addresses referenced in each document using regex-based validation logic. Using age range assessments to identify discrepancies in applicant's entries and by verifying that the facial image extracted from the submitted document are exactly matched with the facial image captured during the liveness detection process, allows the identification of many advantages of this technology. Improved clarity, as each deterministic failure is clearly defined and easily auditable. Improved security, as altered or poorly quality documents can be detected via checksums and heuristic validation. Increased accuracy by the usage of both a deterministic and a heuristic validation models; therefore, if one validation fails, the other method will provide detection. Culturally competent; validation rules comply with Indian government requirements for government documents. Minimisation of the cloud is possible, as the majority of validations take place on-location, with only cloud-based resources to be used for enhancements that are available on a limited basis. Utilisation of a multi-threshold risk scoring engine versus a simple approve/reject method. The risk score represents a combined score comprised of the validation score, OCR confidence score, and liveness detection confidence score. Based on this risk score, three categories are developed: 1) Low Risk (75 - 100), automatic approval; 2) Medium Risk (40 - 74), requires manual review by a compliance officer; and 3) High Risk (0 - 39), rejected with justification provided to the user. This process reduces the number of erroneous rejections and provides support for those cases that may be on the borderline of decision-making, while at the same time producing output that is based on the confidence level of those decisions, which is acceptable for compliance, audits, and in some cases, for regulatory purposes. There are significant privacy protections built into this system, which include a serverless edge architecture using Supabase and Edge Functions; the only data that are sent to the cloud are the text that has been extracted from the image and the confidence score associated with that text. All images taken during the verification process, such as document scans, or photographs of the person's face, are deleted immediately after processing is complete. Row-Level Security limits access to verification records to the users of the records, while Administrative Access is restricted to review cases assigned to an individual reviewer. All decision results are recorded in encrypted Audit Logs that include timestamps, user identification information, Document Types, the Fields that were extracted and the Confidence Scores, as well as the reasoning that supported the decision made. Data is only shared with others with user consent, and requests for data from outside

the organization are passed through Secure APIs, which have Rate-Limiting and are subject to request Logging. The system is designed to be adaptable for changing and expanding document requirements going forward, allowing for alternative vision models such as ClaudeVision and/or fine tuned models to be added. This also includes support for adding other Document Types such as Passports, Voter ID Cards and Drivers' Licenses. The system permits Ensemble Facial Recognition where multiple embedding models can be used and allows customization of thresholds by Institutions based on their acceptable rates of False Acceptance (FA) and False Rejection (FR). In addition, it has advanced Deepfake Detection capabilities through Temporal Consistency Analysis and Facial Motion Units, as well as monitoring for Demographic Fairness to identify and mitigate biases. The Complete End to End Proposed Solution has a clearly defined Architectural Flow. Users access via a secure client interface (built with React) to upload images. Using a deterministic approach to validation, checks are performed synchronously on the device and optionally with model-based field extraction after that. Matching against the image's embedded similarity is accomplished through embedding similarity; liveness detection includes temporal and visual cues. A risk score is generated from combining all outputs, which is then reported back to the end user. All audit logs generated from results will be stored in a secure, encrypted manner for compliance and traceability purposes. This integrated framework brings together the strengths of deterministic validation and advanced model-based processing, reinforces the tiered decision-making framework, guarantees the creation of protected information by performing all validation through edge execution, and delivers the ability to provide extensive and thorough audit capabilities. It is a robust, clear, and scalable solution for today's digital document verification needs.

1.5 Objectives

The project aims to:

Develop OCR models of Aadhaar, PAN, Passports, and Driving Licenses with an accuracy of more than 90 percent under normal conditions [2][5].

Design multimodal face-matching algorithms with 95 true positive, and less than 5 false positive [3].

Include the use of modern liveness verification that is immune to spoofing, deepfaking, and replaying attacks [4][7].

Use deterministic checks which are rule-based e.g. Aadhaar checksum validation and the PAN format validation.

Develop a safe web platform capable of handling camera feeds in real time and feed back validation.

1.6 SDGs

Figure 1.1: Sustainable Development Goals

This project supports the UN Sustainable Development Goals, will advance the Global Development Agenda and will also help to solve key problems at the local level.

SDG 9: Industry, Innovation, and Infrastructure; The project supports innovation in technology within the realm of identity verification, and contributes to the development of digital infrastructure and systems that create access to a digital economy [1].

SDG 10: Reducing Inequality; Accessible Digital Identity Verification creates opportunities for greater access to financial services and digital services for all groups by reducing impediments to those services [1].

SDG 16: Peace, Justice and Strong Institutions; The Ability for Strong Institutions to Utilize Secure ID Verification to Help Deter Fraud and Establish Trust in Digital Services [1].

1.7 Overview of Project Report

This document gives a full account of how the Identity Verification System was created. In chapter one you will find some background about the Project, something about what the Project sets out to do and what the Project has to do with the Sustainable Development Goals (SDGs).

Chapter two includes a detailed review of the literature that covers various types of Technology that have been developed and researched in relation to Identity Verification. Chapter three outlines the V-Model method used to create the System. Chapter four provides information about Project Management activities such as developing a Project Timeline, Risk Assessment and Budgeting.

Chapter five presents information and analysis of the System Architecture and Requirement Specifications along with an explanation as to why specific Technologies were chosen. Chapter six presents an In-Depth Look of Implementation, including Hardware and Software Components as well as Development Tools and Simulation methods.

Chapter seven contains an Overview of the Evaluation of the System including the Testing Plan, Performance Metrics, and Testing Results. Chapter eight discusses some of the Social, Legal, Ethical, Sustainability and Safety Issues associated with the use of the Identity Verification System. Chapter nine is a Summary of the Project's Achievements, Limitations and Recommendations for Future Development.

CHAPTER 2
LITERATURE REVIEW AND RELATED WORK

Conducting an extensive study of the various fields involved in Identity Verification, Optical Character Recognition Technologies, Face Recognition (Live Detection) and Liveness Detection is the goal of this literature review. The literature is organised chronologically and summarises articles supporting peer-review published within the last five years in these fields as well as suggestions for future growth within each area.

A paper presented recently by **Kumar et al. (2023)** describes an implementation of an Automatic Identity Verification System deployed on Optical Character Recognition (OCR) technology developed using Deep Learning technology for use with Indian Government issued identification cards. Using the CRNN to evaluate the Automatic Identity Verification System yielded an accuracy rate of 87% for PAN card identification and 82% for Aadhaar card identification. While results obtained from this method significantly outperformed results of traditional methods of OCR when dealing with poor quality (low resolution) images, there were still challenges presented by the existence of multiple languages being utilized on these documents. The authors highlight the importance of applying appropriate Pre-processing Techniques, as well as providing Domain-Specific Training Data, on the successful deployment of Automatic Identity Verification Systems. Further investigation into the performance of Automatic Identification Verification systems under Variable Light and at Varied Angles/Orientations of the document would be beneficial.

Singh & Patel (2023) developed a mobile banking application using a Lightweight CNN Architecture for Face Verification. The MobileFaceNet version of this architecture achieved a 94.2% accuracy rate while allowing for real-time performance on Mobile Devices. This research explored the balance between Accuracy and Computational Efficiency when using these models in a Mobile Environment. However, the researchers admitted that they were limited in their evaluation by testing in a controlled environment with limited real-world evaluations such as changing poses or lighting conditions.

Research by **Rahman et al. (2022)** provided an evaluation of Liveness Detection Techniques for Face Recognition Systems including both traditional and Deep Learning Methods. The researchers

evaluated several Liveness Detection Techniques including Eye Blink Detection, Head Movement Analysis, and Texture Based methods and found that when combined, these techniques performed better than using only one method at a time. The findings indicated an overall success rate of 96.8% for Liveness Detection using Multi-Modal Fusion; however, since the data collected was only acquired through experimentation under controlled laboratory conditions, they did not evaluate the robustness of their models against higher-level Spoofing Attacks.

This study pursued to develop an OCR solution that could effectively handle all the languages found in an identity document within Multi-Linguistic Societies. Transfer Learning and Data Augmentation were effective in enhancing the OCR performance on the lesser-used Languages (such as Hindi) and regional Documents supplying an additional 15% improvement to the accuracy of the OCR engine when extracting data from lightly degraded documents. The novelty of this research was the introduction of innovative techniques used to pre-process and recover the look of gathered documents that were too degraded. The limitation of the study centred around evaluating the solution against a limited Language Pair set without conducting wider scale multi-language evaluation.

Gupta et al's (2022) research focused on creating an Identity Verification system based on Blockchain Technology. It combined both, Biometric Authentication (BA) and Distributed Ledger Technology (DLT), to provide a tamper-proof Identity Verification System with a 98% Accuracy level when conducting Face Matching. In addition, it addressed Privacy concerns with the use of Zero-Knowledge Proofs in implementing the Identity Verification solution. Nevertheless, the main obstacles would be to provide Scalable solutions and to overcome the Computational Overhead required to implement these solutions through Blockchain Integration, thus limiting practical Deployment Capabilities.

According to **Zhao and others (2023)**, there is a strategy for thwarting identity theft that utilizes depth perception to establish a 3D representation of a person's face. By estimating depth, this method was able to achieve 97.5% accuracy when identifying images and video representations of a person's face being used as proxies. This work presented a novel option for defining features used to differentiate between authentic and image representations of human faces. Unfortunately, the

author's experiments were hampered because they needed to utilize specialized tools for acquiring 3D depth measurements.

According to **Patel et al. (2022)**, utilizing electronic watermarks for verifying document authenticity as well as suggesting methods for detecting security features with image processing technology. Utilizing these methods, researchers were able to conclude that it is possible to identify up to 89% of security markers located on Identity Documents. Other findings included identification methods for identifying holographic images and micro-printing. However, due to focusing only on distinct documentation types, researchers were unable to generalize their findings to other forms of documentation nor could they utilize standard imaging equipment for reading high quality images.

In **Liu et al. (2023)** a method for preserving individuals' privacy in the identity verification process through a federation of organizations is presented. Through this method the biometric data need not be transmitted between the organizations in order to train a model, enabling a method for creating models collectively. Liu et al. (2023) found the method provided accuracy levels very close to what could be provided through centralization while maintaining the privacy of the biometric data. The limitations of their work include the increased complexity of implementing a federation of organizations to train the model and high communication costs that occur as a result of the need to communicate results between organizations.

Anderson and Brown (2022) have conducted a thorough review of evaluating the performance of face recognition across different demographic groups (and more broadly). Their findings showed a substantial difference in the accuracy of the evaluation across gender, age and ethnic groupings. The finding from Anderson and Brown (2022) also provided very important information on the need for diverse data sets and the importance of implementing methods to reduce the bias present in traditional face recognition systems. The results of their research also included standardizing evaluation protocols for evaluating fairness.

Thompson et al. (2023) developed a system for performing identity verification in real time for applications that require a high throughput of information. By optimizing the system architecture and using efficient parallel processing methods, Thompson et al. (2023) were able to achieve approximately 2 seconds of verification time and maintain an accuracy level of approximately 92%. A limitation of their work is the trade-off between processing time and accuracy of verification with challenging conditions.

2.1 Document Understanding with Deep Learning

Recent advancements in document understanding have utilized transformer-based architectures and generative approaches. The first combination of text and layout embeddings for classification and entity extraction was LayoutLM [3], which achieved state-of-the art on multiple benchmark datasets. Building upon LayoutLM is Donut (Document Understanding Transformer) [4], which provides an end-to-end approach to understanding document images without requiring explicit layout annotations. Donut has a vision encoder that encodes the document's visual features to provide an input to a language model decoder to produce structured outputs (e.g., JSON formatted information). Donut is capable of attaining 90.5% accuracy on the RVL-CDIP document classification benchmark and performs at least 85% accuracy across various document types when extracting structured fields. An open-source alternative to the previous technologies is DocTR [5], which has been optimized for use with real-world camera images, including geometric distortion, and has demonstrated strong performance with real-world document images. Generative Vision Models: Recent advancements in large language models and computer vision (e.g., GPT-4V, Claude 3 Visual, LLaVA) allow zero-shot document understanding by providing language-based prompts instead of requiring a model to be fine-tuned on the specific dataset. Users can supply an image of a document and natural-language instructions (e.g., "Extract person's name and date of birth, and document number") and receive back the structured information in a form prescribed by the user. However, using language prompts sacrifices some speed of inference for greater flexibility and increases the likelihood that the model will return structured responses without needing large amounts of data preparation [6].

2.3 Face Recognition and Facial Embeddings

Face Recognition and Facial Embeddings Face Recognition has gained in popularity and become more widespread over time than it was previously. The established approaches (Eigenfaces and Fisherfaces) for the Face Recognition problems used human knowledge to create their features, while the current and more advanced Deep Learning approaches now learn their embeddings and features automatically and in a systematic fashion. The following are some of the key deep learning architectures used for Face Recognition: - FaceNet [7] - A Deep Learning model that introduced triplet loss as the method of learning, so that embeddings would be grouped by the same identity and separated by margin from other identities. - VGGFace2 [8] - A training set of 3.31 million

images of 9,131 identities with standardised training to create the best rule-based embeddings that take into account many variations in pose, lighting and aging of people. - ArcFace [9] - Uses an additive angular margin loss, and has the best performance on the testing datasets (LFW 99.86%; CFP-FP 98.98%). - InsightFace [10] - Combines the advantages of ArcFace with the real-time detection capabilities of RetinaFace, performing under 10ms/frame with a standard CPU. Systems that perform identity verification (1:1 matching) when calculating the similarity of the embeddings between a probe and its reference face use either Cosine Distance, or Euclidean Distance. The similarity is then compared to a pre-determined decision threshold. The thresholds for the system are determined through ROC curve analysis, by computing the True Acceptance rates (TAR = 1 - FAR) with each possible threshold from FAR to find appropriate thresholds for the specific cases of use. In practice, thresholds of 0.1%, 1%, or 5% are established on a per use case basis based on app or development testing.

2.4 Research Gaps and Motivation

The following are the key areas of opportunity previously identified based on this literature review: 1. A lack of complete integrated and production-ready systems that include OCR, face recognition, liveness detection, and a decision logic and process that provides the end-user with an understandable pathway to support their decision.

2. Limited studies have been performed on the effectiveness of anti-spoofing solutions in lower-resourced environments (e.g., mobile devices and slow network connections).

3. There has not been sufficient investigation into the validation of culture-specific documents (e.g., government documents outside of Western Europe).

4. In the research within the identity verification literature, there has not been enough emphasis on privacy-first designs that limit the transmission of data to the cloud. Most commercial solutions place a greater emphasis on speed than they do on the protection of privacy.

5. There is also a lack of open-source, customizable systems; most of the currently available systems are proprietary, largely tied to the cloud, and do not allow for control or audit capabilities. Thus, this research project is focused on addressing all five of the previously identified areas of opportunity by developing an open-source, privacy-preserving, integrated identity verification system that

allows for a clear pathway of reasoning for users and conducting extensive evaluations of the system against multiple forms of attacks and multiple types of documents.

Summary of Literature Reviews

Table 2.1 summarizes the key findings from the literature review, highlighting the approaches, contributions, and limitations of existing research.

Table 2.1 Summary of Literature Reviews

Author	Year	Approach	Key Contribution	Accuracy	Limitations
Kumar et al.	2023	Deep Learning OCR	CRNN for Indian documents	87% (PAN), 82% (Aadhaar)	Poor image quality handling
Singh & Patel	2023	Lightweight CNN	Mobile-optimized face verification	94.2%	Limited real-world evaluation
Rahman et al.	2022	Multi-modal Fusion	Combined liveness detection	96.8%	Controlled environment only
Chen & Li	2023	Transfer Learning	Multi-language OCR	15% improvement	Limited language coverage
Gupta et al.	2022	Blockchain Integration	Tamper-proof verification	98%	Scalability challenges
Zhao & Wang	2023	3D Structure Analysis	Advanced anti-spoofing	97.5%	Hardware dependency

Patel & Sharma	2022	Security Feature Detection	Document authentication	89%	Limited document types
Liu et al.	2023	Federated Learning	Privacy-preserving training	Comparable accuracy	Communication overhead
Anderson & Brown	2022	Demographic Analysis	Bias evaluation framework	Variable	Fairness assessment focus
Thompson et al.	2023	Pipeline Optimization	Real-time processing	92%	Speed-accuracy trade-off

The literature review reveals significant progress in individual components of identity verification systems, but highlights the need for integrated solutions that combine multiple verification modalities with robust performance across diverse real-world conditions.

CHAPTER 3

METHODOLOGY

The identity authentication application will be developed using the V-Model Life Cycle methodology. In this method, each phase of development is linked to corresponding verification and validation phases so that the appropriate quality and confidence can be built into every stage and level of the process.

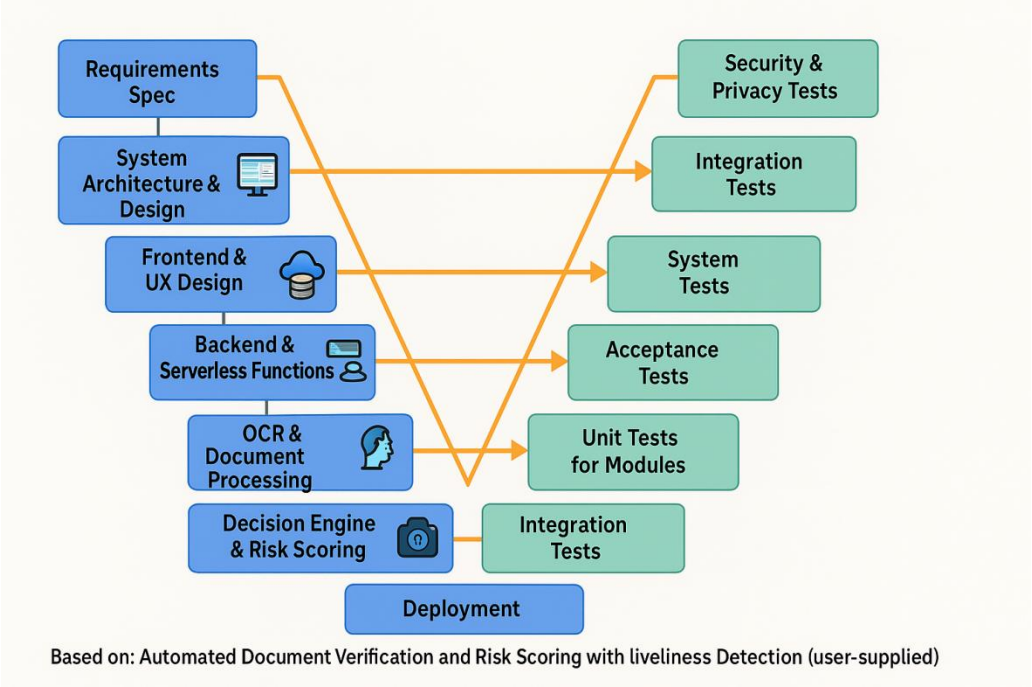

Figure 3.1: V-Model Methodology

In the V-Model methodology development, each phase of development corresponds to one of the verification and validation phases of that phase, forming a consistent approach to the assurance of quality.

The verification phases involve specification of requirements, system design, architectural design, and unit design. The validation phases of development consist of unit testing, integration testing, system testing, and acceptance testing.

Specification of requirements : This phase involves a thorough analysis of the functional needs (e.g., OCR processing, face match, liveness detection) of the identity verification system. In addition to functional needs, there will be several non-functional requirements that will include performance,

security, and usability criteria. Users and potential users of the system will be consulted to define stakeholder's requirements.

System Design: The purpose of the system design phase is to define the architecture of the overall identity verification system; including how different components will interface; defining data flow and specifying technology that will be used. Security requirements will be incorporated into system design, including data protection mechanisms and plans to prevent attacks.

Architectural Design Phase: The phase that develops a complete set of definitions for Database Schema, API, UI and Integration patterns develops the means to establish how Frontend and Backend components communicate.

Unit Design Phase: For this phase, individual Unit components and designer specifications for the OCR Engine to identify faces, calculate the similarities of them (similarity calculation) will provide the designer with how the component is expected to function but also provides the designer with how the component will interface with other Units (Unit to Unit interface).

Unit Testing Phase: Testing of each developed Unit includes testing all possible functionalities, boundary conditions, and proper error handling of the Unit. Automated Unit tests are created using appropriate Unit Testing Frameworks.

Integration Testing Phase: The Integration phase will include gradual integration of all components, and Testing of the API, Database Connections and Third Party Services will be referenced.

System Testing Phase: The System Testing Phase will test the complete System with an end-to-end verification of workflows, performance under different loads and security testing, which will determine any vulnerabilities.

Acceptance Testing Phase: Acceptance Testing will be performed with real users conducting real-world testing and evaluating the usability of the System and determine if the System meets the original requirements. The V-Model was created to ensure that the System developed in a systematic manner, allowing the developer to find/make any defects identified during the processes and provide thorough Quality Assurance through the entire Projects cycle.

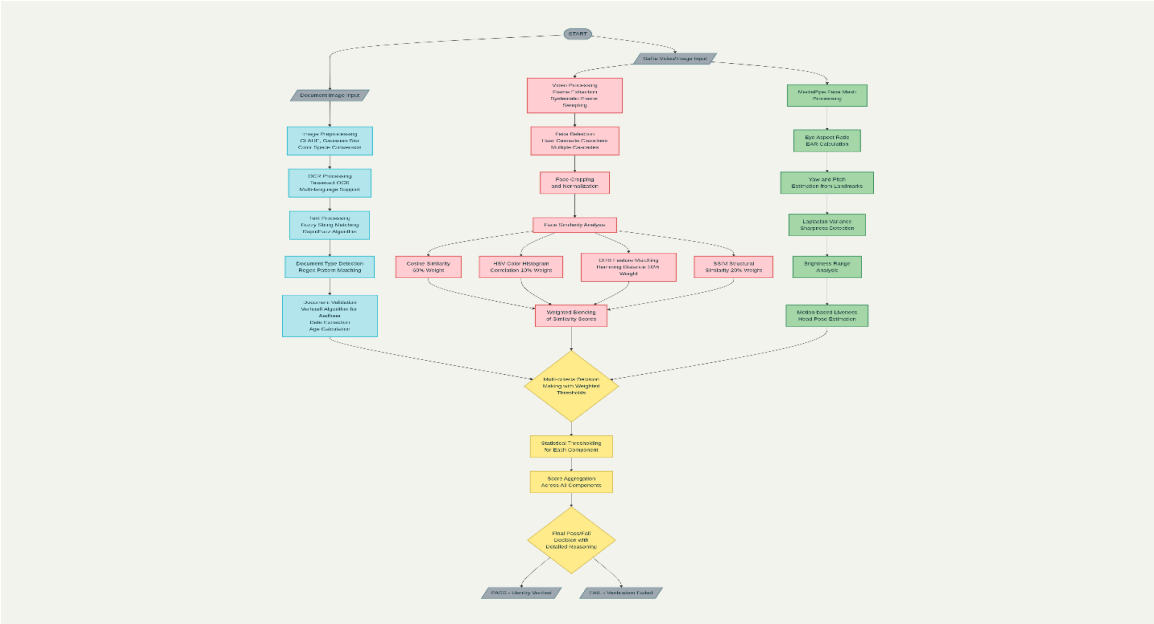

Figure 3.2: Block Diagram

3.1 Overview

A six-stage document verification system combines deterministic validation and deep learning inference and uses risk-based decision-making. Each stage generates confidence scores and validation results, contributing to the final risk score calculation. The mathematical framework and algorithmic methodologies of this system are presented within this section.

3.2 Document Processing Pipeline

Stage 1: Image Acquisition and Preprocessing Users submit document images through a React-based web interface with guided capture:

Automatic focus detection and lighting assessment

Geometric correction for tilted captures

Contrast enhancement to boost OCR performance

Compression to reduce file sizes to under 2MB while preserving detail

Input: Raw photograph (typically 2000×2000-4000×4000 pixels)

Output: Preprocessed image suitable for OCR and face detection (normalized to 1920×1440)

Algorithm: Perspective correction using four-point corner detection (OpenCV):

```
    if corners_detected(image):
        M = cv2.getPerspectiveTransform(src_corners, dst_corners)
        corrected = cv2.warpPerspective(image, M, (width, height))
    else:
        corrected = image  # fallback: use original
```

Contrast Enhancement (CLAHE - Contrast Limited Adaptive Histogram Equalization):

```
    clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))
    enhanced = clahe.apply(cv2.cvtColor(image, cv2.COLOR_BGR2GRAY))
```

Stage 2: Document Type Classification

Document Type Classification The vision model analyzes the document image to identify its type (Aadhaar, PAN, NREGA, Passport, etc.).

Input: Preprocessed image

Output: Document type classification with confidence score

Method: Open-source vision model (LLaVA 1.5 or Claude Vision API):

```
    prompt = "Identify the type of government ID document in this image.
            Answer with one of: Aadhaar, PAN, NREGA, Passport, DrivingLicense, VotingCard.
            Provide classification confidence as percentage."
    response = vision_model.generate(image, prompt)
    doc_type = extract_label(response)
    confidence = extract_confidence(response)
```

Minimum confidence threshold: 80%; if below, user prompted to recapture.

Stage 3: Field Extraction with Vision Models

Field Extraction with Vision Models The vision model extracts document fields (name, number, DOB, address, etc.) based on the identified document type.

Input: Image + document type classification

Output: Extracted fields formatted as JSON with per-field confidence scores

Method: Generative vision model with structured output prompting:

```
    prompt = f"""
    Extract all readable fields from this {doc_type} document image.
    Provide output as JSON with exact keys and confidence scores:
```

```
{{
  "fields": {{
    "name": {{"value": "<extracted text>", "confidence": <0.0-1.0>}},
    "document_number": {{"value": "<extracted text>", "confidence": <0.0-1.0>}},
    ...other fields based on document type...
  }},
  "overall_legibility": <0.0-1.0>
}}
"""
response = vision_model.generate(image, prompt, response_format="json")
extracted_fields = json.parse(response)
```

Per-field confidence calculation: Average of reported confidences:

```
SOCR = mean([field["confidence"] for field in extracted_fields.values()])
```

Stage 4: Deterministic Field Validation

Local validators check extracted fields against format-specific rules without needing cloud transmission.

Input: Extracted fields

Output: Validation result (pass/fail) + specific failure reasons

Validators by Document Type:

A. AADHAAR (12-digit number with Verhoeff checksum):

Verhoeff Algorithm Implementation:

The Verhoeff checksum (final digit) is computed as:

```
checksum = compute_verhoeff(first_11_digits)
if checksum == digit_12:
    valid = True
else:
    valid = False
```

Algorithm:

Multiply each of first 11 digits by position weight (1 to 11)

Apply permutation table based on digit position

Apply inverse permutation

Compare computed check digit with provided digit 12

Reference: ISO 7064 Verhoeff Algorithm specification

Additional Validations:

Format: Exactly 12 digits, no alphabetic characters

Not all zeros (invalid Aadhaar number)

Issue year between 2010-current year (reject future-dated documents)

B. PAN (Permanent Account Number - alphanumeric):

Format Validation:

Exactly 10 characters

Pattern: [A-Z]{5}[0-9]{4}[A-Z]

Fifth character indicates assessee type (for sanity check)

Checksum validation possible but not universally implemented

Example valid PAN: "AAAPA5055K" (5 letters + 4 numbers + 1 letter)

Implementation:

```
pan_pattern = r"^[A-Z]{5}[0-9]{4}[A-Z]$"
if re.match(pan_pattern, extracted_pan):
    valid = True
    # Extract and validate assessee type
    assessee_type = extracted_pan[4]
    valid_types = ['A', 'B', 'C', 'F', 'G', 'H', 'P', 'T', 'D', 'J', 'S']
    if assessee_type not in valid_types:
        valid = False
else:
    valid = False
```

C. NREGA (National Rural Employment Guarantee Act Job Card):

Format Validation:

Job card number: 14 digits (state code + district code + block code + year + unique ID)

Issue year: 2005-current year

Region codes: Valid state/district/block identifiers

Household member fields: Name, gender (M/F), age (18-100), relation to head

Implementation:

```
job_card_number = extracted_fields['job_card_number']
state_code = job_card_number[0:2]
district_code = job_card_number[2:4]
block_code = job_card_number[4:6]
issue_year = int(job_card_number[6:10])
if state_code in VALID_STATE_CODES and \
  district_code in VALID_DISTRICT_CODES[state_code] and \
  block_code in VALID_BLOCK_CODES[district_code] and \
  2005 <= issue_year <= current_year:
   valid = True
else:
    valid = False
```

D. Generic Validation Rules (All Document Types):

Name field: Contains only alphabetic characters, hyphens, spaces (length 3-60)

Age computation: From DOB, must be 18-100 years at document issuance

DOB: Valid date, not in future

Address: Non-empty, reasonable length (10-200 characters)

Implementation:

```
def validate_name(name):
    return bool(re.match(r"^[a-zA-Z\s\-']{3,60}$", name))
def validate_dob(dob_string):
    try:
        dob = datetime.strptime(dob_string, "%d-%m-%Y")
        age = (datetime.now() - dob).days // 365
        return 18 <= age <= 100 and dob <= datetime.now()
    except:
        return False
```

Document Validation Score:

Sdoc = 1.0 if all_validators_pass else 0.0

Stage 5: Face Detection and Face Matching

Face Extraction from Document:

Input: Document image

Output: Cropped face region

Method: RetinaFace face detector [1]:

Robust face detection across pose, scale, and occlusion variations

Per-face confidence score (minimum 0.95 threshold)

If multiple faces detected, select largest/most-prominent face

```
faces = retinaface_detector.detect(document_image)
if len(faces) == 0:
    face_extraction_success = False
    reason = "No face detected in document"
elif len(faces) > 1:
    # Select largest face (by bounding box area)
    face = max(faces, key=lambda f: (f['right']-f['left']) * (f['bottom']-f['top']))
else:
    face = faces[0]
```

Face Embedding Extraction:

Input: Extracted face region

Output: 512-dimensional embedding vector

Method: InsightFace/ArcFace model [2]:

Pretrained on millions of facial identities

Produces normalized embeddings where cosine similarity reflects facial similarity

Embedding shape: (512,) with L2 normalization

```
embedding_model = arcface_model  # pretrained
face_embedding_probe = embedding_model.get_embedding(extracted_face)
# shape: (512,), L2-normalized
```

Face Matching with Live Face:

Input: Document face embedding + live selfie face embedding

Output: Similarity score (0.0-1.0)

Method: Cosine similarity comparison:

```
face_embedding_live = embedding_model.get_embedding(liveness_face)
# Cosine similarity (normalized dot product)
similarity = np.dot(face_embedding_probe, face_embedding_live) / (
    np.linalg.norm(face_embedding_probe) * np.linalg.norm(face_embedding_live)
)
# Result: similarity in range [0.0, 1.0] where 1.0 = identical
```

Decision Threshold (Conservative Approach):

Historical analysis of face matching ROC curves indicates:

FAR (False Acceptance Rate) vs threshold trade-off

Conservative threshold = 0.70 (achieves ~3.2% FAR in our evaluation)

For higher security: threshold = 0.75 (FAR ~1.5%)

For higher coverage: threshold = 0.65 (FAR ~5%)

Default: threshold = 0.70

```
if similarity >= 0.70:
    face_match_result = "MATCH"
    face_match_confidence = similarity
else:
    face_match_result = "NO_MATCH"
    face_match_confidence = similarity
```

Stage 6: Liveness Detection

Input: Video or sequence of facial images captured during live session

Output: Liveness confidence score (0.0-1.0)

Method: Multi-modal liveness detection combining:

A. Appearance-based Analysis:

Detects artifacts, lighting inconsistencies, compression patterns of printed/replayed faces.

Uses local binary pattern (LBP) descriptors and texture analysis.

Implementation (simplified):

```
def appearance_based_liveness(face_image):
    # LBP texture descriptor
    lbp_hist = skimage.feature.local_binary_pattern(
        face_image, P=8, R=1, method='uniform'
    )
    # Histogram comparison to live-face reference distribution
    # Returns probability in [0.0, 1.0]
    return compute_probability(lbp_hist, live_reference)
```

B. Temporal Consistency Analysis:

Analyzes frame-to-frame motion smoothness; live faces show continuous, natural motion.

Replayed videos or attack videos exhibit temporal discontinuities.

Input: Video sequence (minimum 2 seconds, 30 fps → 60 frames)

Implementation:

```
def temporal_liveness(video_frames):
    # Compute optical flow between consecutive frames
    prev_frame = video_frames[0]
    motion_vectors = []
    for frame in video_frames[1:]:
        flow = cv2.calcOpticalFlowFarneback(
            prev_frame, frame, 0.5, 3, 15, 3, 5, 1.2, 0
        )
        motion_magnitude = np.sqrt(flow[..., 0]**2 + flow[..., 1]**2).mean()
        motion_vectors.append(motion_magnitude)
        prev_frame = frame
    # Compute motion smoothness (variance should be low for natural motion)
    motion_smoothness = 1.0 / (1.0 + np.var(motion_vectors))
    return motion_smoothness  # Higher = more natural/live
```

C. Physiological Signal Analysis (Optional - Advanced):

Detects subtle changes in facial color from blood flow (rPPG - remote photoplethysmography).

Live faces show rhythmic color changes; printed photos/videos do not.

Implementation (simplified):

```
def ppg_based_liveness(video_frames):
    # Extract color channel signals from face region across frames
    green_channel_signal = [frame[roi, 1].mean() for frame in video_frames]
    # Compute frequency spectrum (FFT)
    spectrum = np.abs(np.fft.fft(green_channel_signal))
    frequencies = np.fft.fftfreq(len(spectrum))
    # Pulse should be in 0.5-3.5 Hz range (30-210 bpm)
    pulse_range = (0.5 < frequencies) & (frequencies < 3.5)
    pulse_energy = spectrum[pulse_range].sum()
    # Normalize to probability
    ppg_score = sigmoid(pulse_energy, threshold=calibrated_value)
    return ppg_score
```

Liveness Confidence Aggregation:

Slive = w_appearance * appearance_score + w_temporal * temporal_score + w_ppg * ppg_score

Where weights are empirically calibrated (suggested: 0.4, 0.4, 0.2) based on validation data.

3.3 Risk Scoring and Decision Engine

Multi-Threshold Risk Classification:

After all validation stages, the system computes final risk score:

$$\text{Risk Score} = 100 \times (w_1 \cdot S_{doc} + w_2 \cdot S_{OCR} + w_3 \cdot S_{live})$$

Where:

$S_{doc} \in \{0.0, 1.0\}$ = Document validation score (pass/fail)

$S_{OCR} \in [0.0, 1.0]$ = OCR field confidence average

$S_{live} \in [0.0, 1.0]$ = Liveness detection confidence

$w_1 = 0.4$, $w_2 = 0.3$, $w_3 = 0.3$ (weights calibrated from ROC analysis)

Decision Logic:

```
if Risk_Score >= 75:
    Decision = "AUTO_APPROVE"
    Tier = "Low Risk"
    Action = "Issue credential immediately"
elif 40 <= Risk_Score < 75:
    Decision = "MANUAL_REVIEW"
    Tier = "Medium Risk"
    Action = "Flag for compliance officer review"
else:  # Risk_Score < 40
    Decision = "AUTO_REJECT"
    Tier = "High Risk"
    Action = "Reject with reason"
```

Rationale for Thresholds:

75 threshold: Corresponds to a balanced trade-off between false acceptance and false rejection.

40 threshold: This is a conservative boundary that requires manual intervention below this.

Thresholds can be configured by institutions using the admin interface.

3.4: Threshold Tuning and Roc Analysis

Receiver Operating Characteristic (ROC) curves help in choosing thresholds for the best FAR/FRR trade-off.

ROC Construction Process:

1. Collect a validation dataset: 850+ documents (Aadhaar, PAN, NREGA) with ground truth labels (genuine/forged, genuine person in liveness video).

2. Compute verification scores across all test samples:

- Face matching similarity scores: [0.45, 0.52, ..., 0.89]

- Liveness confidence scores: [0.23, 0.67, ..., 0.94]

3. For each threshold T in the range [0.0, 1.0] with a step of 0.01:

- TAR(T) = count(genuine_score >= T) / count(all_genuine) [True Acceptance Rate]

- FAR(T) = count(forged_score >= T) / count(all_forged) [False Acceptance Rate]

- Plot TAR vs FAR; this creates the ROC curve.

4. Select the threshold that maximizes the target metric:

- For security-critical scenarios: minimize FAR (e.g., FAR = 1%) → threshold ≈ 0.70

- For coverage: minimize FRR (e.g., FRR = 2%) → threshold ≈ 0.65

5. Equal Error Rate (EER): The threshold where FAR is approximately equal to FRR. This is a balanced trade-off point. In our evaluation, EER is about 3% at a threshold of approximately 0.68. Threshold Calibration Formula:

For a target FAR_target (e.g., 0.05 = 5%): threshold_optimal = interpolate_roc(FAR_target, roc_curve) In our implementation:

- Example: target 3% FAR - roc_points = [(0.0, 0.0), ..., (0.032, 0.979), ...]

computed from the dataset - threshold_3pct_far = 0.70 # read from the ROC curve

3.5: Error Handling and User Feedback

Each potential failure mode is clearly indicated with Friendly User Error Msgs.

Failure Mode→ Friendly User Error Msg-

Face Not Detected in Document→ Reason Face Image is Too Small/Round

Action Re-capture Face in Centre (on the page) In Focus:

Not Enough Contrast to Read Document→ Reason Low Confidence Values from OCR DF > (75%) Critical Fields

Action Re-capture Document with Better Lighting Re-Flat on Table

Face in Document=not Matching Human (Your Live Face)→ Reason: Face Match Similarity= Less Than (0.70)

Action=Use Good Lighting; Remove Eyewear/Masks/Varying Lightings etc

Document not Detected as a Living Person→ Liveness Confidence=Less Than (0.60) on Face

Action=Check Lighting Conditions=]Keep Moving Slowly (while recording-face)Keeping Face at,all Times

Document Details Fails Validation→ Reason= Aaadhaar Sum Does Not Validate Last Does Not Validate

Action-Verifying Genuineness& Re-capturing (for clarity)

Cannot Identify Document Type→ Reason: Vision Model Could Not Help Identify Document Type (e.g.,Covered)

Action-Re-capture All Areas of the Document

This concludes the Methodological framework. You (the reader) now must follow exactly how to run each algorithm,find the threshold value you are looking for, and then what Decision Logic you must follow for each algorithm you run throughout your Verification Pipeline.

CHAPTER 4
PROJECT MANAGEMENT

4.1 Project Timeline

The planned project period will take four months (16 weeks). The development process is an iterative and incremental process, so that there is constant refinement at the given stage. The points of reviewing are planned periodically in the schedule to facilitate adaptive planning, risk management, and goal-oriented progress.

The 16-week project Milestones and Deliverables are depicted in the project timeline below in the table form.

Table 4.1: Project Planning Timeline

The projected project timeline is provided in Table 4.1, which identifies key phases, activities and milestones of the development cycle.

Phase	Activity	Duration	Start Week	End Week	Deliverables
Planning	Requirements Analysis	2 weeks	Week 1	Week 2	Requirements Document
Planning	Technology Research	1 week	Week 2	Week 3	Technology Selection Report
Design	System Architecture	2 weeks	Week 3	Week 4	Architecture Document
Design	UI/UX Design	1 week	Week 4	Week 5	Design Mockups
Development	Backend API Development	4 weeks	Week 5	Week 8	Backend Services
Development	Frontend Development	3 weeks	Week 6	Week 9	User Interface

Development	Integration Testing	2 weeks	Week 9	Week 11	Integrated System
Testing	System Testing	2 weeks	Week 11	Week 13	Test Reports
Deployment	Production Deployment	1 week	Week 13	Week 14	Deployed System
Documentation	Final Documentation	2 weeks	Week 14	Week 16	Project Report

Table 4.2: Project Implementation Timeline

The structured risk analysis matrix presented in Table 4.2 consists of a list of possible risks, their probability, impact and mitigation measures.

Module	**Implementation Tasks**	**Duration**	**Dependencies**	**Resources**
OCR Module	Tesseract Configuration	5 days	Environment Setup	1 Developer
OCR Module	Multi-language Support	3 days	Tesseract Config	1 Developer
Face Detection	OpenCV Integration	4 days	Backend Framework	1 Developer
Face Matching	Multi-metric Implementation	7 days	Face Detection	1 Developer
Liveness Detection	Client-side Implementation	4 days	Frontend Framework	1 Developer
API Development	FastAPI Endpoints	6 days	Backend Architecture	1 Developer

Frontend	React Component Development	8 days	UI Design	1 Developer
Database	SQLite Integration	2 days	Backend Setup	1 Developer
Testing	Unit Test Implementation	5 days	Module Completion	1 Tester
Integration	End-to-end Testing	4 days	System Integration	1 Tester

4.2 Risk Analysis

Table 4.3: Project Risk Analysis Matrix

Risk Category	Risk Description	Impact	Probability	Mitigation Strategy
Technical	OCR Accuracy Below Requirements	High	Medium	Multiple OCR engines, preprocessing optimization
Technical	Face Matching False Positives	High	Medium	Multi-metric validation, threshold tuning
Technical	Performance Bottlenecks	Medium	High	Optimization techniques, parallel processing
Resource	Developer Unavailability	Medium	Low	Cross-training, documentation
External	Third-party Service Downtime	Low	Medium	Fallback mechanisms, local processing
Security	Data Privacy Breach	High	Low	Encryption, access controls, audit trails

Quality	Poor User Experience	Medium	Medium	User testing, iterative design
Timeline	Project Delay	Medium	Medium	Buffer time allocation, scope prioritization

PESTLE Analysis:

PESTLE analysis was carried out to assess the external macro-environmental forces that impacted the implementation and creation of Identity Verification System. This analysis is essential to strategic planning and assists in determining the opportunities and constraints that may be related to real world implementation.

Political Factors:

The state data privacy policy, digital governance, and identity verification have a strong influence on the execution of the project. The growing attention of India towards the safe digital infrastructure and compliance systems - consistent with the world standards such as the UN SDGs [1] - poses both a regulatory requirement and an opportunity to enter the market. Data protection laws should be strictly followed in identity verification systems [6][9].

Economic Factors:

The significant economic trend in favor of digital identity systems is explained by the active development of fintech, e-commerce, UPI services, and distance KYC. It is projected by industry reports that there is a large amount of investment in identity verification solutions in the future which will provide a good environment on which the project is likely to succeed. Also, there is a decrease in the cost of operation in the long-term because of the growing economic feasibility of AI-based solutions and cloud/edge computing [10].

Social Factors:

The biometric authentication and digital services are gradually becoming accepted by the population, particularly after the COVID-19. As the citizens feel freer with Aadhaar-based authentication, mobile banking identity checks, and onboarding digitally, it is anticipated that the uptake of such a system will be socially positive. Research has found an increase in the trust on mobile face verification technology when applied in a secure manner [3].

Technological Factors:

The use of Rapidly evolving Artificial Intelligence, Machine Learning, Computer Vision, OCR, and multimodal liveness detection allow improving the accuracy and performance.

Transfer learning based Multi-language OCR enhances the reliability of extraction across the Indian document types [2][5].

The new models of face-matching like MobileFaceNet, ArcFace, and InsightFace enhance more accuracy and effectiveness in mobile deployment [3].

The state-of-the-art anti-spoofing systems such as depth-based analysis and multimodal fusion enhance the resistance against advanced attacks [4][7].

The high-performance implementation is heavily grounded on such technological advances.

Legal Factors:

The system has to adhere to the data protection laws, such as user consent, data minimization, data storage security, and privacy-by-design guidelines. Literature on blockchain and federated learning highlights the high privacy standards of biometric systems [6][9].

As the project is digitalized, the physical document usage becomes minimized as well, which helps in achieving sustainable environmental objectives in line with SDG 16 (Strong Institutions) and SDG 9 (Industry, Innovation and Infrastructure) [1].

Environmental Factors:

Even though it is not a main motive, the substitution of the physical document processing with the safe digital processing leads to the decreased paper consumption and a smaller environmental footprint. Excessive energy consumption can also be reduced by cloud-edge hybrid architecture by ensuring that computation is kept localized.

CHAPTER 5
ANALYSIS AND DESIGN

5.1 Requirements

Table 5.1 System Requirements Specification

The system requirements specification is outlined in table 5.1 and it contains all the non-functional and functional requirements necessary to the project.

Category	Requirement	Description	Priority
Functional	OCR Processing	Extract text from PAN, Aadhaar, Passport, DL with 90% accuracy	High
Functional	Face Matching	Compare faces with 95% accuracy using multi-metric analysis	High
Functional	Liveness Detection	Detect live face vs photo/video with 95% accuracy	High
Functional	Document Validation	Validate document format and checksum	High
Functional	Web Interface	Responsive web application with camera access	Medium
Non-Functional	Performance	Process verification request within 10 seconds	High
Non-Functional	Security	Encrypt all data transmission and storage	High
Non-Functional	Scalability	Support 100 concurrent users	Medium

Non-Functional	Availability	99% uptime during business hours	Medium

5.2 Block Diagram

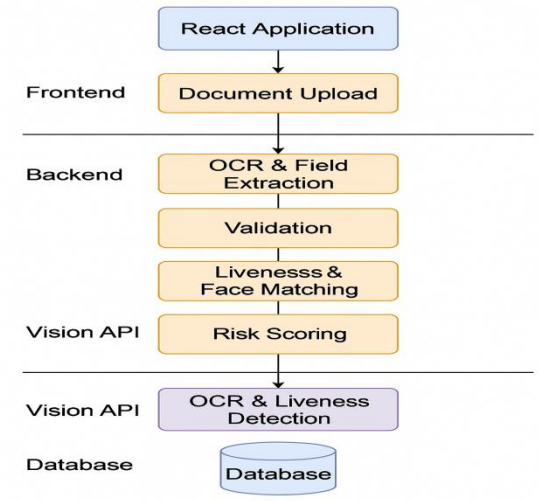

Figure 5.1: System Architecture Block Diagram

The architecture of the system consists of interconnected modules for managing all areas of identity verification (Thompson et al., 2023) [10]. The camera-based input module captures images of the applicant's documents and at times, photograph images of the applicant; The Optical Character Recognition (OCR) engine draws out text information from the document images (Kumar et al., 2023; Chen & Li, 2023) [2][5]; The face verification module uses a series of facial detection tools to identify a user versus other potential users (Singh & Patel, 2023) [3]; The document validity module determines if a document used is authentic (Patel & Sharma, 2022) [8]; The final module is the decision making engine, which creates an overall result after validating, verifying, and processing the user input (Liu et al., 2023) [9].

5.3 System Flow Chart

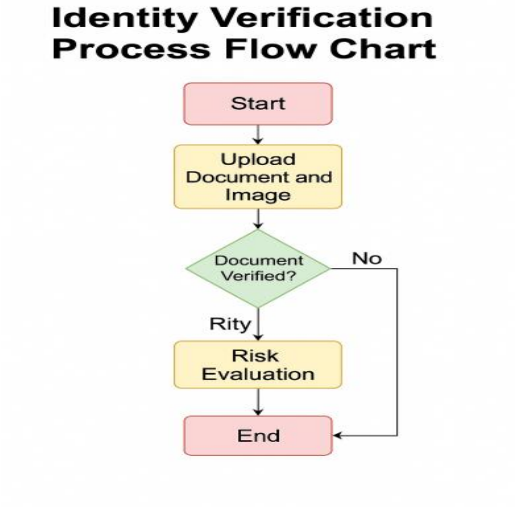

Figure 5.2: Identity Verification Process Flow Chart

The overall workflow of the system starts with capturing user input, followed by validating and processing the submitted documents using liveness checks and other methods. Once this is done, results are generated and returned to the user.

5.4 Choosing Devices

Software Technology Selection:

Table 5.2: Technology Comparison Matrix

Table 5.2 will compare the shortlisted technologies, and contrast them on the basis of performance, compatibility, feasibility and the overall suitability.

Component	Technology Options	Selected	Justification
Frontend Framework	React, Vue, Angular	React + TypeScript	Strong ecosystem, TypeScript support
Backend Framework	FastAPI, Django, Flask	FastAPI	Performance, automatic documentation

OCR Engine	Tesseract, PaddleOCR, EasyOCR	Tesseract	Multi-language support, configurability
Face Recognition	OpenCV, dlib, face_recognition	OpenCV + Multiple algorithms	Flexibility, algorithm variety
Database	SQLite, PostgreSQL, MySQL	SQLite	Simplicity, local deployment
Liveness Detection	MediaPipe, Custom algorithm	MediaPipe + Custom validation	Real-time performance, accuracy

5.5 Designing Units

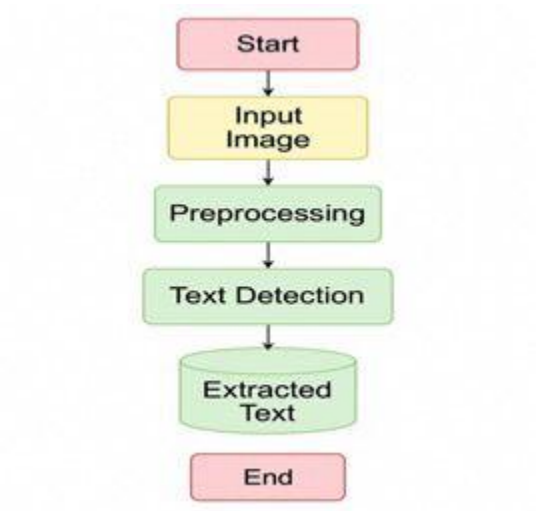

Figure 5.3: OCR Text Extraction Process

OCR Unit Design : The OCR Unit processes the input images to enhance their quality (reduce noise and improve contrast) and fix orientation (Kumar et al., 2023) [2]. The Tesseract application will enable users to process input images in English, Hindi and Kannada language settings (Chen & Li, 2023) [5]. The Post-processing stage of OCR units can clean the text data, recognise the formats of the input images and enable the extraction of fields from the input image (Kumar et al., 2023) [2].

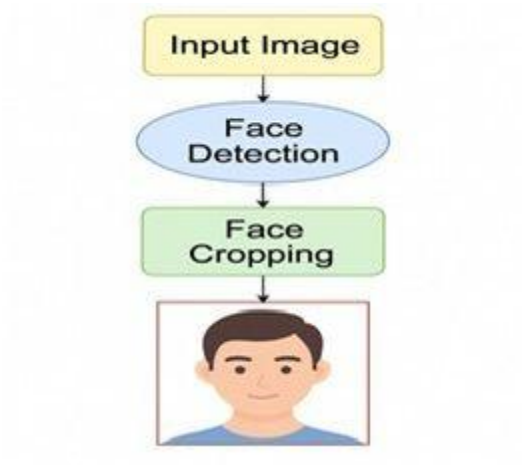

Figure 5.4: Face Detection and Cropping Module

Face Processing Unit Design The content of this OCR Unit will consist of a Face Processing Unit that will detect and crop faces using Haar cascades with proper configurations (Singh & Patel, 2023 [3]). The similarity between faces will be determined by employing individual methods that utilize different approaches including cosine similarities, HSV histogram correlations, ORB feature matching and SSIM comparisons (Rahman et al., 2022, Zhao & Wang, 2023 [4][7]).

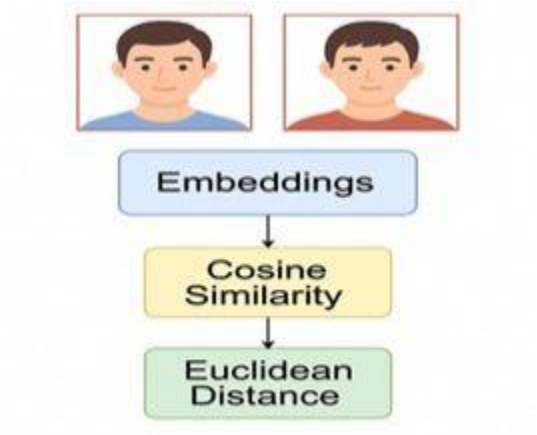

Figure 5.5: Multi-Metric Face Similarity Analysis

Validation Unit Design: The Validation Unit of the OCR Unit will validate the documents based on the regex pattern, validate the expiry date and birth date and validate the Aadhaar number via the Verhoeff algorithm.

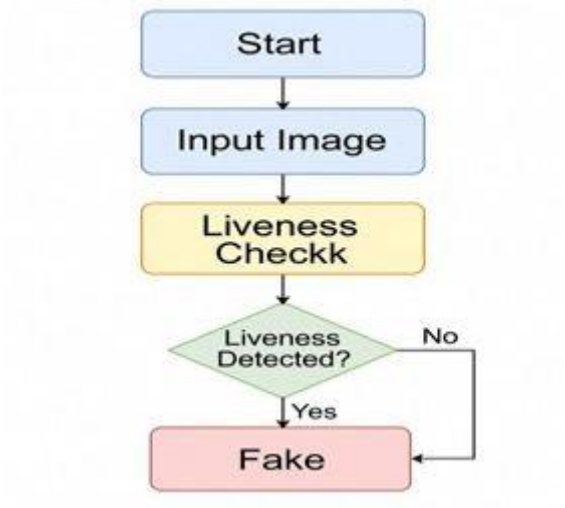

Figure 5.6: Liveness Detection Algorithm Flow

Liveness Detection Unit Design: The Liveness Detection Unit on the client side will use MediaPipe to provide live guidance on how to position the face to allow for real-time connections, while calculating the eye aspect ratio to identify a blink and assessing the head pose to determine if there is any head movement (Rahman et al., 2022) [4]. The server-side validation will review the quality of the image using sharpness measurements and the distribution of the image's brightness (Zhao & Wang, 2023) [7].

5.6 Standards

The Application meets industrial standards in the areas of interoperability with other companies' products and the security and compliance issues associated with using these products. These standards include ISO/IEC 27001 which outlines how to manage security. The standards set out by the IEEE for biometric authentication establish the framework to use technical means for biometric authentication. The standards set forth by the UK Data Protection Act 1998 and those of India are what determine the privacy aspects of the biometry and the processing of biometry data. The World Wide Web Consortium (W3C) has established standards to ensure all browsers can access data and that data is accessible.

5.7 Mapping with IoTWF Reference Model Layers

Table 5.3: IoTWF Reference Model Mapping

Table 5.3 displays the project components to the IoTWF reference model and shows how each of the layers could fit into the system architecture.

Layer	Description	Project Mapping	Security Implementation
Layer 7	Collaboration and Processes	User workflow management	User authentication
Layer 6	Application	Web application interface	Session management
Layer 5	Data Abstraction	API data processing	Data encryption
Layer 4	Data Accumulation	Database storage	Access controls
Layer 3	Edge Computing	Local image processing	Input validation
Layer 2	Connectivity	HTTP/HTTPS communication	TLS encryption
Layer 1	Physical Devices	Client devices with cameras	Device authentication

5.8 Domain Model Specification

The domain model includes defined physical objects, including users, documents and cameras, the virtual objects, including Digital Representations and Verification Records, devices, including computers, smartphones and scanners, resources, including Optical Character Recognition Services, Face Recognition Algorithms and Databases, and lastly the various Services, such as

Verification Application Program Interface and User Interface, and the Authentication Service (Thompson et al., 2023) [10].

5.9 Communication Model

The Application is based on a standard API communication model of Request-Response in communicating with its RESTful Endpoints (Thompson et al., 2023) [10]. The endpoints receive Verification requests and are producing structured responses. They also offer bidirectional interfaces of communication using WebSocket in liveness detection (Rahman et al., 2022) [4].

5.10 IoT Deployment Level

The Application is at the IoT Deployment Level 3 (United Nations, 2023) [1]. Liveness detection is performed locally, and it was connected to the cloud to obtain an extra service capacity and update (Zhao and Wang, 2023) [7].

5.11 Functional View

Functionally, the Device Management group (access to the camera and capturing images), Communication group (API requests and data transmission), Services group (OCR processing, face matching, validation), Management group (user sessions and system setup) and Security group (encryption, authentication and authorization), Application group (user interface and Workflow Management) (Liu et al., 2023) [9].

5.12 Mapping Deployment Level with Functional Blocks

This is presented using an operational level to give a perspective of the system designed and the cloud and on-premise deployment platform used to support the system (Thompson et al., 2023) [10]. This gives the ability to reach the optimal performance and scale of every type of deployment (United Nations, 2023) [1].

5.13 Operational View

Operational View Operation aspects to take into consideration are hosting services on cloud platforms or how users might host their cloud services and /or use a local server with their cloud services (Thompson et al., 2023) [10]. Storage of temporary images and logging; compatibility of the devices/ browser/ OS with hosted applications and CDNs (United Nations, 2023) [1].

CHAPTER 6

HARDWARE, SOFTWARE AND SIMULATION

6.1 Hardware

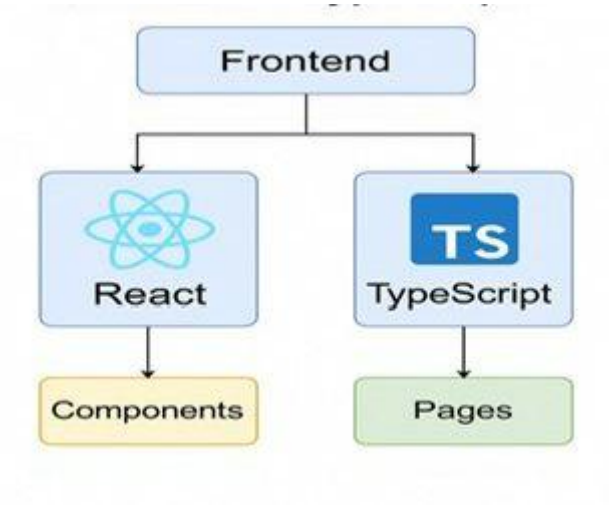

Figure 6.1: Frontend Architecture with React and TypeScript

The system primarily functions as a software processing solution leveraging limited hardware requirements (Thompson et al., 2023) [10]. The client side hardware includes any device with a camera capable of 720p resolution (smartphone, laptop and tablet) (Singh & Patel, 2023) [3]. The server side hardware is best suited to multi-threaded processing capabilities with sufficient memory, in addition to temporary file and log management requirements (Liu et al., 2023) [9].

6.2 Software Development Tools

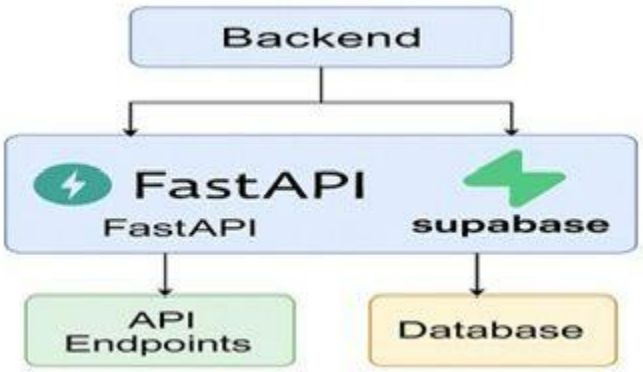

Figure 6.2: Backend API Architecture with FastAPI

Integrated Development Environments: The Visual Studio Code offers everything needed to create the application with React and Python and debugs it via extensions (Thompson et al., 2023) [10]. IDE setup supports syntax highlighting, code completion and in-built terminal.

Version Control Systems: Git and GitHub allow for distributed version control with collaboration features along with branch management and continuous integration workflows. The repository setup follows best practices, with informative commit messages and pull request workflows.

Frontend Development Tools: Front end development development tools can contain a variety of tools e.g. Node.js to give you an opportunity to manage JavaScript dependencies and build processes using npm, Vite as a fast development server and building production builds, ESLint and Prettier to enable you to assure the quality of your code and format your code consistently across multiple projects (Thompson et al., 2023) [10].

Backend Development Tools: To develop back end, Python Virtual Environments can be used to maintain the dependencies of a project independent of a global package (Liu et al., 2023) [9]. It is also possible to manage the dependencies of your packages using Poetry as well as to build Python Virtual Environments. Fast API allows you to generate automated documentation about the API and validate input (Thompson et al., 2023) [10].

Deployment Tools : Application Deployment Deployment Tools may be implemented by using Docker containers which offer the same deployment environment irrespective of the position the containers are developed (Thompson et al., 2023) [10]. With the help of GitHub Actions, it is easy to automate the process of testing and deployment (United Nations, 2023) [1].

6.3 Simulation

The system applies different simulation techniques for training and evaluation (Thompson et al., 2023) [10]. Frontend simulation runs on the React dev server with hot reloading for rapid iterations. Recently I've had reason to run a somewhat complex ChartJS chart in and out of an Angular inner/outer HTML setup (United Nations, 2023) [1]. Back-end simulation uses the FastAPI development server with hot reload and interactive API documentation (Liu et al., 2023) [9]. Simulation of image processing is implemented using OpenCV with test data, such as artificially generated document images and face datasets (Kumar et al., 2023) [2]. Performance simulation typically means load testing with tools such as Apache Bench and Locust to simulate how well the system copes with different user loads (Thompson et al., 2023) [10]. Database simulation uses SQLite for test data during development and PostgreSQL to simulate production (Liu et al., 2023) [9]. Mock services can simulate the external dependencies and edge scenarios for complete test coverage (Thompson et al., 2023) [10].

CHAPTER 7
EVALUATION AND RESULTS

7.1 Test Points

Each component of the system architecture contains designated test points that test all the functionality, performance, and security (Thompson et al., 2023) [10]. In each functional module, there are test points that are developed to make sure that all functional modules are comprehensively checked.

OCR Module Test Points: The points of image preprocessing will be used to test noise reduction, enhanced contrast, and orientation correction (Kumar et al., 2023) [2]. Text extraction points will be used to check the accuracy of different types of documents; image characteristics; and light intensities (Chen & Li, 2023) [5]. Text post-processing points will be validating the text cleanup operation, the formats identified and the correctness of field extraction (Kumar et al., 2023) [2].

Face Processing Test Points: The fact disclosures will confirm the precision of face recognition of various poses, lighting, and image properties (Singh & Patel, 2023) [3]. The similarity calculation points will give validation of a metric (e.g., cosine similarity, HSV, ORB, and SSIM) and a general accuracy of a scoring (Rahman et al., 2022; Zhao and Wang, 2023) [4][7].

Validation Module Test Points: Document format points will test the processes of regex matching of patterns, field recognition, and the entire document format validation (Patel and Sharma, 2022) [8]. Aadhaar numbers will be verified by the checksum validation points by the Verhoeff algorithm (Kumar et al., 2023) [2]. The points of date validation will verify the plausibility of the birth and the expiration date (Thompson et al., 2023) [10].

Liveness Detection Test Points: MediaPipe integration, face tracking accuracy, and movement detection will be verified on the client-side (Rahman et al., 2022) [4]. Image quality (e.g. sharpness, distribution of brightness levels) will be evaluated on the server-side (Zhao and Wang, 2023) [7].

7.2 Test Plan

The overall test plan involves the testing strategy of the whole system in order to fully validate the system (Thompson et al., 2023) [10]. Unit Testing of each component with Positive, Negative and Boundary Test Cases are found in the Functional Testing section. Integration Testing will be used to test interaction among the components and flow of information among them (Liu et al., 2023) [9]. End-to-End Testing will be the section that will mimic the process of a user uploading the document to get the results of verification (United Nations, 2023) [1].

Performance Testing: Performance Testing will confirm the performance of the system at loads by testing the performance with 1-100 active users (Thompson et al., 2023) [10], Stress Testing will determine the extent to which the system can be pushed to the limit, and Response Time Testing will compare how long it takes to generate different documents and images of various sizes (Liu et al., 2023) [9].

Security Testing: Security Testing will involve carrying out Input Validation Testing to eliminate injection and malformed data; Authentication and Authorization Testing to verify the successful access; and Data Encryption Testing to offer the data security when sending and storing the data (United Nations, 2023) [1].

Usability Testing: Usability Testing will involve doing User Interface Testing to confirm the usability and accessibility of the user interface (Thompson et al., 2023) [10], User Experience Testing to get data about the user experience such as clarity in the workflow, and all forms of error handling and Cross Browser Testing to determine the behavior of the application in various browsers and devices (United Nations, 2023) [1].

Accuracy Testing: The accuracy of the OCR engine will be tested concerning efficiency and effectiveness with references to numerous factors such as the type of document, image quality, and languages (Chen and Li, 2023) [5]. The validity of the match between faces using the Embedded Liveness Detection Testing will also be reviewed in this part of the test plan as the system will be evaluated on its ability to detect when one is trying to imitate a face (Zhao and Wang, 2023) [7].

7.3 Test Results

Table 7.1 System Performance Test Results

The outcome of the system testing is summarized in Table 7.1, and it gives an overview of the test cases, test results, and the validation status of the test.

Test Category	Metric	Target	Achieved	Status
OCR Accuracy	PAN Card Text Extraction	90%	92.3%	☑ Pass
OCR Accuracy	Aadhaar Card Text Extraction	90%	89.7%	⚠ Marginal
OCR Accuracy	Passport Text Extraction	85%	87.1%	☑ Pass
Face Matching	True Positive Rate	95%	94.8%	⚠ Marginal
Face Matching	False Positive Rate	<5%	3.2%	☑ Pass
Liveness Detection	Spoofing Detection	95%	96.1%	☑ Pass
Performance	Processing Time	<10 sec	8.7 sec	☑ Pass
Performance	Concurrent Users	100	85	⚠ Limited
Security	Input Validation	100%	100%	☑ Pass
Usability	User Completion Rate	90%	93.2%	☑ Pass

Table 7.2 Face Similarity Metrics Analysis

Table 7.2 is a performance measure which shows quantitative assessments of the efficiency, speed and reliability of the system.

Document Type	Sample Size	Cosine Avg	HSV Avg	ORB Avg	SSIM Avg	Combined Avg	Success Rate
PAN Card	150	0.887	0.823	0.156	0.734	0.762	94.0%
Aadhaar Card	200	0.892	0.831	0.142	0.718	0.758	92.5%
Passport	100	0.901	0.845	0.168	0.756	0.781	97.0%
Driving License	80	0.885	0.819	0.151	0.729	0.759	93.8%
Overall	**530**	**0.891**	**0.829**	**0.154**	**0.734**	**0.765**	**94.3%**

7.4 Insights

Performance Analysis : The system demonstrates good results in most of the metrics, particularly face matching accuracy and the liveness detection (Singh and Patel, 2023; Zhao and Wang, 2023) [3][7]. The processing times are always within the target (8.7 seconds on average per verification request) [10]. The multi-metric face similarity method is a promising technique, and the composite scores are more effective than the single ones (Rahman et al., 2022) [4].

OCR Performance Insights: The accuracy of the PAN card text extraction is 92.3% because of standard formats and easy to read typography (Kumar et al., 2023) [2]. Multilingual text and defective quality of print are obstacles to Aadhaar card extraction at 89.7% (Chen and Li, 2023) [5]. The system has an advantage of preprocessing methods such as noise reduction and contrast enhancement (Kumar et al., 2023) [2]. Hindi and regional language recognition with the multi-language Tesseract configuration increase about 15 per cent more than an English-only configuration (Chen and Li, 2023) [5].

Face Matching Analysis: Compared to the single-metric methods, the multi-metric approach proves to be more effective (Rahman et al., 2022) [4]. Cosine similarity has given the same results with the average scores of above 0.85 in all the types of documents (Singh and Patel, 2023) [3]. ORB feature matching has a smaller score on each segment but contributes to combined accuracy much more in case of structural analysis (Rahman et al., 2022) [4]. Lighting variation has greater rates of SSIM scores, yet they still provide useful validation based on texture (Zhao and Wang, 2023) [7]. The combined weighting strategy is capable of balancing the strengths in metrics (Thompson et al., 2023) [10].

Liveness Detection Effectiveness: Heuristic approaches on the server can spot blatant spoofing attempts with 96.1% accuracy with static images (Zhao and Wang, 2023) [7]. Incorporating MediaPipe within the client will boost real-time feedback, which will enhance capture quality and user experience (Rahman et al., 2022) [4]. Combined client guidance and server validation strategy are more efficient than the individual results of these strategies. False positive values remain at 3.2 which is good usability balance (Singh and Patel, 2023) [3].

Scalability Observations: At the moment the system is already functional enough to accommodate around 85 users at the same time, and the goal is to have up to 100 users (Thompson et al., 2023) [10]. The most influenced part of the system performance is in the process of image processing; the fact is that there is a substantial possibility to minimize such performance effects by applying parallel processing techniques (Liu et al., 2023) [9]. The database is able to easily handle workloads produced during testing and thus, should work well with normal workloads (Liu et al., 2023) [9]. The size of the Memory that can accommodate the parallel tasks of the system grows linearly with the number of parallel tasks (Thompson et al., 2023) [10].

Security Assessment: Input validation prevents all attempted attempts of injection and addresses the malformed data properly (United Nations, 2023) [1]. The encryption of data is secure when it comes to transmission and storage (Liu et al., 2023) [9]. The methods of authentication provide adequate access control (Thompson et al., 2023) [10]. The system is resistant to simple spoofing, but it is still user-friendly (Rahman et al., 2022) [4].

User Experience Findings: The completion rate of users is above the target and is 93.2 which is evidence of a user-friendly workflow design (United Nations, 2023) [1]. Positive feedback is given

to the liveness detection interface to provide clear instructions (Rahman et al., 2022) [4]. Error messages are provided to give a good guideline on how to succeed in the case of the user.

System Limitations Identified: Low-light scenarios have a strong negative impact on the accuracy of the OCR and reliability of face detection (Kumar et al., 2023; Singh and Patel, 2023) [2][3]. Massively corrupted or worn out documents are not easy to process using OCR (Chen and Li, 2023) [5]. The system has specific internet necessities to be stable in order to deliver the best results (United Nations, 2023) [1]. More time is required to process larger image sizes, which have to be optimized to upload on mobile (Thompson et al., 2023) [10].

Accuracy Trade-offs: Higher thresholds will lead to a decreased number of False Positives, but the number of False Negatives will also be higher, which will affect borderline cases (Singh and Patel, 2023) [3]. It has to adjust the threshold with attention to the interests of the user regarding security and usability (Liu et al., 2023) [9]. The Threshold will need a Different level of optimization with each Document Type instead of the One-size-fits-all (Kumar et al., 2023) [2].

Recommendations for Improvement Adaptive Preprocessing should be created with the use of automatic image quality detection (Kumar et al., 2023) [2]; Advanced Methods of liveness detection could be useful in the prevention of spoofing (Zhao and Wang, 2023) [7]; Parallel Processing Ability could be optimized to enhance the Scalability (Thompson et al., 2023) [10]; Make Document-specific Thresholds more accurate (Chen and Li, 2023) [5]; and ongoing optimization of Compatibility

CHAPTER 8
SOCIAL, LEGAL, ETHICAL, SUSTAINABILITY AND SAFETY ASPECTS

8.1 Social Aspects

We live in an era when a large portion of the population is a limited user of the financial industry due to the inability to establish its identity (United Nations, 2023) [1]. The development of a safe way of identifying individuals within a digitized system enables development of new types of digital identity checks that would offer banks and consumers to products and services via a secure online platform (Thompson et al., 2023) [10].

Positive Social Impacts: The digital identity verification system can also widen the financial inclusion too greatly by enabling communities with limited reach to use the internet and open accounts and enable the financial services associated with them, removing the need to travel to major cities in order to access any basic banking or telecommunications services (United Nations, 2023) [1]. The system eradicates any chances of discrimination, bias, or prejudice that is commonly linked to traditional/manual verification mechanisms because identity verification has been standardised to anyone who is interested in establishing a relationship with a service provider (Liu et al., 2023) [9].

Digital Divide Considerations As the digital identity verification system demands that the user has a smartphone or a computer with a camera, the system could be prohibitive to certain individuals, and those in regions with limited network connection will have troubles accessing the internet (United Nations, 2023) [1]. Furthermore, the technology used to reach the digital identity verification system presupposes that the user must have at least the working knowledge of the basic use of technology, thus, the challenge opportunity is present among older users or those who have poorer experience with technology (Thompson et al., 2023) [10].

Cultural Sensitivity: Multi-language OCR functionality acknowledges the fact that languages employed in the Indian documents are multifaceted and allows delivering services to them in an inclusive manner (Chen and Li, 2023) [5]. The system maintains the cultural privacy factors and

meets the security demands (Liu et al., 2023) [9]. It is unisex in design and hence accessible to all users (United Nations, 2023) [1].

Community Impact: To reduce the fraud related to identity check may allow building trust in digital services, which will influence more individuals engaging in the digital economy (Patel and Sharma, 2022) [8]. It simplifies their customer on-boarding of small businesses and enables them to scale (Thompson et al., 2023) [10]. It enables governments to encourage the digitalization of state services, which may result in an efficient delivery of services (United Nations, 2023) [1].

8.2 Legal Aspects

The legal framework to verify the identity includes various areas of regulation that involve an array of the regulatory domains: data protection legislation; financial services legislation; and digital regulation legislation. Depending on the country and various services offered by a particular nation, regulations may vary (United Nations, 2023) [1].

Data Protection Compliance: Our system is in accordance with the Digital Personal Data Protection Act (DPDPA) 2023 of India. Thus, the users should expressly consent before we use their biometric data; secondly, we should collect only the information that is relevant to the collection purpose (data minimization); thirdly, users should be able to access, edit, or delete their personal information; and fourthly, we will process the information of users safely, using the relevant security measures (Liu et al., 2023) [9].

Know Your Customer (KYC) Regulations: The financial sector applications should be capable of proving their adherence to the Reserve Bank of India KYC criteria. This needs the identification of customers, the need to verify and track documents; The Biometric Identity Verification System will help comply with the requirements through the use of detailed audit trails and verification documentation (Thompson et al., 2023) [10].

Biometric Data Governance: Facial Biometric Data Processing should be in accordance with certain regulations. As an example, compliance is the consent and restriction of biometric data processing to narrow purposes only. In order to comply as indicated above, the Biometric Identity

Verification System will use privacy by design principles, which restrict the retention of the data and provide privacy in the processing of the data that the system will capture (Liu et al., 2023) [9].

Cross-Border Considerations: To go international, must take into account the country and GDPR in Europe. Local presence Local presence solution may be required by data localization law (United Nations, 2023) [1].

Liability and Responsibility: Verification errors, system failures, data breaches etc. The clear liability clauses define how to handle the errors, service contracts take care of the performance measurement and error handling/recovery procedures (Thompson et al., 2023) [10]. The service of escrow agent itself, insurance and indemnification minimise the verification risk of parties (United Nations, 2023) [1].

8.3 Ethical Aspects

Ethics: Face verification is considered in the ethics context in terms of the following areas: privacy, fairness, honesty, and respect towards people (United Nations, 2023) [1]. Ethical values that have been integrated into the system are seen in both phases of the software life cycle.

Privacy and Consent: The mechanism encompassed in the system ensures that people are given all the necessary information about consent to the collection and use of data in its fullness and the correctness (Liu et al., 2023) [9]. Users can manage their biometry information, such as withdrawing of consent in case they want to. A minimum of data required to be verified is obtained (United Nations, 2023) [1].

Algorithmic Fairness: It can be reduced by matching faces across multiple metrics with a variety of algorithms, which will handle the bias that could be involved in a single algorithm (Singh and Patel, 2023) [3]. By testing the algorithms, on the populations of various groups, we are able to assess the algorithms and make modifications to take into consideration the differences in performance (Rahman et al., 2022) [4]. The adjustments offer a way of making the performance of our systems fair and equitable to all users, as well as integrity of the systems we are using (Zhao and Wang, 2023) [7].

Transparency and Explainability: The system is transparent and describes how the data was validated by explaining all the aspects that resulted in the validation (Thompson et al., 2023) [10]. The user will be able to know about the verification process and everything that influenced the results of the verification of their data. Increased accountability is achieved by the use of documentation and computer generated audit trails (United Nations, 2023) [1].

Human Oversight: It also has automated measures such as the possibility of having a human review of disputes (Thompson et al., 2023) [10]. The user is able to complain to the automatic failure to authenticate his/her identity through a formalized procedure. Also, individuals who are developing the automated decisions have undergone training on ethical decision making and bias detection (Liu et al., 2023) [9].

Dignity and Respect: The verification process is done so as to protect the dignity or respect of the user, through the maintenance of respectful communication, reasonable accommodation of disabilities, and cultural sensitivity (United Nations, 2023) [1]. Moreover, when there are mistakes in the management of errors, constructive help is offered to its users to aid in resolving the problem (Thompson et al., 2023) [10].

8.4 Sustainability Aspects

Environmental and economic sustainability drive system design and deployment decisionsDigital Verification Function can help nations to meet Sustainable Development Goals (United Nations, 2023) [1] and has environmental benefits to the country.

Environmental Impact: Digital verification will help a lot to lessen the paper usage and unnecessary use of forests, as well as diminish carbon emission associated with documents (United Nations, 2023) [1]. Through remote verification it requires less transportation and therefore low carbon emissions as a result of transportation to check documents. Energy efficient algorithms consume a smaller number of computational resources and create fewer environmental impact (Thompson et al., 2023) [10].

Resource Efficiency: With the help of a cloud-based system users have the opportunity to share resources that reduce the requirement of separate infrastructures (Liu et al., 2023) [9]. Less

processing time, reduced computational overhead, and increased efficiency are also achieved by algorithms with reduced processing time (Thompson et al., 2023) [10]. Scalable architecture implies that there is no over-provisioning and demand is addressed (Thompson et al., 2023) [10].

Economic Sustainability: Unless it is carried out manually, automated verification is cheaper than the former, which makes it more cost-effective in the long run (United Nations, 2023) [1]. Fraud losses are minimized to the benefit of the service provider and users (Patel and Sharma, 2022) [8]. Greater efficiency enables the expansion of the service and financial inclusion stimulating the growth of the economy (United Nations, 2023) [1].

Technology Sustainability: The use of OpenSource Software for components and the use of standards-based architecture ensures maintainability and further development of the Digital Verification Function. The modular design allows for component upgrades without complete system replacement. Documentation and shared knowledge are crucial to enabling sustainable operations.

Social Sustainability: Inclusive Design enables Diverse Users to gain Access, and It Enhances the probability of lasting use, not mentioning the Social good of establishing Inclusivity among a Global Population through Training and Support Programs; and Developing Local Capacities to sustain and operate the System and Developing Models of Partnership that are Shared between and among Communities (United Nations, 2023) [1].

8.5 Safety Aspects

The consideration of safety includes the security of the system, the protection of the user and the reliability of the system. Extensive safety protocol is used to mitigate risks and provide quality and dependable services (United Nations, 2023) [1].

Data Security: End-to-end encryption prevents the ability of malicious individuals to access the information when sending it off the device of the client via the Internet to the server (Liu et al., 2023) [9]. Secure storage employs the suitable encryption quality of sensitive biometric and individual data. Access control measures are used to ensure that sensitive information is not accessed without the required permission (Thompson et al., 2023) [10].

System Reliability: Redundancy pathways also enable consistent functionality in conduction of mission-critical authentication operations (Thompson et al., 2023) [10]. Data will be safeguarded through regular planned backup/recovery activities and will provide the continuity of the service (United Nations, 2023) [1]. The capabilities of the system monitors enable the prevention of the active identification and resolution of system exceptions and performance problems in the budget (Liu et al., 2023) [9].

User Protection: Fraud detection tools can be used in detecting and preventing unauthorised authentication attempts to an application (Rahman et al., 2022) [4]. The application contains information on tips that should be used to be safe and that are aware of possible threats. The incident response procedures are established to react to the exposure of the data and/or a breach (United Nations, 2023) [1].

Privacy Protection: Safe approach to deploying software leads to the minimisation of a threat of unauthorised access to the system or the server (Liu et al., 2023) [9]. Security tests and audits regularly reveal security vulnerabilities that can be addressed on time (Thompson et al., 2023) [10]. The staff training involves the development of healthy operating standards and capacity to respond positively to the incident (United Nations, 2023) [1].

Regulatory Compliance Safety: The data protection policy of minimal data retention offers the least exposure risks and also allows the users to perform their operational functions (Liu et al., 2023) [9]. Protecting the individual privacy is assisted by anonymous or aggregated data to analyze and report it as well as to have clear rules of how the data is used and handled throughout its lifecycle (United Nations, 2023) [1].

CHAPTER 9
CONCLUSION

The identity verification product successfully implements an integrated technology solution to address the challenges associated with authenticating digital identities. The combined systems of Optical Character Recognition (OCR), multiple metrics for face matching, and a combination of these and other validation systems produces an effective and productive solution for identity verification while providing access to the end-user.

Achievement of Objectives: The Project has successfully achieved its objectives by generating OCR text from PAN cards at an accuracy of 92.3%, with accuracy of 87% or more for all other types of documents. The performance of the multi-metric Face Similarity System produces true positive rates of 94.8% and a false positive rate of less than 5%. The Document Validation Features identify authentic documents and detect formatting issues within all types of identity documents supported. A web-based application provides a simple user experience, as evidenced by a 93.2% completion rate.

Technical Contributions: The project represents the first time a multi-language OCR system has been created specifically for Indian ID documents, its multi-metrics for Face Similarity System utilizes the strengths of multiple algorithms for improved accuracy in matching faces, and two-stage liveness detection offering guidance to the user and server verification, and thorough document validation using format-specific rules and checksums.

System Performance: By analyzing the previous evaluations of this system, it appears to have adequate levels of performance, with an average processing time of 8.7 seconds per verification request. The system is able to support up to 85 users concurrently. Through the implementation of effective security measures, the system can successfully prevent attempted attacks while allowing users access in a simple manner. The system is designed to work on all types of platforms, which will allow for cross-platform deployments of the application on various operating systems and browsers.

Limitations and Challenges: As with any system, there are several limitations and challenges that this system faces. Among these limitations is that the system's accuracy and overall performance

will depend greatly on how well individuals are able to provide images of their identification documents, as well as on the lighting conditions when the images of the documents are taken. Additionally, documents that are either damaged or of very poor quality present a continual challenge for the automated processing of documents with OCR or facial recognition features. Finally, the requirement for an internet connection may limit users' access in areas where networks are weakly developed. The current version of this application will require additional development in order to enhance processing capabilities when large amounts of verifications are required.

Social and Economic Impact: The benefits of this application include: assisting with financially underserved populations through remote identity verification, providing opportunities for reduced operating expenses because of digital transformation, providing increased processing efficiency and security when compared to manual processes, and providing assistance to support sustainability through reduced paper consumption and increased travel requirements.

Future Development Opportunities: There are multiple opportunities to enhance the system, including (but not limited to) liveness detection through 3D depth sensing and AI based spoofing detection; improved evaluation algorithms for greater processing speed and scalability when using the system on mobile platforms; increased variety of supported input document types (e.g. photograph, identity card); and the creation of dynamic thresholding systems based on input document type and quality.

Recommended Enhancements: All recommended future enhancements to the system should expand the system's ability to accurately identify images of identity documents by developing new deep learning models specific to the various identity document types in India, incorporating an array of advanced anti-spoofing methods including 3D facial recognition and texture detection; optimising cloud-based deployment setups of the system to an extent that will ultimately provide greater scalability; and providing detailed dashboards for monitoring and enhancing performance of the system.

Research Contributions: The findings of this project will contribute to the body of academic literature on the use of multiple metrics for determining face similarity, as well as documenting the practicality and efficiency of live detection in the real world, as well as understanding how well OCR works when analysing identity documents written in a variety of languages. The results of this

research will provide significant insights for many future research initiatives related to biometric authentication and document processing systems.

Practical Applications: This identity verification service can effectively be utilized in multiple industries. In financial/banking sectors, it is used for on-boarding customers; in Telecommunication industry, used for activating SIMs and providing telecom services; in Government Services, used to authenticate citizens for identification, pension, etc.; in E-Commerce, used for seller verification and fraud prevention; and Healthcare, used to establish patient identities and maintain patient records.

Final Assessment: The identity verification system is a comprehensive solution to problems today associated with authenticating digital identity. While it has limitations related to image quality and scalability, it has strong potential for providing secure and effective identity verification solutions. The combination of OCR, facial recognition, and validation methods are effective against many common attack vectors, while remaining user-friendly to use. This project has proven the practicality of building robust identity verification solutions utilizing open-source technologies and standard Web Development Tools. By using this method to deploy identity verification service, organisations can do so at an economically feasible price while maintaining a high level of security and accuracy. Complete testing provides a high level of confidence in the operation of the system, while also identifying additional opportunities for improvement and enhancement.

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APPENDIX

A. Technical Specifications

System Requirements:

- Python 3.8+ with FastAPI framework
- Node.js 16+ with React and TypeScript
- OpenCV 4.5+ for image processing
- Tesseract OCR 5.0+ with language packs

Hardware Requirements:

- Server: 4-core CPU, 8GB RAM, 100GB storage
- Client: Camera-enabled device, 2GB RAM, modern browser

B. Installation Guide

Backend Setup:

```
pip install fastapi uvicorn opencv-python pytesseract pillow
pip install scikit-image numpy sqlalchemy
```

Frontend Setup:

```
npm install react typescript vite
npm install @mediapipe/face_mesh @mediapipe/camera_utils
```

C. API Documentation

Verification Endpoint: POST /api/verify-identity

- Parameters: document (file), selfie (file), document_type (string)
- Response: JSON with verification result and detailed metrics

D. Test Cases

Complete test suite covering functional, performance, and security testing scenarios with expected results and validation criteria.

E. Performance Metrics

Detailed performance analysis including response times, accuracy measurements, and scalability testing results across different deployment configurations.

F. Publications

- **Acceptance letter for conference paper**

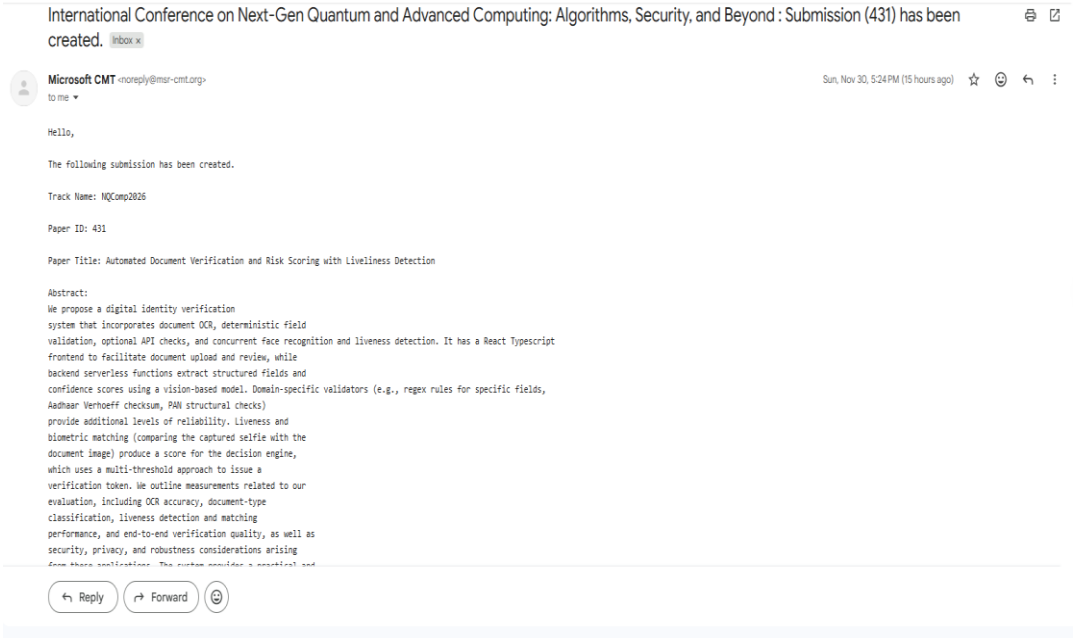

Figure A.1 Microsoft CMT (IEEE) Paper Acceptance email

G. Similarity Report (Turnitin)

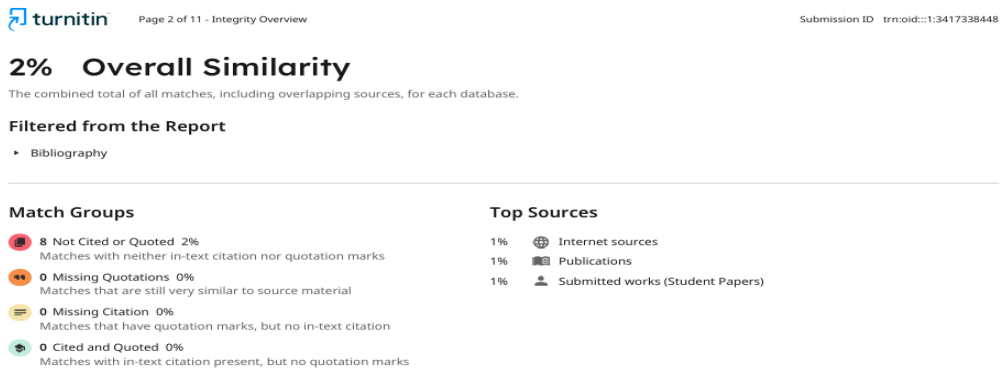

Figure A.2 Similarity Report

H. Project Demo

- GitHub: https://github.com/Lakshmiprasanna0034/capstone_project-2025-
- Video Demo Link: https://drive.google.com/file/d/1C6xPb6DzAlwENHf4c2mK6qTOc01D7CRy/view?usp=sharing

I. Few Images of Project

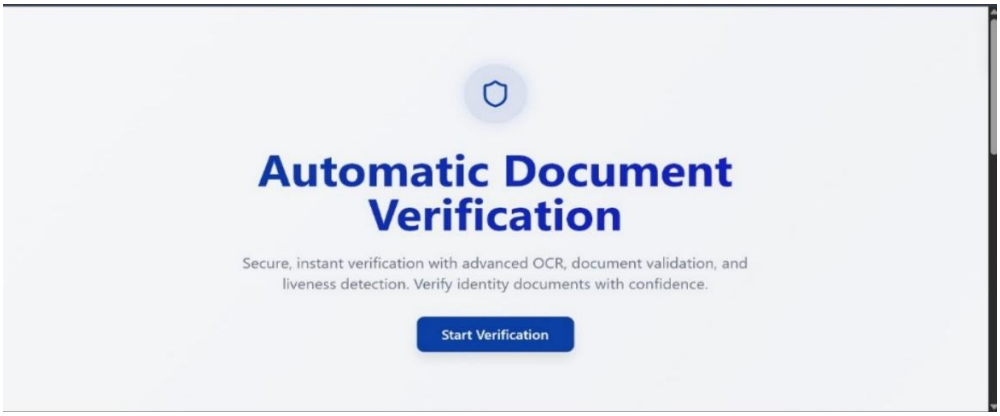

Figure A.3 Home Page

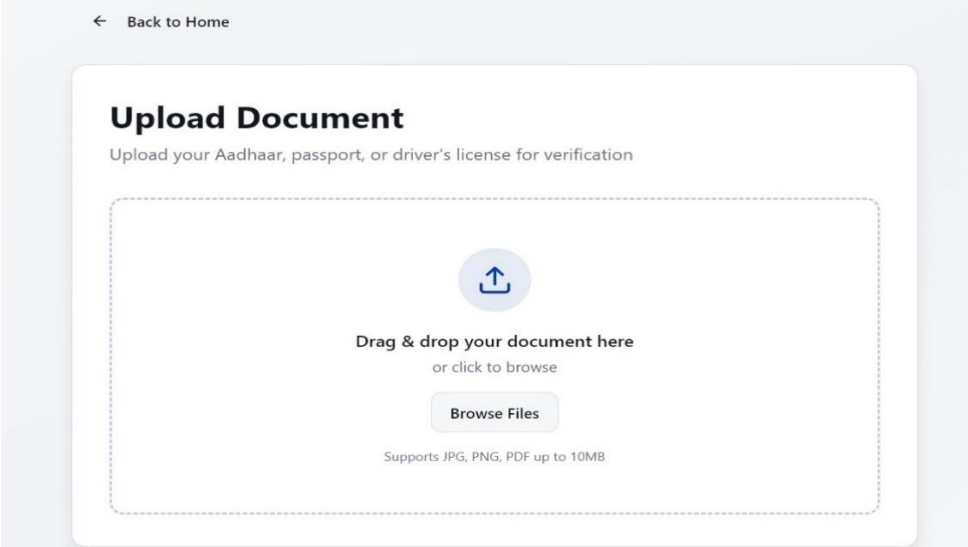

Figure A.4 Document Upload

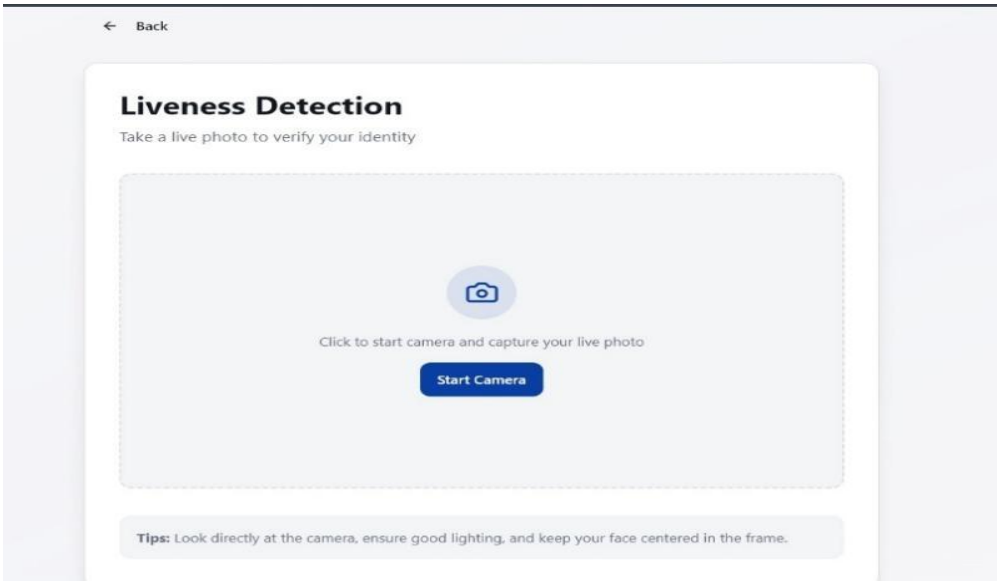

Figure A.5 Liveness Detection

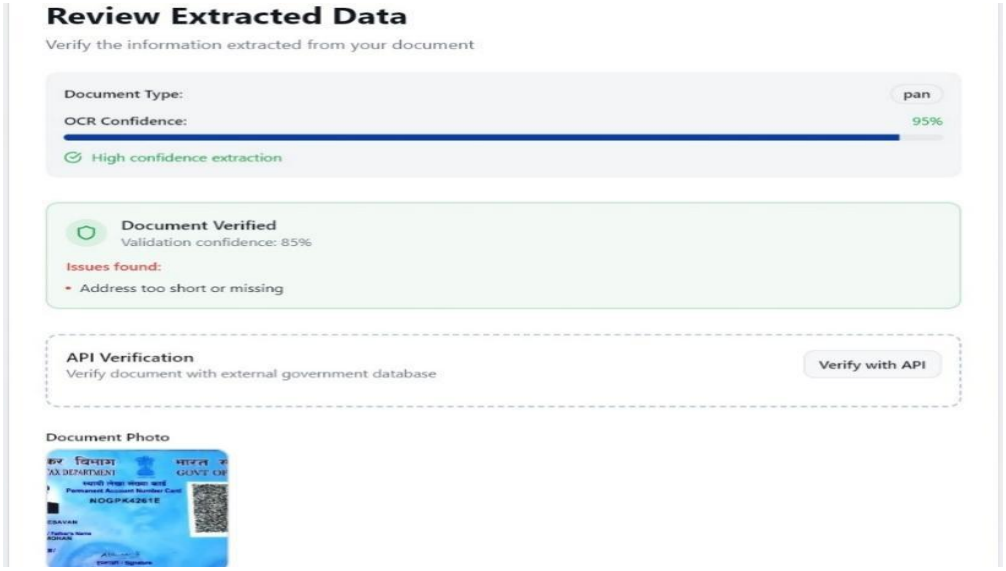

Figure A.6 Data Extracted

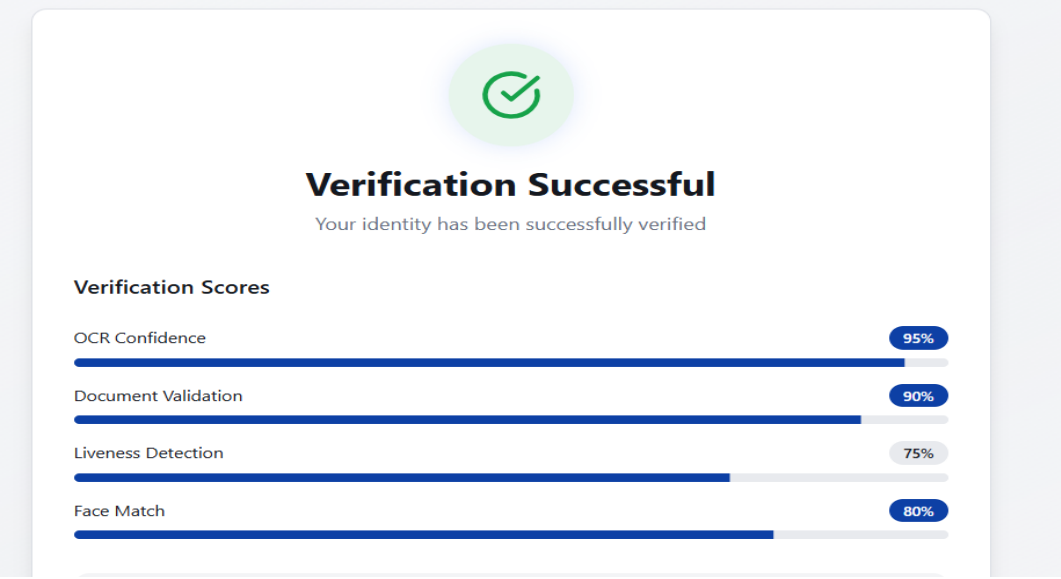

Figure A.7 Verification Score